CREATING LIVABLE, HEALTHY AND ENVIRONMENTALLY VIABLE CITIES – AN ASIAN PERSPECTIVE
Funding Organisation

COMMERCE AND ECONOMIC DEVELOPMENT BUREAU
THE GOVERNMENT OF THE HONG KONG
SPECIAL ADMINISTRATIVE REGION

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Foreword for the SB07 Hong Kong Post-conference Book

The contents of this book present a summation of recent events and activities responding to a global initiative to promote sustainability for the building and construction industry. A number of papers that were deliberated at the International Conference on Sustainable Building Hong Kong, December 2007, have been included to share with readers novel ideas and unique experience in the pursuits of sustainability from different perspectives. Though it might seem an outworn elucidation, each paper presents faithfully an untold story; reviewing the path to achieving sustainability, no matter it is motivated by a quest for intellectual or physical transformation. It is hoped that readers would use this book as an idea generator to continue the effort, and engage in constructive debates, arguments and actions to recreate a livable Planet.

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夏热冬暖地区建筑防热发展的方向

杨仕超
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1 引言

《夏热冬暖地区居住建筑节能设计标准》自 2003 年 10 月起在中国南方开始执行，至今已有 5 年的时间了。其间，南方的四个省都发布了实施的细则，而且省的政府部门也为节能标准的实施进行了大量的宣贯，采取了一系列的措施。尽管如此，这本标准的执行却不能令人满意。

究其原因，许多的建筑设计人员没有真正懂得南方的建筑节能应该有哪些措施，该如何去做，如何才能真正做好。更有许多人认为节能就是需要增加大量的成本，会大大减少房地产的利润。

但这两年，南方住宅的价格一路上涨，房地产的利润异常的丰厚。住宅的价格也并不取决于建筑的内在品质，更多地取决于地头、外形、使用面积等。由于房价的上涨，建筑是否节能、性能是否优越等问题已经不是平常百姓的热门话题了。

然而，从事建筑研究的人士应该保持清醒的头脑，重视南方建筑的内在品质，发展高性能的南方建筑。

2 我国夏热冬暖地区的气候
夏热冬暖地区位于我国南方，主要表现为夏季炎热，冬季温暖。

在夏季，太阳高度角比较大，处于北回归线南方的地区，在夏至甚至会出现太阳在北方的情形。夏季的太阳辐射强烈、气温高、降雨多、湿度大，因而，建筑需要遮阳、通风和防热。由于南方夏季湿热，为达到人体舒适，室内一般需要空调。

但是，南方的夏季与北方有很大的不同，主要表现在夏季持续时间长、平均气温高、湿度大，最高温度却不是很高。针对这样的特点，南方的夏季防热措施与北方也应有很大的不同。

3 适用于夏季的建筑防热措施

夏热冬暖地区居住建筑防热设计有三大重点：通风、遮阳、隔热。
要做到建筑室内热舒适，建筑周边应有好的室外环境。住区需要有良好的通风，要有好的遮阳措施给住区提供阴凉的环境，场地需要绿化，需要有湿地、水景调节气候，硬地面应能透水。

对于建筑单体，应有良好的自然通风，屋顶和东西墙应隔热良好，透明的窗应有好的遮阳。

### 3.1 建筑周边环境规划

夏季建筑周边环境要求：适当的风速、阴影（遮阳、绿化）、适宜的温度（绿化、湿地）、阴凉周围的环境（遮阳、绿化、水景、透水地面）。

为使得住区通风良好，建筑群体应布局适当，建筑有适当的间距，并进行适当的架空。住区的通风设计应针对夏季的主导风向设计。

住区遮阳可采用大树、凉亭、廊道，以及建筑物的互相遮挡。采用绿化改善住区环境，绿化最好用大树，其次是灌木、喜阴植物，最差的是草地。湿地可以改善住区环境，但湿地应是尽量接近自然的湿地。水景（水池、喷泉、流水）也可以在一定程度上改善住区的环境。硬地面采用透水的地面（有缝的铺砌、透水材料铺砌），可以使得硬地面对环境的热效应降至较低的程度。

传统的岭南自然村布局和客家围垅屋均非常注意住区的环境。一般在夏季主导风向上游有水面，房屋顺风向排列，背后有高地或山以抵挡冬季的北风。

### 3.2 建筑单体通风

单体建筑通风良好，建筑室内可以更加舒适，从而减少空调的使用，这样室内污染物浓度也会大大降低，对人体健康也比较有利。

为使得单体建筑有比较好的自然通风，建筑应有较好的朝向、好的体形。组织穿堂风对改善室内热环境非常重要，建筑设计室应合理布置门窗位置、建筑内部通道，注意开口大小、注意设置一定的导风装置或构造。
传统的岭南竹筒屋，虽然空间狭窄，但通风组织却相当好。传统的广州西关大屋也很重视自然通风，其户门是为通风而专门设计的。

图 2 传统西关大屋的门

### 3.3 减少普通玻璃使用面积和建筑遮阳

建筑夏季防热，窗户是最重要的部分。建筑应减少窗墙面积比，使得玻璃的使用面积尽量小。东西向尤其应尽量降低窗墙面积比，减少使用普通的玻璃。

例如戈壁的建筑，由于当地太阳辐射强烈，所以建筑采用厚的墙、小窗户，太阳直射很难射入，这样在蓄热量大的墙的围护下，建筑室内比较阴凉。

建筑遮阳是最直接和有效的措施，在可能的情况下应尽量采用。建筑遮阳措施可大大减少太阳直射。

建筑遮阳的效果：产生阴影，改善建筑室外局部热环境；产生阴影，减少阳光对建筑的照射；减少透明围护结构的太阳辐射照度。

在南方，由于温差小、太阳辐射强烈，建筑一般比较轻巧，通风、遮阳良好。
充分的建筑遮阳能够使得室内较舒适，这也是最能够体现岭南建筑特色的地方。建筑可以采用大的外廊、遮阳构件、屋面挑檐等。在广州，商业街道有很多骑楼。在这样的环境下，人们既能够避雨，又不受阳光直射，是购物、休闲的好地方。

3.4 透明围护结构

在建筑遮阳措施不足时，可以应用遮阳产品或系统，在窗户、幕墙等透明围护结构上采取遮阳措施。这些遮阳措施一般在建筑遮阳措施不充分时采用。

直接在窗上采取遮阳措施很有效，且措施多样、灵活、便于控制。在管理方面，装拆方便、维修方便。这种做法也可以应用到即有建筑的节能改造中，是很好的节能改造措施。
采用特殊品种的玻璃也是非常有效的遮阳措施。吸热玻璃有一定的隔热效果；热反射玻璃效果更好，但往往反光较强，在住宅使用有较大的问题；单片阳光控制型 Low-E 玻璃效果较好，窗的成本也比较低；透明的中空玻璃没有太大的遮阳作用；热反射玻璃与透明玻璃配合成为中空玻璃效果很好，但采光不好，也有反光；遮阳型 Low-E 中空玻璃可以达到比较好的遮阳效果，而且还能保证有较好的采光。

在玻璃的改善措施中还可以采用太阳膜，太阳膜有吸热型和热反射型，都有一定的效果；Low-E 贴膜有单片 Low-E 玻璃的效果。现在还有电控变色遮阳玻璃，也可以在中空玻璃内部加百叶。可见，玻璃的遮阳选择还是比较丰富的。

### 表 1 典型玻璃的光学、热工性能参数

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<th>玻璃品种</th>
<th>可见光透射比 $\tau_v$</th>
<th>太阳能总透射比 $g_s$</th>
<th>遮阳系数 SC</th>
<th>中传热系数 $K$ [W/(m²·K)]</th>
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<tr>
<td>透明玻璃</td>
<td></td>
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<td>3mm 透明玻璃</td>
<td>0.83</td>
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<td>吸热玻璃</td>
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<td>0.64</td>
<td>0.76</td>
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<td>0.62</td>
<td>0.72</td>
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<tr>
<td>5mm 茶色吸热玻璃</td>
<td>0.50</td>
<td>0.62</td>
<td>0.72</td>
<td>5.7</td>
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### 玻璃品种

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<td>0.37</td>
<td>0.50</td>
<td>1.4</td>
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</table>

### 3.5 屋面隔热

屋面对于顶层用户至关重要，屋面节能和屋顶房间的舒适是相关联的，其隔热好坏直接关系到顶层的热舒适性。

屋面隔热的主要方式有：设置保温层、屋顶遮阳和架空通风、有土或无土的种植、蓄水、浅色处理等。其中屋面种植是非常好的隔热方式，既可隔热、又可增加城市绿地、改善屋顶视觉环境。由于南方雨水多，空气湿度大，屋面种植的管理成本相对比较低。而且，南方的植物非常容易成活，可选择的植物很多。因而，屋面种植技术可以在建筑工程中大量应用。
3.6 墙体隔热

墙体隔热对于东、西房间非常重要，节能和房间的舒适也是密切关联的。墙体隔热的方式有：采用隔热好的墙体材料自保温体系、设置保温层、设置通风夹层、墙体绿化种植、浅色处理等。

由于北方温差大，而且存在热桥问题，所以外墙外保温技术非常适用于北方；南方温差比较小，热桥问题不重要，而外保温成本又相对比较高，施工难度大，要求高，容易产生开裂、脱落等安全问题，因而外保温在南方较少采用。

夏热冬暖地区的住宅还是主要采用墙体材料进行自隔热。适用于南方墙体隔热的墙体材料有：加气混凝土（粉煤灰、砂加气等）、陶粒空心砌块、空心粘土砖、填充保温材料的混凝土空心砌块等。

对于剪力墙、大面积混凝土梁和柱等，可采用无机保温砂浆进行内保温。

4 建筑防热设计的思路
夏热冬暖地区居住建筑节能设计有三大重点：通风、遮阳和隔热。

居住建筑的防热设计一般可采取如下基本原则：

1）适应气候；2）整体考虑；3）适宜项目；4）经济；5）精心设计。

通风设计，首先要考虑城市的大环境、小区自然通风等；其次考虑建筑单体的通风；然后进行建筑平面设计、开口布置等。在通风不良的情况下，可采用机械辅助通风措施。

在进行小区通风设计时，应针对夏季主导风向，使得小区上游有好的环境，小区内应有明显的风通道，风通道宜前大后小。对于建筑的布置，应采用前矮后高，在夏季主导风向下保证每栋建筑前后均有风压差，建筑宜交错排列、顺主导风斜向或曲式排列，或者采用主导风方向开口的围合布置。

单体居住建筑的防热设计，应采用如下思路：

1）确保室内在自然通风条件下有较舒适的热环境

为了首先满足热舒适的要求，建筑周围应有适宜的室外环境（温度、湿度），室内有足够的风速（0.5m/s 以上），满足通风换气要求。在自然通风的环境下，可以降低室内二氧化碳含量，减轻室内的有害气体污染，有利于居住者的健康。

2）隔热

屋顶隔热：绿化、保温、浅色处理、架空、遮阳；

墙体（东、西墙）隔热：墙体自保温、内保温、外保温、浅色处理、通风、绿化等。

隔热的设计指标：满足《民用建筑热工设计规范》5.0.1 条的要求。
一般来说，普通的 240mm 厚粘土砖墙可基本满足隔热要求，180 加气混凝土砌体满足隔热要求。其他墙体应达到相近的隔热要求。

屋面保温、通风、遮阳、绿化等均可以达到隔热节能的目的；保温屋面是很好的选择，30mm 厚聚苯乙烯泡沫塑料板可基本满足住宅屋面的隔热要求，绿化屋面可以满足要求。

5 结语

健康、舒适是南方建筑防热的基调。

南方建筑防热的主要措施包括：组织良好的自然通风，减少空调时间；建筑遮阳、窗遮阳；采取好的玻璃方案实现玻璃遮阳；墙体隔热；屋面隔热；双层通风；绿化等等。

玻璃系统的恰当应用是很好的遮阳解决方案，综合考虑各种遮阳措施可以满足各方面的不同需要。建筑遮阳的合理应用是建筑师建筑艺术的充分体现，也给建筑师很大的发挥空间。建筑遮阳是南方传统建筑的风格，也是应该是现代南方建筑应该具有的风格；建筑遮阳的大量应用可以改变目前“千村一貌”的局面。

虽然广东的建筑节能工作才刚刚开始，但可喜的是广东省有一批积极从事建筑节能，且有丰富经验的研究机构和专家。广东省曾经引领全国的建筑业发展，创造了岭南建筑的辉煌。我们完全有理由相信，随着建筑节能和绿色建筑工作的深入，广东必将引领南方的建筑节能。
1. 规划也能出绿色效益

在我看来，做绿色地产，一个很好的规划非常重要。从节能环保角度考虑，远距离一般选择轮船和铁路，短距离选择骑自行车和走路。但当前，对城市空气造成最大污染的是汽车尾气。在中国很多城市，汽车使用量越来越多。我出国考察过很多国家，在英国伦敦的 6 车道只相当于我们的 4 车道，而中国的一些城市道路越修越宽，结果路越宽反而越堵。一些城市往往出现大动脉被堵，交通就基本陷入“瘫痪”。其中一个重要的原因是路网规划设计不够合理。在欧洲许多城市，路窄而密，而且大部分被设计成单行线，但可以绕回来。这就好比人的毛细血管。毛细血管一多，血液循环就更加畅通。这样一个很简单的社会现象，但我们却熟视无睹。

在招商地产开发的蛇口工业区，就很好地考虑到了路网的合理规划。我们的道路密度是按每平方米多少米长来计算，而不是按每平方公里有多少平方米路面面积。结果我们做到了每平方公里能拥有 6.6km 长的公路，尽管路不宽却很密，可以很好地解决交通堵塞的问题。在蛇口生活，我们的生活可以“慢半拍”，而在交通拥堵的大城市里生活就没有这么舒适。

2. 不要只局限于单个建筑
我们的眼光不要只局限于单个建筑，而要从整个社区环境、城市环境入手。大环境好了，小环境就好做了。比如降低整个小区的热岛效应，可以起到很好的节能作用。我们通过计算机模拟热岛效应发现，小区温度每降低 1 度，室内空调温度可以平均调低 2~3 度。

如何降低小区的热岛效应呢？可以通过保存雨水的办法。目前许多城市都采用硬地面处理，这样对雨水循环构成极大的影响，许多城市降雨越来越少。如果采用透水砖，就能起到很好的保存雨水的作用。这是大家容易忽视的常识。另外，可以通过种树进行绿化，也可以涵养水分。现在有些开发商在进行项目开发时，从很远地方把树移植过来，由于不是本地植物，维护成本相当高，往往吃力不讨好。如果栽种本地植物，不仅成本低，而且生长也很好。

因此，在大力推广绿色建筑，绿色地产时，我们更应大声疾呼的是，大力发展绿色住区和绿色城市，在越落后的地区越应该发展绿色地产，这样就可以避免犯更多的错误。

3. 要从全社会更新观念入手

如何发展绿色地产、绿色社会，我们应该从全社会的观念更新入手。这次大会（IHA 年中大会）给常州市副市长颁了一个绿色建筑人物贡献奖，我觉得很有意义，对激励政府参与绿色事业有很大作用。美国现在流行一种叫“新城市主义”的规划理念，原因是现代的城市规划引发了许多新问题，他们从传统规划中反而发现了许多有用的东西。国外还出了本书，叫《Design With Nature》，其实翻译过来，就是中国的“道法自然”。事实上中国有很多好的思想和哲理，比如天人合一，强调与自然的和谐统一。在社会不断追求创新的同时，我们可以从一些中国传统哲理中去寻找合适的方法，来解决当下许多问题。2003 年，我去美国参加绿色建筑大会。在一次小范围交流中，一
位美国朋友在演讲前说了这样一段话，“你们不要只听我们讲好的，你们要听我们讲不好的，你们要吸取我们的教训，不要犯我们同样的错误”。

附：【美国《新闻周刊》11 月 26 日（提前出版）一期文章】题：感受凉风（作者 乔治·韦尔弗里茨）

总有一天，深圳泰格酒店公寓会在环境史上占据重要地位。这栋新月型的公寓建成于 2005 年，是中国第一栋绿色商用建筑。该公寓的窗户可吸收微风，减少空调的使用。雨水从屋顶流下，进入花园周围的灌溉系统。结合了先进的设计理念、新技术和安全的材料，该建筑对住户来说是健康、对所有者来说是节能的、对地球来说是可以承受的。泰格的收支状况是其成功的最好衡量标准：在投入使用的第一年，与规模相似的传统建筑相比，泰格酒店公寓通过节能节省了 177857 美元。这使深圳泰格酒店公寓和亚洲几座类似的建筑处于当今气候辩论的中心。亚洲不断增长的能源需求是推动油价达到每桶 100 美元的主要因素，也使它成为生物燃料最热门的市场，危及了粮食的供应。它也是发展最快的温室气体排放者。显然，中国和印度需要更清洁的发电站，但有一点正变得越来越清楚，即减少温室气体排放的最快、成本最低的办法是利用环保技术建设更节能的城市。

为什么是亚洲？因为极快的经济增长和该地区仍然极大的农村人口使它成为 21 世纪城市化的中心。现在的难题在于不能重复西方在发展方面所犯的错误。如果目前的趋势持续下去，那么到 2020 年，仅中国就将进口全世界一半的煤、1/5 的石油，并将拥有 1.58 亿辆汽车。替代方案是：利用现有的绿色建筑技术发展更健康的亚洲城市。多数专家认为，这样建设的城市将比传统城市节能约 30% 至 50%，而建筑成本只增加很少一部分。

对于亚洲乃至整个世界来说，今后的挑战是将如今试验性建筑中的关键因素变成未来建筑的标准。目前的趋势令人鼓舞。尽管起点低，但几乎在每一个城市，得到环
保证书的工程的数量都在增加。开发商们还发现，不管是出租还是销售，节能建筑的加价都要超过额外的建筑成本。不遵守环保标准的代价变得越来越大，这也许是最好的晴雨表。世界绿色建筑委员会的前主席沃尔先生说：“新的非绿色建筑正面临提前被淘汰的命运。”
地区建筑营建体系的“基因说”诠释
——黄土高原绿色窑居住区体系的建构与实践

INTERPRETATION OF THE “GENE” THEORY
FOR THE CONSTRUCTIVE SYSTEM OF REGIONAL ARCHITECTURE
——THE CASE STUDY ON THE GREEN CAVE DWELLING ON THE LOESS PLATEAU

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摘 要：论文以“地域基因”概念及方法作为地区建筑营建体系的研究途径，揭示地区建筑生成生长的内在调控机制，并依据可持续发展原则与科学的评价体系，建立地域基因库与适宜性的技术支持体系，以黄土高原窑居住区营建的个案研究，来验证研究路线的可行性。

关键词：地区建筑营建体系　地域基因　绿色窑居　可持续发展

Abstract: Inspired by the “regional gene” theory to the research into the constructive system of regional architecture, this paper attempts to reveal the inherent adjusting mechanism of the evolution of regional architecture. On the basis of the principles of sustainable development and scientific evaluation system, it is aimed to establish regional gene database and optimum technology, and to verify the feasibility of research way through the case study on the Green Cave Dwelling on the Loess Plateau.

Key words: The constructive system of regional architecture; regional gene; green cave dwelling settlement; sustainable development
1. 混沌状态下的清晰思考

在全球化趋势下针对地域性的研究始终是建筑界关注的焦点，但目前的理论与实践研究更多地局限于“概念的阐述”与“形态的表象”上，尤其是针对地区建筑的继承与发展这个长久争论未果的辩题，我们缺少科学的思维体系与理论支撑，始终纠缠于“像什么！似什么！”的争论中，而不去探究“应该是什么！”在说不清、理更乱的混沌中，道路越走越窄。

地区建筑营建体系应该是发展的，它的建构应体现三方面的内容：首先是原创性：地区建筑是有机的生命体，需要不断注入新的活力，它拒绝简单的模仿与复制。根据环境与社会的变化，它甚至可以是地域文化的重建与新创；其次是前沿性：对当前人类的根本处境、人与自然、社会、自我的关系及未来发展的新图景等焦点问题的关注，着力于对这些焦点问题的适宜性途径与策略的探究；第三是科学性：地区建筑营建体系的建构决不仅依赖于主观的判断与经验，而是运用科学的方法与可操作的综合评价体系，建立可调控的运行机制。

2. 地区建筑营建体系解析

2.1 建筑的地域文脉

以往提到建筑文脉，更多的是强调传统与文化，习惯于向后看，谈到地域性更多想到的就是“大屋顶”与“马头墙”们。今天的地域建筑决不仅仅通过移植传统建筑的某些技术与形态，就被冠以所谓的“地区建筑”的头衔。

以动态的眼光，正确理解建筑的地域文脉内涵，不仅是纵向上的历史传承，还应包括：前后、左右、上下多维视野中的人文元与自然元。“前后”指在纵向的历史方面，传统与现代的对话及对传统建筑文化价值的超越；“左右”指经济、技术、文化、风俗等人文因素在横向与整个时代对话及与其他
建筑文化的交融：“上下”指任何地域建筑的生成生长都离不开气候、资源、地理、生态等自然因素。

2. 2 地区建筑原型与营建体系

借助“原型”理论来解析一定地域内建筑发展演变规律，发现人们在营建中自觉运用的那些模式，其精巧的构造与营建手段无不包含着对地域气候、地形地貌及环境资源限制的适应，空间形态也回应着气候、地理与物资资源条件下，人们适应性的生计方式、社会组织与习俗民风特性。这些地区建筑原型的存在确立和维持了一定地域内建筑发展演变的内在秩序与方向，其中所隐含的朴素的生态学思想与人们对客观世界最本真的认识，仍然在当前地区建筑创作中是具有恒久的生命力。我们应该从地域营建的智慧与现代科学技术的原则中寻找蹊径，建构起适宜于地区的营建体系。

2. 3. “地域基因”与营建体系的演进

2. 3. 1. “地域基因”的概念

生命科学领域中人类基因组的研究，标志着人类正越来越科学地认识生命系统的生成和进化过程及其与环境的关系。基因是决定一个生物物种生命现象的基本因子，生命体可通过自身具有的基因调控机制，适于环境的变化，使自身与其他生物能够更健康的生存与发展（见图1）。
笔者在《建筑学报》2004年第3期中已提出了“地域基因”的概念。“一方水土养一方人”，每个地方都会给这一地区的人一种“地域基因”。同理，“一方水土也会生成一方的营建体系”。将我国种类繁多的生物种群与诞生于各地区的住居形态作一比较，可以看出地域建筑对气候、资源、地理、生态等自然因素与经济技术、社会、民俗等人文因素的应对，如同生物一样映着特定地域遗传信息的特质，这些因素影响着住居形态的生成与生长，其生成和生长的规律与生物基因调控机制存在着“异质同构”现象（见图2）。创造性地提出“地域基因”的概念，从深层次把握地域建筑的生成与发展机制，可以为地区建筑的营建提供科学方法与理论支持，使其产生质的阶跃。

2.3.2 “地域基因” 的识别与判断

合理的地区营建体系不是所有的应对手段都是优势基因，有些技术手段在当下的营建活动中仍具有生命力，如生土建筑的节能节地与厚重型被覆材料、干阑建筑适于不同地形和避免破坏生态而架空生活层面等；有些应对手段虽不十分适宜，但经过一定的转化与重组，可谓良性基因；而有些基因，无法与社会的发展和生计方式的变迁同步，失去了发展的意义，甚至成为危及新的生命体健康发展的毒瘤。因而，我们需要对营建体系的“地域基因”进行正确的识别与判断，以便清晰地辨别良莠，对症下药。对地域基因的正确识别与判断应始终以可持续发展为目标，判断地域基因的生命力指数，将导致
地区建筑演进过程中“患病”的基因修整或替换，激活健康基因，并注入新的优势基因，使地区建筑的营建体系得以良性发展。

2.3.3 “地域基因”的重组与整合

在对住居“地域基因”识别与判断的基础上，将各种相关因子置于适宜措施的调控之下，重组与整合营建体系的“地域基因库”。这一过程的关键是应对手段的确定，即适宜性技术的选择。适宜性技术是针对特定地区而言的技术难度和经济成本适当的技术，是集环境、社会、经济效益于一体的多层次技术的综合运用，将地域技术与现有技术优化组合运用于住居的营建中。

2.3.4 “地域基因”的运行机制

地区营建体系的“地域基因库”是一个彼此联系、相互制约的整体。任何一个基因的变化都会引起其他基因对营建体系不同程度的改变，甚至有可能彻底改变地区建筑的生成与发展模式。因此，将地区营建体系作为受控系统（见图3），一方面通过负反馈机制，不断调整营建体系的“地域基因库”，另一方面，系统又通过正反馈机制，强化其优势基因，促进系统排除干扰尽快达到可持续发展的目标。“地域基因”对环境的应对不仅是消极被动的改良，而是一个积极的创造过程。主动地调控系统的基因组，使其适应新的环境与目标，这是完善健康基因的必要，是地区建筑得以不断进化的保证。
2.4. 地区建筑营建体系的评价方法

由营建体系的构成因素“进化”为更符合可持续发展目标的“地域基因”，必然需要一个科学的评价体系，这直接关系着“适宜性”途径的判断是否真的适宜。笔者引入神经元BP网络的方法建立可持续发展指标体系的评价模型，并加入模糊规则，从而构建出地区建筑评价体系的基本框架（详见《华中建筑》2003年第3期P7—8）。

地区建筑营建评价体系通过量化计算与实例检验相结合的方法确定标准模板（评价优劣等级的参照样板），建立综合评价其营建体系的操作程序与方法；从众多的相关因子间确立分项指标；调查与综合分析典型案例，建立案例模型库，进行专家调查；建立综合评价网络模型，进行计算、反馈与完善研究。

3. 黄土高原地区建筑营建体系的诊断与解析

“窑洞”作为黄土高原地区住居中最具代表性的建筑类型，其就地取材，节能节地的建造方式与冬暖夏凉的特征，堪称朴素的生态建筑的代表。

3.1. 原生窑洞

原生窑洞的形态千姿百态，但从其布局与结构形态可概括为三种基本类型：靠崖式、下沉式和独立式窑洞（见图4）。

3.2. 原生窑洞“地域基因”的诊断、识别与判断

课题组对原生窑洞进行了科学的诊断，通过测试提供了一系列室内外环境因素的测试结果：室内日光与通风、冬夏两季窑洞的室内温度分布、紫外线辐射分布、室内外噪音与室内回声的变化、室内CO2及粉尘的分布等等（见图5），在科学分析的基础上，进而绘出原生窑居营建体系的“地域基因”图谱（见图6）。
图 4 黄土高原原生窑洞类型
（图片来源：侯纪尧、王军：《中国窑洞》）

图 5 原生窑洞“地域基因”的诊断
经过分析我们可以看出，窑洞的生成与生长始终伴随着其“原始模型”基因而生长，具有趋利避害的调节机制。原生窑洞营建中具有生命力的优势“地域基因”归纳如下：

图 6 原生窑居营建体系的“地域基因”图谱
厚重型被覆结构：维持室内相对稳定的热环境。

封闭规整的空间布局：力求避免建筑过多的得热与失热。

背风向阳的选址：最大限度地获取日照，营造温暖的室温。

节地与庭院经济：在山坡地建造，立体划分有限的居住空间，屋顶覆土种植达到了节地与经济双赢。

乡土材料与简便易行的技术：天然的黄土及砖石作为建造材料，箍窑技术施工便捷，经济实用，便于邻里互助参与营建。

灶台、火炕与火墙——生活用能的多级利用

自然的构成与民俗装饰的协调。

同时将原生窑洞的劣势 “地域基因”归纳为如下：

村落结构缺乏整体规划——土地利用不紧凑、缺乏给排水、交通等必要的基础设施；

居住空间与现代生活方式不相适应；

室内空间质量差——通风换气不畅、采光日照不足、潮湿阴暗；

安全性差——缺乏整体抗震、抗滑坡和泥石流的措施；

对太阳能及可再生能源的利用效率不高；

没有与简便、成熟的现代技术结合。

3.3. 绿色窑居营建体系“地域基因库”的建立
### 表1 绿色窑居营建体系 "地域基因库"

<table>
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</tr>
</thead>
<tbody>
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</tbody>
</table>

注：
- ○：一般
- ●：重要
- ★：特别重要

说明：
- 不同位置的标注表示不同级别的重要性。
通过对原生窑居营建体系“原始模型”基因的解析与把握，针对黄土高原的自然生态条件、资源、社会经济、生产生活体系的分析，对窑居营建体系的各构成因素作出权重判断，判别决定性的关键因子与一般性因子之间的结构关系，建构起绿色窑居营建体系的“地域基因库”（见表1），并对关键因子施以重点地调控，明确绿色窑居营建体系趋于可持续发展的目标靶点，实现窑居营建体系的生态、生产与建筑生活诸系统的整体协调发展。

4. 黄土高原绿色窑居的建立与阶跃

4.1. 从原生走向可持续发展——绿色窑居营建体系的进化

“窑洞”这一古老的居住形态实现从原生走向可持续发展，必须抢占新的“生态位”，找到具有地区营建特色的、适合自身发展的环境与资源空间。通过对窑居“地域基因库”的反馈平衡调控机制，摆脱旧有因子的约束，吸纳现代科学技术，使窑居营建体系阶跃到更高一个层面。

4.4. 1. 从“原始窑洞模型”到“绿色窑居模型”

绿色窑居保持了传统窑洞冬暖夏凉的生态原理，改善其与现代生活品质不相符合的方面，采用主动式与被动式设计相结合的技术对策，创造具有优良的光、热环境与高质量的空气质量，建构绿色窑居的综合模型（见图7、图8）。

图7 从“原始窑洞模型”到“绿色窑居模型”
具体对策如下：

①在保持拱券结构的基础上，利用圈梁与楼板结构使窑居后部上下错层，解决窑居后部采光的问题；同时划分室内不同的功能空间，适应现代生活需求；

②增加窑居后部的通风竖井，改善采光、通风与除湿的问题；

③主动式与被动式相结合的太阳能采暖系统，利用太阳能集热板提供热水；阳光间调节室内空气湿度，维持冬季室内高效热环境；

④采取地沟隔温除湿换气自调节空调系统，改善窑居室内通风换气的质量；

⑤双层玻璃与保温窗帘可维护室内稳定的热环境；

⑥屋顶覆土种植，可保温蓄热，调节微气候，且促进发展庭院经济；

⑦双层结构（砂层与土层）防水、防渗及蓄水种植的生态型窑顶构造措施；

⑧庭院的植物可控制太阳辐射与通风。

图 8 绿色窑居适宜性技术集成模式
4.1.2 从黑暗污浊到明朗健康的室内环境质量（见图9、图10）

4.1.3 从原生的乡土技术到合理的适宜性技术

改进与完善乡土材料与箍窑技术，将乡土材料与现代加工材料结合推广运用，如：开发生态型砌块材料；运用部分混凝土构件，以提高多层窑居的整体性与抗震能力；改良窑居的土基处理、砖石砌筑、拱膜制作、窑顶覆土及屋顶植被恢复技术等，建构地域技术与现有技术优化组合的适宜技术支持体系，弘扬邻里互助式的营建传统（见图11）。

4.1.4 从散乱分布的村落到邻里生活单元

合理地利用坡地组织生产与生活，紧凑配置居住用地，依据地形组织不同的道路层次和统一的公共基础设施管网；高效利用宅基地，将各户相互穿插叠置，发展立体的庭院经济模式，既节约土地减少道路等基础设施的经济投入，又丰富了居住环境的空间层次。

合理的窑居邻里生活单元由7—8户组成，为了适应黄土沟壑的转折与台地，利用地形的高差错落形成邻里活动中心、窑居院落、步道、绿化和与休闲平台等丰富的空间形态，既营造明确的空间领域，同时又便于邻里间的互助交往，重建浓郁的乡土生活氛围（见图12）。
4.1.4. 从荒芜贫瘠的黄土窑洞到生机盎然的绿色人居

人类生存起源经历着从荒芜贫瘠到与生态的和谐共存，窑居营建体系同样经历从原生到可持续发展的进化（见图 13）。

4.2. 地区建筑营建体系建构的技术

以“地域基因”概念及方法作为研究途径，取黄土高原绿色营建体系的个案，验证研究思路的可行性，帮助我们找到切实可行的地区建筑营建体系建构的技术路线：奠定核心科学的基础——把握其“原型”的现代意义——建立营建体系的“地域基因库”——运用正确的评价方法——找出目标靶点——明确适宜的技术支持体系——进行实验与建设。

一旦某一地区的“基本模板”建立起来，就架构了一个协调共享的基点平台，其地域营建体系也就有了科学的发展方略和营建导则。
参考文献

3. 王竹, 魏秦, 贺勇等. 从原生走向可持续发展——黄土高原绿色窑居的地区建筑学解析与建构. 建筑学报, 2004, 3:34-37
杭州西湖综合保护工程

周为

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1 引言

2002 年初，西湖南线景区整合工程开工，标志着西湖综合保护工程正式开始。同年 10 月 1 日，南线工程竣工。

2003 年初，西湖湖西综合保护工程和新湖滨景区建设工程同时开工，同年 10 月 1 日，湖西、湖滨竣工。

2004 年初，西湖北山街历史文化街区保护工程和西湖湖西综合保护工程二期工程同时开工，同年 10 月 1 日，北山街、湖西二期工程竣工。

2005 年初，西湖两堤三岛修缮保护工程开工，同年 10 月 1 日竣工。

至此，西湖综合保护工程东、西、南、北、中五大核心区块全部完成。

2. 南线

西湖风景名胜区南线景区环湖段绿地，北起湖滨一公园，南达长桥公园，南山路以内环湖绿地的整合规划涉及西湖岸线 3 公里，占西湖岸线总长度的 23%，总面积 50.38 公顷，占西湖环湖路以内陆域面积的 27%。这是一片极为独特的景区，环境容量大，历史内涵丰富，文化底蕴深厚，个性十分独特，景观资
源具有唯一性和不可替代性。这里既有有着杭州历史上最辉煌的南宋、吴越两朝遗址，又有着襟江带湖的风景优势和鱼米之乡的富庶民俗民风遗存，还曾经产生了梁祝、白蛇传、济公传这样既有严酷现实意义，又有极端浪漫主义色彩的民间传说和故事。充分保持、发掘、深化、发扬其个性，是规划的指导思想所在。以景区个性为规划的个性，使之贯穿于规划建设始终，这也是规划立意所在。

整合前南线旅游及景观状况不如人意，游人只能在柳浪闻莺、少儿公园、老年公园、花港观鱼、太子湾等独立成景、互不关联的公园间奔波，无法获得连续丰富的景观感受。基于对对环湖南线景区现状的充分认识，整治的指导思想充分保持、发掘、深化、发扬南线景区的个性。一是文化性。历史文化：景区有汉之金牛出水、唐时开六井、吴越之钱王祠、宋之聚景园与西湖十景、明清之十大城门、钱塘十八景，至民国后拆城墙、造公园，具有延续不断的历史演变过程，并留下十分丰富的遗迹与传说。采用不拘一格的设计手段，在园林绿地中充分体现该景区的历史遗韵。艺术文化：中国美院近百年的历史，使该地长期浸淫在浓郁的艺术氛围中，具备了深浓的积淀。规划充分发挥美院作为巨大“艺术磁铁”的作用，在适当拆除部分沿南山路建筑，拉开空间屏障后，把酒吧、画廊、咖啡厅、美术馆、艺术宫、茶艺室等引入环湖绿地内部，使艺术表现的“线”变成“面”，以整个南山路地段的空间来接受、展现艺术的魅力，使该地成为艺术的“聚落”，并为艺术创作、艺术消费、艺术欣赏、艺术展示、艺术保存提供天堂般的空间。民俗文化：杭城素为鱼米之乡、天堂胜境，民风殷实，四时八节活动多多。该景区地属城景结合地带，是官员、富人居住之地，也是百姓出城游湖的必经之所，蕴藏了江南鱼米之乡、杭州城市民俗的丰厚积淀，是西湖风景名胜区十分重要的风景资源。充分发掘此类特色资源，使之充实于景区之中，让现代市民及游人体味民族的、历史的人文风景。景观文化：西湖美景，其独特性、唯一性与不可替代性，以水域景观为代表，环湖南线占有西湖四分之一的湖岸线，能全
面体现西湖以秀美见长的景观特色，其源于自然，高于自然，天人合一，淡雅秀逸的园林构景文化，体现了东方民族的哲思与精神。整治充分服从西湖风景名胜区的总体格调，使整合后的景区能充分融合并适当发展该地的景观文化。二是闲适性。南山路地区平坦面湖，贴邻城区，舒展开阔，可游宜憩，具备优秀休闲绿地的气质，能体现杭州西湖独特的闲适特性。整治工程强调空间布局及设施的休闲性和舒适性，追求每一块绿地都可进入、可休憩，每一栋建筑能为游人提供服务，成为杭城夜生活的特色场所。三是公众性。柳浪闻莺公园历来是进行大规模园林展会的场所，钱王祠的建设、公园的全面开放，将使其更易于组织民俗节庆及园林展会活动，并为该地增加持久的人气，提高该处绿地的资源利用率。

具体的设计思路，一是在空间处理上做减法，即重点以疏为主；二是拆除过密的建筑，疏理过密的植物，开河通港引入水体，形成导景空间走廊，使景区空间形态疏密得当，开合有致。三是加强游览及赏景视线的可达性，把西湖美景导入南山西面；四是空间上做减法，在文化意境上则做加法，充分挖掘、显露、恢复该地丰富的文化元素，使该区一景一物皆有灵魂。

整治后环湖南线的空间景观有了极大的改善，南山西面成为连续优美的景观带，串珠成链连起丰富多彩的景点景物。充分利用南山西面湖地区空间余地、深厚的历史积淀和人文特色，整治南山西面沿湖景点，打破独立公园的组景概念，以全局的眼光，整体组织沿路空间景观，引入西湖水体，实现西湖“南下”和“东伸”，使南山西面与西湖的景观联系更为直接，以山水美景串联沿途自然、人文景观，充分展现其迷人魅力。

3. 湖滨

湖滨景区位于西湖东北至东面，北起断桥，沿白沙路、圣塘闸、环城西路、湖滨路至一公园沿湖用地，涉及西湖岸线1.5公里，总面积11.988公顷，呈
狭长状。区域内有许多历史遗迹，周边又是杭州的商业集中区域，湖滨新景区范围该景区作为城市与西湖风景区的过渡地带，不仅是体现“城湖合璧”风貌的重要区域，也是西湖的门厅，是展示西湖文化的最佳地点之一。由此，其整治着重体现其历史文化内涵、商业文化内涵与自然景观的融合。着力解决商业步行街与西湖风景区的过渡问题，使自然景观和商业活动相得益彰。

在整治中，我们的指导思想：一是文化性。杭州有独特的风貌和地域文化，湖滨又是重要的景观带，设计汲取历史文化精华，巧妙反映到环境建设中，形成鲜明的风景区和城市结合绿带独有的特色。二是自然性。设计运用园林艺术手法统筹考虑，营造出线条简洁大方、环境优美的绿色景观空间，层次丰富，主次分明。强调生态性，在环境设计中安排大面积的草地花带、树丛、花灌木丛形成各种类型生态良好的绿色环境，成为西湖风景区的重要组成部分。三是协调性。环境设计与湖滨商业街建筑相映成趣，形成相得益彰的整体，与周围建筑、道路景观相协调。四是渗透性。总体布局及小品设计体现出简洁、明快的艺术风格，空间通透，适合大量游客游览休息，把西湖的美景渗透到城市中。五是亲和性。设置众多让人停留和与西湖亲近的设施。

整治遵循以下基本原则：一是因地制宜。湖滨景观带规划设计充分利用现有的有利条件，在圣塘路地段沟通水系，挖湖堆坡，合理布局。二是突出植物造景。湖滨景观带是湖滨地区难得的绿地，设计以植物造景为主，尽可能增加绿地，为人们提供一个舒适的绿色环境空间。三是体现丰富的文化内涵。杭州历史悠久，人杰地灵，文化底蕴深厚，适当地予以体现，从各个方面反映地域特色，让游人觉得亲切。四是坚持功能合理。由于湖滨景观带呈狭长形，规模较大，合理安排功能区域和配套设施，并处理好相互关系。湖滨景观带在后勤管理、人流集散、售货服务、停车、活动、冷饮、卫生间、垃圾收集等方面都有合理的安排。
湖滨景观带整治后，不但最大限度地扩大了该地段的绿地面积，把环城西路绿带与西湖风景区连为一体，综合环境大为改善，使湖滨路商业步行街的价值进一步提升和凸显，交通状况得到改观，湖滨景观带显得精致和谐，成为杭州西湖风景名胜区引人入胜、大气明朗的门厅。

4. 湖西

湖西景区位于西湖西部，以杨公堤为主轴，堤两侧从北至南分别为曲院风荷、金沙港、杭州花圃、茅家埠、丁家山、三台山、花港观鱼、浴鹄湾。其自然格局得天独厚，人文遗存十分丰富。工程设计红线范围东面以西山路为界，包括西山路东侧曲院风荷公园和丁家山之间的原杨公堤地段；北面以灵隐路为界；南以虎跑路为界；西面界线沿青龙山、五老峰、鸡笼山、吉庆山山脚，经黄泥岭与灵隐路相连。总面积约为477.38公顷。

在整治保护工程实施之前，湖西地区的城市化倾向非常严重。建筑密集且布局杂乱、色彩多样，基础设施落后造成污水横流、垃圾遍行并成为西湖的污染源。交通不畅影响了西湖旅游系统网络的完善，已到了必须动大手术的地步。

湖西的整治旨在传承历史传统，还西湖以历史的本原；优化生态环境，改善西湖水质；优化社会环境，整合社会资源；提升风景效果，丰富景观资源、完善景观格局，扩大旅游空间；最大限度地保护该地人文遗存。

整治以区域综合整治为基础，人文内涵为神、自然生态为形，幽趣、野趣、闲趣、逸趣为景观特点，创造出可游宜憩、观光与休闲并重的景区，充分完善西湖风景名胜区的风景格局。湖西地区历来人文活动密集，遗存有丰富的人文遗产，保护整治工程适度、合理、有机地展示、发掘该地的历史遗存，保护、保存该地所存留的大量人文遗产、民俗民风，不仅使悠久的历史得以
传承，也为湖光山色增添了浓厚的文化气息，极大地提升了整个湖西景区的价值品位。

基本原则：一是景观特征求“幽”求“野”，以纯自然的景观外形创造朴素脱俗的生态美景。二是文化内涵突出“茶文化”、“民俗文化”和“名人文化”；三是历史定位以明代为主，兼收其它；四是旅游组织要求“观光”与“休闲”共举；五是旅游服务强调整合现有设施及农居的服务能力，在实现社会、居民及产业调整的同时，塑造富含地域特色的旅游服务景观；六是建筑设计及整治要求“民居化”与“自然化”，强调白墙黑瓦的杭州西湖原生态民居群落的有机感及木、石、泥、竹等自然材料的真实感。规划范围内与自然景观不协调的建筑物均应予以改造和拆迁。

西湖湖西整治通过大面积的水体恢复，使原来被城市化的湖西地区阻隔的山水完全相融，同时还产生了山水之间的过渡带，以其港汊水湾及丰富多变的岸线，创造出不同于外湖之“秀”的“幽”的景致。湖西地区除了为西湖山水创造有机溶合的大格局外，其本身通过因地制宜的建设，也成为风景最为优美的地域。此外，适度、合理、有机地展示、发掘该地的历史遗存，保护、保存该地所存留的大量人文遗产、民俗民风，不仅使悠久的历史得以传承，也为湖光山色增添了浓厚的文化气息，极大地提升了整个湖西景区的价值品位。

5. 北山路

北山街位于西湖北端，紧依宝石山，街北侧遗存有大量历史建筑。北山街滨湖景观带总面积约 52000 平方米，景观纵深不大。滨湖景观整治工程在对原有植被不作大调整的前提下，对绿化局部进行了完善和补充。对原有大树和
古木加强保护；原有绿化植被根据园林景观的需要，适当调整，就近移栽使用。对原有景观建筑如镜湖厅、绿水芙蕖、风雨亭景观建筑等进行修缮，增补建筑院落内外的植物，使建筑与植物结合得更为融洽、和谐。经历史的考证，复建武松墓和苏小小墓。整治后北山街滨湖景观带不但改善和提高了滨湖绿带的景观质量，也确保和加强了北山路的历史人文价值和内涵。

6. 两堤三岛

西湖“两堤三岛”的主要内容是小瀛洲（三潭印月）、湖心亭、阮公墩和苏、白二堤，是西湖中承载着浓重的各时代历史文化遗存的著名景点。“西湖十景”中的“苏堤春晓”、“平湖秋月”、“断桥残雪”和“三潭印月”就在这一区域。实施整治前的两堤三岛已有多处建筑破损，部分景点已缺失，一定程度上影响了景点质量；基础设施不完善，服务设施不配套，与现代旅游不适应。

针对现状存在的问题，整治体现最小干预，按“保护为主，适当修缮”的要求，进行切实可行的修缮和保护。尊重原有总的平面格局；保护修缮建筑主体，消除安全隐患，去除与周边环境不协调的设施；挖掘人文历史景观，着力完善配套设施；对植物配置和园路体系进行改良。

实施整治后，两堤三岛区块的基础设施得到了完善，服务设施得以配套；历史建筑全部得到了很好的保留和修复，景观特色既似曾相识又不时予人惊喜，环境品位充分与现代旅游相协调。

7. 龙井
“龙井八景”区块位于龙井寺东北部的山谷中，西、北以龙井路为界，北端与西湖湖西景区相连，东、南达南高峰山脚，总面积约 17.32 公顷。这里群峰环绕，环境清幽，古木参天，溪水丁冬，自古以来就是杭州的游览胜地，拥有众多的名胜古迹。乾隆皇帝六次巡游江南，四次亲临龙井，亲笔为“风篁岭、过溪亭、涤心沼、一片云、方圆庵、龙泓涧、神运石、翠峰阁”等“龙井八景”题名，并为龙井茶作诗赋歌。

恢复“龙井八景”，创造多变的饮茶场景，使人们在赏景的同时体验到不同的饮茶氛围，对打响杭州茶都品牌，丰富龙井茶文化内涵，进一步提升龙井茶知名度，具有十分重要的意义。

龙井八景的设计着重考虑以下几个方面：

充分尊重历史，尽可能遵循历史记载再现龙井八景的景观风貌。在尽可能少拆迁的基础上利用现状地形条件，创造完善的游赏格局；利用不同的场所空间，创造不同的饮茶意境，充实龙井茶内涵，丰富人们的品茶体验；与游览活动及农民基本生活无关的企业单位一律搬迁；完善内部游览系统、车行交通及停车设施。

龙井八景区块不仅具有山水之胜、林壑之美，处于茶山环抱之中，还具有强烈吸引力的历史积淀和举世瞩目的茶文化艺术，融自然美与艺术美为一体，且对外交通便利，历来为杭州的游览胜地，根据其资源特色，确定“龙井八景”的性质为以体现“龙井八咏”意境的景观环境为特色，体现龙井历史，具有茶文化艺术内涵，为游人创造多种品茶场所的旅游休闲景点。

该景区的整治应紧紧围绕整治水系、再现八景、以八咏为意境，充分挖掘历史文化内涵，整理历史遗迹，体现茶文化为重点。通过历史景点的恢复，对溪泉、石崖、绿化等自然景观进行改造整治，完善交通与服务设置，将“龙井八景”的历史与品尝龙井茶、龙井茶宴、茶艺表现等通盘考虑，有机结合，
赋予每一处景观空间不同于别处的场所精神，使游人在园林美景中体验“龙井八咏”的丰富内涵与意境，同时，在不同的园林空间中体会到不一样的品茶体验。

8. 灵隐

灵隐景区是杭州西湖风景名胜区的重要组成部分，是驰名海内外的佛教胜地。这里集中分布着高品位的人文景观与自然景观资源。随着海内外旅游事业的发展，每年到灵隐的游客香客与日俱增。由于原灵隐景区面积狭小，仅16.67公顷，农居混杂其中，沿天竺路两侧民居已破旧不堪，许多历史人文景点和佛教寺院、自然山林、农居交织在一起，并处于湮没状态，尚未得到有效的开发利用，对游览线路及游客流量的合理分布均有不利影响，因此灵隐寺、飞来峰等老景区已无法满足日益增长的旅游需求，同时也不利于对原灵隐景区内的人文历史及自然环境资源的保护。

灵隐整治的规划指导思想是遵循建设部关于风景名胜区建设的十六字方针：严格保护、统一管理、合理开发、永续利用。

规划原则：在充分保护生态资源的前提下，保持和发展灵隐特色，完善宗教朝觐功能，恢复特色旅游服务，深入挖掘历史文化内涵，体现历史的连续和发展，加强集体经济发展后劲，远近结合，为远期发展留有余地。

景区控制性详细规划在维护和改善生态环境的基础上，紧扣佛教文化拓展活动空间，增加游憩内容，完善旅游设施，使新的灵隐景区既保持佛教胜地的传统风格，又符合现代旅游文化的需要。

游览区内，行政单位大部分迁出，保留部分农居，同时相应增加旅游服务设施。区内的现存佛寺均作保留。在与佛协协调的情况下，适当扩大寺院的用
地范围，以配合整个景区的开发建设。原景区内的茶地、山林做适当调整，但原则上以保留整合为主。

服务区内原则上保留所有茶地和山林，原有民居以综合整治为主，为景区配套管理服务的行政单位统一安置在行政用地中。该区域已建或已批建的单位有灵隐管理处、街道办事处、工商、消防及省安全厅、警卫局、公安八处等，总建筑面积控制在2万平方米。

灵隐景区以佛教文化为内涵，自然与人文景观交相辉映，相互渗透，相互包容，典型地体现了东方文化体系中天人合一的哲学思想以及和谐为美的审美情趣。因此，保护生态的合理性，展示佛教文化与自然环境的和谐交融，让人们能永久持续地拥有和欣赏人文与自然美景，体味历史民俗风情，是灵隐景区规划宗旨所在。在灵隐景区中向游人展示的景象游览内容是观光欣赏、宗教朝觐为主，在一定区域提供旅游所需的服务内容。
都市内文物建筑的移动保护
——广州锦纶会馆整体移位保护工程介绍

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广州锦纶会馆建于清初雍正年间，位于广州旧城西关地区，是广州当时海外贸易鼎盛期丝织行业的会馆。建筑原为一路二进，到了道光年间加建第三进并建东、西路，占地面积 1050 ㎡。现在会馆里面保存着 20 方古石碑，上刻从清初、清中、清末到民国初期的锦纶会馆大事记。解放后，会馆由民政局接管，安排多户居民入住。由于锦纶会馆是中国近代丝织业海外贸易的见证和建筑的主体格局基本保存，1999 年被广州市人民政府公布为广州市文物保护单位。

2000 年，广州市政部门决定在该区开辟一条南北走向的主干道“康王路”，新路就从锦纶会馆用地通过。于是文物保护和道路建设的矛盾就摆在面前：一方主张“后人让前人，道路让文物”。另一方主张“前人让后人，文物让道路”。为了解决矛盾，受文物主管部门的委托，广州大学建筑设计研究院（常务副院长：沈粤总建筑师）“岭南设计所”（项目负责人：汤国华教授）经勘查和实验，设计了锦纶会馆整体平移保护初步方案，并向广州市文化局提交“锦纶会馆平移可行性研究报告”。2001 年 3 月 14 日广州市建委召开专家论证会，该研究报告获得通过。

锦纶会馆的新址选在新开辟的康王路西侧的一个占地面积 1400 ㎡公共地下停车场的顶面上。锦纶会馆要平移的建筑包括中路的三进和东路的后两进，其他部分因已经严重损坏和改变太大，不作平移。总平移面积是 668 ㎡。又因
平移后的新址地面标高比原地面高 1M，所以锦纶会馆的整体移动包括整体平移和整体提升两大工程。最后，确定了锦纶会馆的整体移动过程是：
(1) 开挖建造从南向北的半地下通道；
(2) 锦纶会馆整体从南向北平移 80M；
(3) 锦纶会馆整体提升 1.08M；
(4) 锦纶会馆整体从东向西平移 22M；
(5) 整体落地。

锦纶会馆整体移位保护工程的实施，是通过移动前的文物保护和基础置换，平移技术，顶升技术和移动中的检测来完成的。在平移初期，广州大学用“单摆法”对多次起动和止动进行了实测，发现起动时惯性加速度趋于零，而止动时的惯性加速度接近重力加速度的千分之三。即使如此小，整体向前的惯性力还是要注意克服的，所以加强了防前倾的支撑。

锦纶会馆经历了一个多月的移动施工，终于成功地到达了新址，坐落在新建的公共地下停车场顶盖上。平移后面临艰巨的修复任务，只有修复成功，锦纶会馆的移动保护才算成功。整体成功移动只是锦纶会馆保护的第一步。如果锦纶会馆松绑后倒塌，那么第一步的整体移动就没有意义，而且是最大的浪费和对文物最大的破坏。所以，对整体移动后的修缮不可轻视。在对其结构维修中采取了松绑和临时支撑和整体结构加固。在建筑修缮中实施了建筑布局的复原、装修工程、防护工程和装饰工程。移动后的各种修复准备工作持续了 21 个月，2003 年 6 月开始维修，至 2004 年 8 月，锦纶会馆修复工程终于圆满结束。

广州锦纶会馆的移动保护策划从 2000 年 6 月开始，经历近一年的勘查、实验、研究、论证、设计、审批，被迫移动的文物建筑—广州锦纶会馆于 2001 年 8 月 18 日开始移动，经历近 40 天紧张的平移和顶升施工终于到达新址。又经历近三年的修复设计、审批、施工，于 2004 年 8 月锦纶会馆最终以健康、完整的原貌展示在世人面前。
RESTORATION PROJECT OF EMBROIDERY GUILD HALL,

GUANGZHOU

SHEN YUE

In the age of transforming economic circumstances between Ming and Qing Dynasties, Guangzhou merchants have organized trade groups according to trade practices and traditional ties known as guilds, which in turn built guild halls. The elaborate Embroidery Guild Hall is the only remaining of one’s kind in Guangzhou. The set up of the guild in 1732 and its subsidence in late 19th century demonstrated the evolution of the merchants’ classes and the social morality. To accommodate a road project, the Guangzhou Cultural Department utilized an innovative technology to lift and move this ancient monument by 200m sideways. The overall restoration works also made use of various traditional crafts like brick lying, timber jointing, and repairs of wood / stone carvings. The result was the reappearance of the glory of the Xi-guan merchants.

The implementation of the Embroidery Guild Hall’s whole moving conservation project was based on the protection of foundation displacement before moving, moving technique, lifting technique and detection during the moving process. At the beginning, experts from Guangzhou university used "Pendulum" to measure the starting and stopping many times, they found that the inertial acceleration tends to zero in the beginning, while the inertial acceleration nearly reached to $3/1000$ of the gravitational acceleration when it was stopping, Even it was so small, the overall forward inertial power was still need to overcome, so the experts add hob on it to prevent forward tilting.
After over a month’s experience of the ambulation, the Embroidery Guild Hall successfully had arrived to the new address finally, on the cover of the new-set public underground parking. There was a hard task of repairing after the ambulation. Only the repair succeeded, could the protection of the Embroidery Guild Hall came to success. The success of unitary ambulation was just the first step of the protection. If the Embroidery Guild Hall collapsed after relaxation, the unitary ambulation would became meaningless, furthermore, it’s a greatest waste and breakage to the hall. Therefore, we dare not repair the hall rashly. In the repair of its frame, we adopted relaxation, temporary braces and reinforces for the unitary frame. In the process, we actualized the reversion of the layout, fitment projects, defending projects and decorating projects. It took 21 months to prepare for the repair, which started in June, 2003. Finally, the repair of the Embroidery Guild Hall succeeded at an end in August, 2004.

The Embroidery Guild Hall's mobile protection started from June 2000, which is experienced nearly one year of exploration, experimentation, investigation, argumentation, design, examination and approval. The compelled ambulation of cultural object building- the Embroidery Guild Hall was beginning to move on August 18, 2001. It has finally arrived at the new site, experienced 40 day -long strained parallel moving and the construction of raising the roof . Then through three years of repairing design, examination, approval and construction, the Embroidery Guild Hall finally stood in front of the whole world by the original face of health and integrity on August 2004.
佛甲草屋顶绿化新技术可行性分析

杨水龙
广东玉宇环保科技开发工程有限公司

1. 简介
广东玉宇环保科技开发工程有限公司是 2001 年 9 月注册成立的高科技环保科研开发单位，注册资金 100 万元人民币，目前总部设在广州市天河区，并在广州经济开发区建有一个占地 200 余亩的种苗试验培育基地。玉宇环保拥有自主知识产权的中国专利技术产品——“佛甲草屋顶绿化新技术”。该技术隔热、保护防水层效果明显，可减少大气污染，缓解城市热岛效应，增强景观效果，为综合治理屋顶脏、乱、差开辟了新的途径。2007 年 11 月 23 日，广东省建设厅、广东省建筑设计科研院、华南理工大学建筑节能研究中心、广东省建筑节能标准办公室组织相关专家对“佛甲草屋面绿化新技术”进行了会审，并顺利通过；编入广东省建筑设计通用图集（粤 07J/216）。

2. 我国建筑业的发展与节能
目前，我国正处于工业化和城镇化快速发展阶段，经济增长方式粗放，能源资源与经济发展的矛盾十分突出，经济发展面临着巨大的资源约束瓶颈和环境恶化压力。一方面，随着经济发展和人民生活条件的改善，人均能耗迅速增加；另一方面，随着农村富余劳动力向城镇转移，每年约有 1500 万农民进入城市，而城市居民的人均能耗为乡村人口的 3.5 倍。如果不采取切实有力的措施，缓解能源资源与经济发展的矛盾，势必会对我国经济平稳快速发展造成严重后果，使我国现代化进程受挫。
与工业节能相比，建筑物节能的起步更晚，推广力度较弱。目前建筑节能工作仍然进展缓慢，到2004年底全国节能建筑面积仅2.3亿㎡，占全国建筑总面积的0.3%。尽管在政府的推动下，建筑节能标准的制订和颁布在近年都取得了很大的进展，但与发达国家相比，仍然在标准数量、能效值的确定等方面存在着较大的差距。在我国许多城市，住宅建设仍然采用并沿袭了几千年的分散建设方式，不仅功能较差、质量低下、科技含量不高、环境脏乱，而且严重浪费土地资源和能源。

1.1 我国所面临的能源挑战

我国成为能源消耗大国，进口依赖度提高。2003年我国已经成为世界上仅次于美国的第二大石油消费国。全年原油消费量达到2.5亿吨以上，其中进口原油8900万吨，分别占世界石油需求增长总量的41%、32%。2004年以来，我国的原油消费需求仍以年10%以上的速度增长。预计到2020年，我国石油需求量为4.5亿吨，年均递增12%。我国对海外能源的依赖程度将达到55%以上。

可见，我国能源消耗需求旺盛的同时，进口依赖度提高，这使得国内经济受国际形势的牵制增大。

1.2 建筑节能要求十分紧迫

建筑能耗约占社会总能耗的1/3。我国建筑能耗的总量逐年上升，在能源总消费量中所占的比例已从上世纪70年代末的10%，上升到近年的27.45%。随着城市化进程的加快和人民生活质量的改善，我国建筑耗能比重最终还将上升至35%左右。我国目前处于建设鼎盛期，每年建成的房屋面积高达16亿至20亿平方米，超过所有发达国家年建成建筑面积的总和，而97%以上是高耗能建筑。以此推算，预计到2020年，全国高耗能建筑面积将达到700亿平方米。因此，如果现在不开始注重建筑节能设计，将直接加剧能源危机。因此，建筑节能在我国具有更加突出的重要意义。
1.3 政府高度重视建筑节能问题

许多发达国家在上世纪 70 年代“石油危机”之后，就相继制定并实施了节能的专门法律，对民用建筑节能作了明确的规定，并采取了一系列经济鼓励措施。东欧国家也在近十年颁布并执行了相应的法律，因而建筑节能工作取得了迅速的发展。面对 2004 年新的能源危机与世界能源格局的变化，我国政府也开始重视建筑节能问题，并开始进入具体的调试阶段。

1.4 具有长远的经济效益

据预测，我国要达到节能 60% 标准的建筑造价并不高。节能建筑的成本只是在原来建筑的造价基础上再增加 5 至 7 个百分点，而且增加的造价预计在 5 年到 6 年的时间内就可以收回。它给人们提供的室内环境是完全不一样的，它对外部环境的影响也有很大不同。而高能耗建筑，虽然前期造价成本略低，但是长达 50 年的能源消耗已经远远超过前期节省的成本费用，甚至中途还会因为能源经营问题而导致停用，如国内一些上世纪 80 年代的写字楼已出现这种情况，造成社会资源的浪费。

3. 市场展望

本项目产品属于绿化材料，主要是屋顶绿化材料。随着城市化进程的加快，高楼林立，水泥建筑物的大量涌现，热岛效应更为明显；为增加绿地面积，对屋顶绿化、天台绿化等的需求更加强烈。本项目为利用佛甲草加强推广屋顶绿化，提高绿化面积，改善人们生活环境质量，提供一种新型的屋顶绿化材料。该项目的提出是人类居环境改善的渴求所在，也是环境保护的有力对策，可以预计市场前景广阔。
4. 行业及市场状况

城市绿地是城市中的主要自然因素，是减轻热岛影响的关键措施。绿地能吸收太阳辐射，能从环境中吸收热量，降低环境空气的温度。而屋顶绿化吸收太阳辐射的能力更强，能够更好地降低环境温度缓解城市热岛效应。

据报道，美国芝加哥为减轻城市的热岛效应，正在进行积极的推动屋顶花园运动；日本、东京、大阪等城市已经把屋顶绿化作为改善环境，而不占用土地的最佳选择。一个绿化屋顶就是一台自然空调，绿化地带和绿化屋顶，可以通过土壤的水分和生长的植物降低大约 80%的自然辐射，以减少建筑物所产生的负作用。在生态环境及城市建设中的重要性日益增加。在我国，北京及上海等大城市已意识到屋顶绿化的重要性，并准备将其列入规范条例中以进行强制实施。屋顶绿化，对于提高人民的生活质量，维护城市可持续发展具有重要的意义。

屋顶隔热与防渗漏一直是建筑界面临的难点和住户十分关注的“热点”。未经绿化的屋顶在强烈日光照射下，温度变化梯度较大，其结构易遭破坏，防水层因而也容易失效。而且顶楼住户的空调能耗大大超过统一建筑物的平均水平。经过绿化的屋顶，大部分太阳辐射热量消耗于植物水分蒸发中或被植物吸收，剩下的少部分太阳辐射热量不会使屋顶温度急剧升高。经测试，夏季绿化好的屋顶植物层底部温度约 20℃-25℃。这一事实说明，经过绿化的屋顶，有效地阻止了屋顶温度的升高，遏制了温差对屋顶造成的强烈的破坏，达到了隔热和保护防水层的目的，而且可以大幅度降低顶楼住户的空调能耗。
5. 项目技术简介

本项目的屋顶绿化主角佛甲草，属景天科多年生植物草本，喜阳；主茎匍匐生长，直径 3 毫米至 4 毫米，高 100 毫米至 150 毫米，着地各节能长出不定根和分枝，这些根枝伏地蔓延，可发展成为庞大的株丛。佛甲草叶片呈半圆柱状条形，长 10 毫米至 20 毫米。佛甲草根系短小。驯化后，佛甲草便可应用于屋顶绿化。其具有如下显著特点：

● 耐旱性好、生命力强

佛甲草属多浆植物，含水量极高，叶、茎表皮的角质层具有超常的防止水分蒸发的特性。可在夏季高温干旱的屋顶生长，耐旱时间长达 200 天。

● 养护简单、美观朴实

种植初期，为促进佛甲草尽快长满成园，需进行科学管理，此后，几乎无需浇水、无需施肥、无需修剪。佛甲草分枝茂盛，茎杆直立，高矮基本一致，常年保持自然平整，叶片青翠欲滴，给人以朴实之美感，极具观赏价值。

● 覆盖率高、供氧量大

佛甲草株距密集（每平方米 4000 株至 5000 株），枝繁叶茂，绿化覆盖率达 90% 以上。佛甲草夜间吸收二氧化碳，白天放出大量氧气，对人体健康大有好处，对改善生态环境有重要意义。

总之，佛甲草运用于屋顶绿化，既是隔热和保护防水层的有效措施，又是城市园林绿化的创新，它为改善城市的生态环境，创建花园城市展示了广阔的前景。
6. 产品性能及其特点

技术性能

● 隔热保温效果

佛甲草绿化后的屋顶，夏天隔热 3-5 度，可节约降温电费 50%-70%；冬天保温 3-5 度，可节约热能 30%-40%，是名副其实的节能型建筑。据日本林业厅计算，1 公顷绿地 1 年可蒸发 4500—7500 吨水，一昼夜蒸发水的调温效果相当于 500 台空调连续工作 20 个小时所释放出来的“冷量”。

![屋顶温度图]

● 净化空气效果

绿色的草坪可以吸附灰尘、吸收二氧化碳，并放出大量氧气，能有效提高空气质量，改善生态环境。据日本林业厅计算，1 公顷绿地 1 年吸尘量为 22.3 吨；绿地空气中的细菌含量比非绿地空气中的细菌含量少 85%以上。

● 绿化美化效果
不占城市建设用地，大大增加城市绿化的面积。一举改变目前绿色在城市中为城市在绿色中，极大地改善城市的景观，增添都市人们的生活情趣。

● 保护屋面效果

绿化后的屋面冬暖夏凉，温差缩小，因而能有效缩小热胀冷缩对屋面结构造成的损坏。延长防水层的防护年限，防止屋面渗漏水。

主要特点

● 基本不用泥土。负荷轻，每平方米仅重30-35公斤。

● 基本不用管理。除种植初期需要维护外，长好后（30-60天）无需浇水施肥修剪，且能保持长期（冬天稍有枯萎）的绿化效果。

● 易掌握，好操作。可机械化生产、大面积施工。

绿化后的屋顶隔热保温，吸附灰尘、吸收二氧化碳、放出氧气，是名副其实的“生态隔热板”、“人造氧吧”。既节能（顶层住户大幅度减少空调使用时间）又环保。对改善城市生态环境有重要的意义。

7. 我国屋顶绿化状况

屋顶绿化各地观

据了解，从今年开始，深圳将逐步推行屋顶绿化，在开始实施阶段通过出台相关法规进行强制性推广，对响应政策者辅以经济杠杆。此举标志着深圳开始关注建筑物第五立面的绿化。深圳具有推行屋顶绿化的气候条件，能够保证绿化植物长势良好。目前，深圳有关部门已经开始制定相关政策，包括如
何改造旧的楼房，使其能够承载屋顶绿化的重量；要求新建楼房必须进行屋顶绿化等。

上海市 2002 年建设的“屋顶绿化”主要有三种形式：花园式、组合式和地毯式，实施方案视房屋具体情况而定。目前屋顶绿化选用的是一种叫“佛甲草”的植物，它本身是一种中草药，从几年的观察情况来开，相当不错。

目前北京市仅有屋顶花园几十处，在今后的几年中，要大力推广屋顶花园，充分发挥其不占地面占空间的独特优势，同建设单位和物业单位密切配合，采取使用轻型土壤、耐旱植物等各种方法，充分利用高科技手段，结合北京的屋顶整治，使北京的屋顶绿化达到世界水平。

广州绿化委员会也于 2002 年出台了《关于大力开展建筑物天面绿化美化工作的通知》（绿发字[2002]4号），通知中明确规定：凡大型公共建筑物的顶层都应建设天台花园。几年来，广州已在新机场高速路两侧、广清高速路两侧、广州市政府周边等地进行了较大规模的屋顶绿化，得到了各界的好评。
ABSTRACT: Along with the fast development of energy conservation in China, using river water as the cooling and heating source has been more and more attended. River water’s temperature is relative stability all the year round. In winter, the water temperature is higher than ambient air, but in summer, the temperature is lower. So it will be a quite good cooling and heating source for air condition, and it can save energy, decrease air pollution and CO2 discharge effectively.

This paper will introduce a large business centre’s air-condition engineering in Chongqing. By comparing the process using Jialing river water as source of district cooling and heating with that of traditional air-condition, the paper will analyze the COP of air conditioning unit at different water temperature, system’s operation, energy conservation, and the impact to environment. Study indicates that because use river water, the energy consumption of the project can save nearly 33% every year, so it has great promotion effect.

Keywords: river water source heat pump, district cooling and heating, COP, energy conservation
This project is a large commercial district, and its target is to arrive the award of the gold LEED green building certification. The total construction area of this business community is 82472m², including 52678m² need air conditioning. According to the different architectural function, the whole region was divided into hotel and commercial areas. The hotel also needs cooling in winter to meet different customers’ needs. According to the calculation of air conditioning load, the hotel use a centrifugal refrigerator with 1950kw cooling capacity, and the commercial areas adopt four water source heat pumps with 1950kw as cooling capacity and 2114kw as heating capacity. The water is taken from the centre of the Jialing river which is one of the rivers around the whole Chongqing city by four deep water pumps. The river water is delivered into the plate heat exchanger after treatment in hydro cyclone and integral water cleaner. Fig.1 shows the schematic work principles of the water purification system.

![Water purification system](image)

**Figure 1:** Water purification system.

### 2. THE FEASIBILITY ANALYSIS

#### 3.1 Analysis of river water quality

Comparing with the Jialing River water sample and the Cooling water quality standards, we find that the PH, salinity, hardness, corrosion can meet the air conditioning water quality requirements except the turbidity can’t meet the requirement in summer. To solve this problem, we let the cooling water change heat with river water by plate heat exchanger, avoid directly using river water. But in winter, the river water can be delivered into the air-condition units directly.
3.2 Analysis of river water temperature

The river water temperature has great impact to the cooling water temperature, and the air-conditioning’s performance. So analyzing its annual change is very important. Fig.2 is the average Jialing River water temperature in the year 2005.

![Figure 2: Average Jialing River water temperature in the year 2005](image)

As can be seen in Fig.2, the average river water temperature is 26°C in summer and 9°C to 12°C in winter. But the average air temperature is 28°C in summer. Furthermore the air temperature undulation is very big. Every year, the number of days whose air temperature is higher than 30°C is more than 70 day, the air temperature even up to 40°C. Therefore, the air-conditioning units’ COP is usually very low. But the river water temperature relatively stable, because of its larger specific heat capacity. So the air-conditioning system use river water will have superior performance than traditional system.

3. ENERY CONSERVATION ANALYSIS OF AIR-CONDITIONING SYSTEM

3.1 The strategy of air-conditioning’s operation

3.1.1 The strategy of air conditioning’s operation in summer
In the summer, the cooling water will be cooled by the Jialing River water, than it will be send into the refrigerators. Fig.3 is the air-conditioning system’s schematics in summer.

3.1.2 The strategy of air conditioning’s operation in winter

In the winter, it use four water source heat pumps extract heat from river for heating and use free cooling method to meet the need of winter cooling in the hotel. The average river water temperature is at 9°C to 12°C. The temperature of outlet water ranges from 4°C to 7°C, which is appropriate as chilled water for hotel’s cooling. This free cooling method can achieve the effect without using air-conditioning. So it can reduce greatly the energy consumption. Fig.4 is the air-conditioning system’s schematics in winter.

3.1.3 The strategy of air conditioning’s operation in transition season

In transition season, we still use the same strategy like that is in winter. But during this period, the average river water temperature is from 14°C to 19°C. The outlet water temperature may not achieve the necessary free cooling temperature. So we make the outlet water temperature fall to 8°C by reducing the cooling water flux. If
the rate of cooling water flow is lower than the limits of heat pump units, the centrifugal chillers in the hotel will be used.

### 3.2 Energy conservation evaluation

In order to compare the different air-conditioning systems, the primary energy utilization efficiency (PER) is used. PER means the primary energy consumption for unit refrigerating capacity or unit heating capacity. (Kw/Kw)

For the cooling system in summer:

$$PER = \frac{Q_c}{W + W_b + W_t} \times \eta_f \times \eta_w \times \eta_y$$

(1)

For the heat pump heating system:

$$PER = \frac{Q}{W + W_b} \times \eta_f \times \eta_w \times \eta_y$$

(2)

For the boiler heating system:

$$PER = \frac{Q}{G + \eta_f \times \eta_w \times \eta_y \times W_b}$$

(3)

- $Q_c$ — Cooling capacity (kw)
- $Q$ — Heating capacity (kw)
- $W$ — Power consumption of refrigeration units (kw)
- $W_b$ — Power consumption of water pumps (kw)
- $W_t$ — Power consumption of cooling tower (kw)
- $\eta_f$ — Efficiency of power supply, 30.1% (The coal consumption is 0.41kgce/kwh in China)
\[ \eta_w \] --- Efficiency of power transmission, 92%

\[ \eta_r \] --- Electric efficiency of compressor, 90%

\[ G_s \] --- Consumption of natural gas (m³)

\[ q_{c_u} \] --- Calm value of natural gas(KJ/m³), approximate 40000 KJ/m³

3.2.1 Performance comparison of cooling systems

The cooling water temperature has great impact to the chilling units. When the cooling water temperature fall down, the COP of the chilling units will increase. Fig.5 is the COP change with cooling water temperature.

![Figure 5: The COP change with cooling water temperature in cooling period](image)

In summer, the traditional air-conditioning system use cooling tower to cool water. The design cooling water temperature is 32°C. And the COP of refrigerator is about 4.3 on his condition. However, the COP is always lower than 4.3 because of the sustained high temperatures in Chongqing. In this project, the river water air-conditioning system use river water cooling replace the cooling tower. The average water temperature is about 26°C. The minimum temperature can reach 21°C. Considering the heat loss, the cooling water temperature will be at 28°C. So the COP average increase to 4.7, the highest COP can reach 5.2. So we can know that the COP can average increase 10%, at most even 20%.
According to equation (1), we can calculate the PER of traditional air-conditioning system and river source system. The PER of traditional system is 0.84 in the design condition. The average PER of river source system is 0.98, which increases 18%.

3.2.2 Performance comparison of heating systems

In winter, the river water will be send into the heat pumps directly. Fig.6 is COP value with the change of the river water temperature. [Graph]

*Figure 6: COP value with the change of the river water temperature in heating period*

From Fig.6, it can be seen that, the average COP is at 3.1 to 3.3. According to the equation (2) (3), we can know the average PER of boiler heating system is 0.4, but the river water heat pump heating is 0.7 to 0.8, increase 75% to 100%. The energy conservation effect is significant.

In the transition season, the average river water temperature is at 14°C to 19°C. The COP and PER will be higher than them in winter.

3.2.3 Performance of free cooling system

In the winter and transition season, the river water temperature is very low. When the temperature is lower than the refrigeration units allow, the units can not normally running. At this time, the units will use cooling water recycle in order to increase the cooling water’s temperature. So the highest COP of the chilled units is about 5.5, and the highest PER of the air-conditioning system is about 0.99. But for
the free cooling program, the COP can be seen as infinite, because there is no electricity used for refrigeration. And the PER is about 3.36. Energy saving effect is obvious.

3.3 Economic evaluation

In the river water source heat pump project, the incremental investment is mainly at water system and water purification system. The incremental investment is about 20% to 40% of the conventional cold and heat source system’s investment.

We can estimate the operating cost of the river water source air-conditioning system and the traditional system by reference to the other similar air-conditioning system’s operating time. After calculation, the river water air-conditioning system can save about 116 million RMB every year, nearly 26% cost of the traditional system’s operation. If the boiler gas consumption of the traditional system were changed into corresponding consumption of electricity, we can find out that the river water source system can save 195 million Kwh electricity. The rate of energy saving arrives at 33%. It can be seen that the river water source air-conditioning system has great energy efficiency through reasonable designed. Fig.7 is the result of the comparison between these two systems’ annual operating costs.

![Figure 7: The annual operating costs of two systems](image)

4. ENVIRONMENTAL EVALUATION

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In summer, river water source air-conditioning discharge the waste heat into river instead of into the ambient air so as to mitigate the heat island effect. And in winter, this change can reduce the use of the chemical fuel and the discharge of SO\textsubscript{2} and NO\textsubscript{x} by utilize the clean electricity.

The heat discharged into the river would result in the increase of river water temperature. The excessive high temperature may affect the ecology in the river. In this project, because of the rich water and strong mix in Jialing River, the heat discharged into the river will diffuse quickly. The water temperature increase as little as 0.0019 °C under theoretical calculation which can be ignored. Therefore the river water source air-conditioning system has no destruction to the environment.

5. CONCLUSION
After comparative analysis, it can be seen that the river water air-conditioning system can save 33% energy per year, besides it has little adverse effects on the environment.

In the south regions of China there are many rivers, which contain a considerable amount of renewable. Clean energy can be applied to cooling and heating projects. The adoption of this kind of energy reasonably will promote greatly the development of energy conservation enterprise.

6. REFERENCES


2010世博前的上海高层住宅“阳光事业”

SOLAR SPIRIT OF SHANGHAI HIGH-RISING DWELLINGS BEFORE EXPO 2010

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摘要/本文结合我国太阳能应用现状，就上海高层住宅利用太阳能问题，提出了从小区规划、建筑形态到建筑构件的可操作途径；强调了上海未来高层住宅太阳能一体化设计，已不再是单一技术体系的运用，而是多技术体系与建筑整体的融合过程；并逐步建构以计算机模拟为支撑的体系，优化实现具有地域气候美韵兼能效功能的建筑外观风格。

关键词/高层住宅，太阳能利用技术，建筑节能，一体化设计

ABSTRACT/ Combining with the current situation of building of solar energy utilization in China, this paper proposed that the way to be possible to operate from the residential area plan, the building shape to the building component on Shanghai high-rising dwellings of solar energy use, as well as emphasizes that the high-rising dwellings will be no longer designed to use just a style of solar energy system in future. In fact, it will combine several of the multi-technical system and the whole building. Setting up a computational support system of building simulation, it will presents the work being done on optimising the building envelopes with the energy efficient foundation and aesthetic rhythm of climate.

KEYWORDS/ high-rising dwellings, solar utility, building efficiency, integrated design

1 引言

太阳能的推广利用工作被誉为“阳光事业”。中国地域辽阔，有着丰富的太阳能资源。据估算，我国陆地表面每年接收的太阳辐射能约为 50×1018 KJ，全国各地太阳年辐射总量达 335～837 KJ/cm²·a，平均值为 586 KJ/cm²·a，
属太阳能资源丰富的国家之一 [1]。太阳能资源因受气候条件、地理纬度等环境状况的影响，其分布具有明显的地域性。我国共划分了四个太阳辐射资源区，上海属夏热冬冷地区，处在太阳能辐射资源Ⅲ区 [2]，为亚热带海洋性气候，温和湿热，四季分明。判断太阳能资源充足与否，主要依据太阳日照时数与日照百分率两个因素。经过数年的研究和开发，太阳能热水器的推广应用范围在不断扩大，其发展在我国最为迅速，已形成为一个产业。新型太阳能集热器的试制成功，使太阳能热水器可作为建筑构件应用在屋顶、墙面和阳台上，镶嵌式的太阳能热水器集热板可紧贴屋面或作为屋面建筑的组成部分，上海已有较多住宅屋顶设置集热器，不仅为建筑提供热水，而且对屋面起到了较好的装饰作用。当前上海正尝试建设各种生态节能的示范工程，如上海辛庄工业园区生态办公样板楼，该工程中尝试应用了真空管太阳能热水器、PV 光电板、太阳能空调和地板采暖系统等太阳能技术（图 1）。

图 1 辛庄生态办公样板楼
图 2 上海陆家嘴花园

1、世博会前的上海高层住宅的舒适、节能、美韵

2010 年世界博览会的申办成功，为上海城建的快速发展提供了机遇。上海是中国最大的综合性城市，人口普查数据显示，上海 2000 年的人口密度达到 2588 人/km²，远远高于全国人口密度每平方公里 132 人的数值，居于全国首位 [3]。因人口聚集且受地价影响，在城市聚居区建筑密度日趋提高，高层尤其是小高层住宅建设发展迅猛（图 2）。小高层多为 7～11 层（部分 11 跃 12 层），
高度在 30 米左右，从生理学角度而言这一高度可俯视地面、观看景物、照看儿童等活动，让人感到舒展而亲切，并且结合总体环境可创造出更宜人的居住空间。另一方面，它具有良好朝向，虽塔式高层总有一些套型朝向不够理想，但板式小高层由多层住宅平面发展而来，大多坐北朝南，日照充沛，通风良好，能够充分满足上海人的“朝阳情结”。其次是可以节约土地，增加住房和居住人口。同一面积的土地采用高层住宅，住宅向高空发展，可以实现较高的容积率，对于建设用地紧张，寸土寸金的上海，是一种最适宜的建筑方式。

作为非采暖地区的上海，由于气候的原因，冬夏两季多通过消耗电能来换取室内热舒适度，据统计，百户空调安装率已高达 80%左右，其能耗对城市环境造成了极大的压力[cite 4]。世博会前，经济快速发展的上海必将面临着资源、能源短缺及生态环境恶化的严峻挑战。上海的地理位置决定其具有夏热冬冷的气候特点，其建筑节能技术既要保证建筑物的隔热和保温，同时还要考虑防水、防霉等措施。2001 年 10 月，国家建设部颁发了我国《夏热冬冷地区居住建筑设计标准》，同时上海市建委会同有关部门组织编制了《上海市“十五”期间建筑节能实施纲要》，提出了推进建筑节能的发展思路和工作目标，计划到 2010 年，全部新建住宅建筑由执行节能标准的 50%提高到 60%[cite 5]。目前为使建筑节能工作有序推进，上海市依据国家标准，逐步建立和完善了有关地方标准，基本形成适合上海特点的围护结构建筑节能技术体系；实施了近百万平方米节能住宅项目工程试点（图 3）。

图 3 上海春城（左） 上海新时代花园（右）
太阳能利用在节能建筑中有着重要的地位，太阳能与建筑一体化的发展，不仅能有效的节能和环保，而且也为建筑设计拓展了创作空间。据上海市人民政府新闻发言人焦扬日前介绍，上海已制定 2005 年～2007 年开发利用太阳能《行动计划》，力争 3~5 年内在光伏技术和产业方面走在全国前列，在太阳能光热利用上取得显著成效。应用目标是到 2007 年，安装与建筑结合的太阳能热水系统 10 万平方米（集热面积）。

2、太阳能建筑一体化设计途径

2.1 建筑中太阳能的利用技术体系

太阳能直接应用有光热转换、光电转换、光化学转换三种，在建筑中主要利用的是光热与光电转换。太阳能建筑的应用体系主要可分为四种：太阳能热水系统、被动式太阳房、太阳能光伏发电系统、太阳能制冷与空调。太阳能建筑的技术利用已不再是以往的单一类型体系的技术利用，建筑作为
一个复杂而统一的整体，对太阳能的利用包括了被动应用、主动应用和综合应用等多种技术集合体系（图 4）[6]。

2.2 高层住宅太阳能的利用途径

太阳能技术体系的成熟，为建筑师在设计中的应用带来了便利和拓展的空间。高层住宅作为上海未来发展的必然形式，应将太阳能利用技术体系纳入其整个设计过程，同时考虑继续保持地域文化特色。这需要我们从小区规划中的群体组合、建筑单体的形态及建筑构件，对太阳能利用加以系统的分析与研究，从而建立一个综合性的、开放性的可操作框架。

（1）小区规划中的群体组合与太阳能的利用

任何建筑单体都不是孤立而存在的，都有其特定的地方条件。在规划中建筑群体的不同方位、体形、间距、高低及道路网的布置，广场绿地的分布等都会影响规划区的微气候，影响建筑的日照和通风，影响到建筑的能耗。为合理的规划小区，确保每栋建筑的有效日照，可利用“太阳围合体”（Solar Envelope）对建筑形态进行控制。“太阳围合体”方法是针对特定的区域空间，通过调整围合建筑各立面的法线方向，使建筑在不遮挡临近建筑物日照的情况下达到最大的体积容量。“太阳围合体”的形状和大小取决于开敞空间的尺度、建筑高度、朝向、地理纬度以及需要的日照时间等因素。目前，随着计算机技术的发展，“太阳围合体”设计可以方便的在计算机中进行操作。例如美国南 California 大学制作的软件 SEEDA 可模拟日光对建筑的几何特征及组合情况进行控制，确保建筑不受遮蔽，这是建筑最大利用太阳能提供了必要的条件。

（2）建筑单体方案与太阳能的利用

高层住宅单体的太阳能利用，可从体型与平面布局两面加以考虑。
（a）体型：对高层而言，其体型主要取决于建筑的进深与高度的相对比值。按它的外部体形可分为塔状、板状两大类。在这方面，美国南 California 大学以洛杉矶区域为参照，进行了一个 10 年的住宅研究，通过对城市住宅的 V/S（建筑体积与外表面积比）与密度（每英亩的住宅单元数）的分析研究，发现它们的大小影响着建筑设计表现形式与用能的方式。研究结果显示：对于 3～7 层的建筑，在城市建设发展与节能方面有着较为宽泛的选择优势，也是利用被动式太阳能与低能耗策略的最佳层数；当 V/S 值超过 10 时，建筑使用高能耗是无法避免的；这也从太阳能的利用角度，揭示了住宅建筑不宜追求过高或过密，否则设计中主要应对的是内部能耗问题，而很少能结合自然来进行能效设计。

（b）平面空间：高层住宅平面类型大多为点式或板式。点式中蝶型（或蛙式）住宅平面较为流行，但是它的缺陷是东西侧两套住宅只有半天能接收到日照，有时为保证每户有一间朝南的房间，把大房型放在北侧，除一间卧室朝南外，其他房间均为北向，因此这样的房型日照与通风比较难以解决。据调查，上海居民喜欢房间在有通风的前提下主要卧室一定要有直射阳光，即卧室和客厅要求朝南，它不但可以增加太阳照射的时间，也可以为家庭晒衣被提供场所。据此在将封闭阳台处理成太阳房时，要与通风系统相结合，合理组织气流，给居室带来温暖的同时，也改变其湿冷的状况（图 5）。

图 5 太阳房与通风组织的结合
(3) 建筑构件与太阳能元件的一体化设计

太阳能建筑一体化意味着将传统的建筑围护结构从能量散失的部分转换成能量吸收部分，是将太阳能技术元件与建筑构建的一体化，但这并非简单地在建筑上安装一些太阳能元件，而是将他们与建筑物本身一体化成建筑的组合。这可以从如下的高层住宅外界面进行系统的结合：

墙体：外墙体是高层住宅接收太阳最多的表面，太阳能的应用将进一步优化墙体，现已革新出多种墙体构造和材料，如集热蓄热墙、透明绝热材料以及附加于墙体的集热器等。现代的集热墙颜色不再拘泥于传统的黑色，如深绿、深红、深蓝都是目建筑中常选用的颜色，这些颜色对太阳的吸收效果只稍微逊色于黑色，但却活跃和丰富了立面。除了此之外，太阳能集热器、光伏电池还可与外墙组成“复合型”墙体，如太阳能保温墙板、太阳能集热器墙体、光伏墙体等，这些板兼有装饰、能量与美观于一体。近来发展的太阳墙，是一种将太阳能集热与通风相结合的技术。

屋面：因不受遮挡，其对与太阳能部件具备良好的结合条件，可以选择集热器或光电板的最佳接收辐射的角度，也可以紧贴屋面根据造型的需要设计出优美的外形。

阳台：高层建筑楼顶面积相对紧张，可以利用向阳的阳台。阳台围栏外壁较适合安置分户式集热器系统，也可代替栏杆使用，真空管横向布置还可增添建筑物横向线条。另外还可以将阳台封闭，处理成集热太阳房。

遮阳装置：阳光可以增加人们的舒适程度，但有时阳光也会带给人不舒服。比如在夏季，人们并不需要太强的阳光，这意味要把自然光引向它所需要的地方，也包括排除强而热的直射太阳光。所以除了聚集热量以外，还要能选择性的处理透过玻璃的阳光与能量。在夏热冬冷地区，利用窗户的外遮阳“可
调节附加构件”可以很好的改善窗户的保温、隔热性能。目前新型 PV 的遮阳板遮阳的同时，还可获取能量。

3、阳光：我们的未来

太阳是地球上所有生命的根基，它给予我们光和热的同时，也赐予了我们可谓取之不尽用之不竭的能量。如何有效的利用其这一特有优势，关系到我们的未来。

3.1 确立太阳能建筑的发展目标

合理地综合利用太阳能，尽量多地满足建筑物对于使用功能和环境功能的能源供应需求，以降低建筑能耗在社会总能耗中的比例。同时进一步将太阳能利用与地热能、风能、生物质能以及自然界中的低热能等复合能源的利用进行系统的优化配置，以满足建筑的能源供应和健康环境的需求，实现太阳能建筑发展的最高目标。

3.2 政策导向、太阳能建筑技术和标准编制

首先要制定激励政策，拓宽资金渠道，强化科技投入。对太阳能利用应给予示范导向和税收等激励政策，尤其对于高层住宅则应实行税收激励政策、能源投资机制及业主有偿使用相结合的策略。同时编制设计规范、标准及其相关图集，建立产品（系统）检测中心和认证机构，完善施工验收及维护技术规程等工作；这些是将太阳能利用列入建筑工程设计的环节，也是作为一个新型“专业”纳入建筑体系的前提。

3.3 综合太阳能利用发展策略

多学科的整合理念：对于太阳能的利用，最大的特点是其具有地域性，建筑不是被生硬的强加于一个特定的气候区域，它意味着要针对我国的社会发展、
技术进步、经济能力、区域气候、生活需求和地域文化等多种因素，建立一个技术、建筑与企业多学科交互合作的运行方式。

自然韵律的创新立面：太阳在不同时间运行轨迹的变化，导致其高度角和方位角的不同，因此在建筑的外界面上，接受太阳辐射及形成的阴影状况也随之不断变化。应对日照状况的这种“时间性”，将拓展建筑设计美学的创作空间，为生态设计提供了新的可能性。对夏热冬冷的上海高层建筑，在冬夏两季日照的需求不同，冬季人们需要有更多的阳光进入，以便带来温暖感；而在夏季，则需要一定的遮蔽，躲避太阳的炙烤。这要求立面设计也将会呈现出一种自然韵律以应对气候与日照的变化，由此开辟出上海生态型高层住宅的气候韵律兼节能的个性立面。

技术利用体系的优化选择：面对太阳能利用技术体系的日益成熟和种类的多样，我们针对不同类型的建筑利用太阳能有了更多地选择余地，但同时如何有效与最大的利用宝贵的太阳能资源，将成为我们今后要面临的又一重要课题。荷兰 Delft 大学在这方面立项研究已久，并取得了一定的成效。主要是：在建筑设计的初始阶段，将要选定的太阳能利用体系数据化，利用计算机模拟软件，对各种能源利用体系的选择进行有效的评价，从而在设计之初，就能对太阳能技术体系进行合理的选择与比较，建立一个系统的以太阳能为主的能源综合优化利用体系。

现有建筑的更新改造：随着我国社会发展和人民生活水平的不断提高，“高维持，低使用”的资源消耗的意识已成为我们发展的主要宗旨。对已有的旧建筑的更新改造，是环境保护与资源节约的新的诠释和积极应用，利用太阳能技术对现有建筑进行有效的改造和维护，不仅是平衡经济、技术与建筑间的关系，有效的降低已有建筑的耗能，而且也将美化建筑的外立面。

综上所述，高层住宅与太阳能体系的一体化设计，无疑是将太阳能的利用技术“融进”建筑整体的过程，让建筑也充满着阳光的“味道”，赋予其生命
的气息。建筑师在这一过程中起着毋庸置疑的作用，在与太阳能等各学科专家相互密切合作的同时，也将在概念、技术上相互融合、渗透、集成一体，形成一种持久的、可持续发展的方式。

（本文在成文过程中得到博士生史洁、吴耀华的大力协助，在此一并致谢）

国家自然科学基金（50478101）资助项目

参考文献：
ECOLOGICAL ENVIRONMENTAL BENEFITS OF POROUS PAVEMENT -------AN EXAMPLE OF ECOLOGICAL CONCRETE PAVEMENT

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ABSTRACT: The interior framework of the porous pavement is formed by a series of porous structures connected with the outside air. And at the same time it can meet the requirement of strength and durability. With an eye to solve the environmental and ecological defects of the traditional impermeable pavements, as an example of ecological concrete, this paper introduces the structure of porous concrete pavement and studies the superiority of porous concrete pavement in ecological protection, including such aspects as the improvement on the thermal, sound and luminous environment, the supplement of the urban groundwater, the effective utility of the rainwater, urban flood control in urban areas, cleansing of sewage and improvement of offshore ecology & fishery environments. The Application of porous concrete pavement embodies the regression of urban pavements. Some advice is also suggested.

KEYWORDS: porous pavement, Ecological concrete pavement, ecology environmental benefits, ecological regression

1. THE BACKGROUND

One of important features about urbanization is that impervious pavements replace the original natural soil and vegetation. The permeability of natural soil and vegetation has been changed. Urban harden pavement occupies considerably ratio in urban area, so its ecology environmental benefit has an very important effect on urban ecological environment. Inner structure of porous pavement has a serious porous frameworks and satisfy the needs of strength and durable property. The interior framework of the porous concrete pavement is formed by a series of porous structures connected with the outside air. And at the same time it can meet the requirement of strength and durability. [1] [2] Porous pavement is similar grassland and soil texture because of its good permeability and moist condition, so it gives expression to the ideal of “sympathize with environment” and “ecological regression” awfully. Figure 1 shows the ecological concrete balls
with grass plant developed by the material department of Southeast University. Besides economical benefits, this porous concrete pavement also can provides numerous aesthetic benefits when compared with conventional impervious pavement.

![Ecological concrete balls with grass plant developed by material department of Southeast University, P.R.C](image)

**Figure 1** Ecological concrete balls with grass plant developed by material department of Southeast University, P.R.C

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### 2. ECOLOGY ENVIRONMENTAL BENEFITS OF POROUS PAVEMENT

Ecology environmental benefits of porous pavement manifest in the following:

#### 2.1 the affect of porous concrete pavement in supplementing urban groundwater

Most of traditional impervious pavements collected rainwater by making the surface slope of pavements and using the corresponding drainage pipeline, then these collected water was drained into urban drain pipe. It is not good for the effective utility of the rain-water. Porous pavement can relax the adverse influence of conventional impervious pavement. Through its pervious route, porous pavement permeate rain into soil, the rain is also purified by filtrating in soil. The storm water fills up the void spaces of porous pavement and slowly
percolates into the underlying soil mantle. Groundwater in urban area is supplemented. In the meantime precipitation which is clean comparatively can permeated into underground in order to avoid being polluted. It is also benefit to with the plant’s irrigation.

2.2 the affect of porous concrete pavement in improving sound and luminous environment in urban area

Test researches on noise reduction through sound absorption of porous concrete pavement are developed. Our researches discusses the changing laws of sound absorbing performance of different porosity porous concrete pavement. A regression equation between the porosity of porous concrete pavement and its average sound absorption coefficient is obtained. When thickness to 6cm, the experience formula about effect of the sound absorptions coefficient and porosity for concrete penetrative pavements as follows:

\[ \alpha = 0.1935 - 0.00546 Vv \]

Which: Vv —— porosity ( % ); \( \alpha \) —— sound average absorptions coefficient.

This equation can evaluate the sound-absorbing ability of different porosities of porous concrete pavement. This experience formula has some reference value.
for the optimal designing of porosity for concrete penetrative pavements [3]. Figure 2 shows the special porous concrete can be used as noise barrier to improve sound environment quality of highway.

The surface small hole of porous concrete pavement cause the surface light to diffuse, so it can avoid the glare created by directional reflection on the surface of the polished slab stone and brick. Porous concrete pavement can clear up the rain water on the surface promptly, so it can overcome the weakness of ‘floating’ ‘splashing’ and ‘glaring’. By this measure, porous concrete pavement can improve traffic safety.

3.3 the affect of porous concrete pavement in improving ‘heat-island effect’ in urban area

The rain water that detained in porous concrete pavements and its lower fills evaporates and absorbs a great deal latent heat and reveals heat by solar radiation. The air temperature and pavement surface temperature is dropped. ‘Heat-island effect’ is lightened effectively. Tests of evaporation and cooling of porous concrete pavement are carried out under the condition of simulative heat radiation and ventilation. The results of the tests show the changing laws of the evaporating and cooling performance of different porosity porous concrete pavement. These results provide reference for the optimal porosity design of evaporation and cooling of porous concrete pavement and porous ceramics bricks [4]. The steam evaporates from porous pavement can add air humidity, so it can lighten ‘urban dryness’. This way can also reduce the harm of “dust storm.” An hourly measurement and analysis of the summer thermal environmental index (temperature, humidity and sun radiation) on Nanjing’s typical squares has proved this point [5]. Meanwhile, evaporating added the air humidity, this way could improve “dry heat”. One of the reasons that the “dust storm” in less rain season of north cities was that the air’s humidity was too low. The research of Japan environment department which directed against ‘heat-island effect’ in Tokyo stated clearly that one of the effects by ‘heat-island effect’ was clouds of dust flying up because of less evaporating and
dry air. One of the measurements to solve this problem was the application of porous pavement.

3.4 the affect of porous pavement in improving ecological environment in the earth’s surface.

Porous pavement possess favourable abilities of retaining water, ventilate and permeable. It satisfied the pavement demand, it also has a series of advantages just as natural vegetation and soil. So it can reduce the degree of destroy caused by impervious pavements. The survival space of animal and plant under porous pavement is protected effectively. Depending on its own porous structure, the porous pavement in water can create a favourable environment for some aquatic animals and plants. These aquatic animals and plants can grow well in this surface.

2.5 The Impacts of porous pavement in controlling flood in urban area

![Ecological concrete balls can be used as artificial reef](image)

Figure 4. Ecological concrete balls can be used as artificial reef

Traditional impervious pavements collected rainwater by using the corresponding drainage pipeline, then these collected water was drained into urban drain pipe. This measure led to the increasing of surface runoff and pressure of urban drainage pipeline. It caused water logging in many cities because their drainage pipelines hadn’t enough drain ability or had been artificial silted up. For example, when Beijing’s control area ratio of drainage pipeline was
20%, impervious pavements area ratio was 20%, its flood peak was 1.5 times as original flood peak flow. When control area ratio of drainage pipeline was 60%, impervious pavements area ratio was 60%, then its flood peak was 3 times as original flood peak. This indicated that urban surface runoff increased rapidly along with the increase of impervious pavement’s area, so flow of flood peak was added too, the serious consequence was leading flood disaster. Because of its own permeability, porous pavement can reduce the pressure of flood discharge. The surface runoff flows gently. The peak value of runoff is recede, and its flux raise and reduce gently too. Undoubtedly, controlling flood in urban area can benefit from the porous pavement\(^2\).

**2.6 The Impacts of porous concrete balls pavement in cleansing of sewage and improvement offshore ecology and fishery environments.**

Depending on its own porous structure, the porous concrete pavement in water can create a favourable environment for some aquatic animals and plants. These aquatic animals and plants can decontaminate the sewage in urban area\(^6\)\(^7\). The ecological concrete balls create a favourable aquatic animals and plants environment to cleans the sewage. Figure 3 shows this special ecological concrete balls can be used as ecological regression for river slope protection to improve water quality of river water. This special ecological concrete balls can also be used as artificial reef just as Figure 4 shows. The construction of ecological concrete balls reef is of great importance to regulation and improvement of marine industry, remediation and improvement of marine ecological environment, enhancement and perfection of fishery resources. All these applications testified that porous concrete pavement (balls) have distinct advantages about cleansing of sewage and improvement offshore ecology and fishery environments\(^8\).

**3. THE ADVICE AND COUNTERMEASURES FOR POROUS PAVEMENT’S RESEARCH**
Porous pavement provides numerous economic, environmental and aesthetic benefits when compared with conventional impervious pavement. From the economic view, porous pavements can reduces the land space consumed by conventional detention facilities. reduces the need for curbs, gutters, inlets, and storm sewers. Some experts thought that the design of a porous pavement project is just the first step in the process of finishing with a environmentally responsible project. Proper construction and maintenance are also key to insuring that the porous pavement and recharge beds function for a long time. The infiltration bed located beneath the porous pavement must be excavated without heavy equipment traversing (hence compacting) the bed bottom. Fine grading is done by hand and checked for level. Geotextile fabric is laid immediately after fine grading is completed. Clean (washed) uniformly graded aggregate is placed in the bed as the storage media. This stone provides 40% void space and a stable base for the porous pavement parking surface. Also, the pavement must be protected from excessive sediment and silt that may runoff from adjacent lands to minimize clogging.I think these tips which offered by the experts about construction of porous pavement is useful indeed.

All in all, generalizing and applying porous pavement, exerting the ecology environmental benefit, it is an important measure to improving urban ecology physical environment. Considering the present situation of research for porous pavement in our country and the experience abroad, some advice and countermeasures were also suggested:

(1) Quicken application step of porous concrete pavement (ball) on the base of present research.

(2)Further study the mechanism of combining porous pavement’s application with utility of the rain-water.

(3)Formulating the special urban planning and construction regulations about porous pavement.
(4) The sustained porous structure must be satisfied in construction management and maintaining. Suggest to exploit and manufacture relevant equipments for cleaning.

(5) Developing the mechanism research of cleansing of sewage to protect water environment about porous concrete pavement (ball).

(6) Developing the mechanism research of improvement offshore ecology & fishery environments about porous concrete pavement (ball).

4. REFERENCES


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广州某住宅小区微气候实测与分析

FIELD STUDY AND ANALYSIS ON THE MICROCLIMATE OF A RESIDENTIAL COMMUNITY IN GUANGZHOU

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摘要 微气候有别于大气候，指的是靠近地表，动植物赖以生存的气候环境。在这个环境中，温度、湿度和风速都会随着高度的变化而发生巨大的改变。本文以广州某住宅小区为例，在2007年7月现场实测了该小区的微气候，通过比较所测得的空气温度、相对湿度、黑球温度及风速等参数，考察人工湖、树阴以及下垫面性质等对室外热环境的影响。经过分析发现，水体蒸发作用可使平均温度下降约1.6℃，树阴遮阳可使平均温度下降约0.7℃。与此同时，树阴遮阳及水体蒸发可以延迟最高温度的出现时间约1.5小时，减少最高温度的出现频率约20%。而对于小区风环境而言，开阔空间的风速最高，街谷其次，受建筑遮挡及地形影响的地方风速最低。

关键词 微气候 室外热环境 空气温度 黑球温度 风速

ABSTRACT Microclimate, which is quite different from macroclimate, refers to the atmosphere environment next to ground. This kind of environment is important to animals and plants. Temperature, humidity and wind speed of microclimate change sharply with height. This paper describes a field study on the microclimate of a residential community in Guangzhou in July, 2007. By analyzing the measurement results of air temperature, relative humidity, black globe temperature and wind speed, the impacts of lake, plant shadows and underlying characteristics on outdoor thermal environment. According to the analysis, evaporation effects of lake is able to decrease 1.6℃ of average temperature while 0.7℃ by tree shadows. Meanwhile, both the evaporation and tree shadows can delay the appearances of max temperature by 1.5 hours and reduce the frequency of 20%. To the wind environment, open spaces obtain the highest wind speed, next come street canyons and areas which are obstructed by other buildings or affected by land shapes have the lowest wind speed.

KEYWORDS microclimate outdoor thermal environment air temperature black globe temperature wind speed
微气候(Microclimate)，有别于大气候(Macroclimate)，指的是靠近地表、动植物赖以生存的气候环境。在这个环境中，温度、湿度和风速都会随着高度的变化而发生巨大的改变。同时，伴随着植物的蒸腾作用、水体等地表覆盖物的蒸发及凝结等，大量的能量会在较短的时间内发生转移或传递。正是由于地表环境状况的多样性以及上述环境变量随时间及高度的变化，使得微气候有异于大气混流过程更活跃但总体变化更缓和的大气候。[1]

1 引言

近几十年来，由于城市化的飞速发展、下垫面结构的改变以及交通排热和建筑排热等因素的影响，城市热环境逐渐恶化，“热岛现象”及其负面影响日渐凸显。[2]“热岛现象”在夏季的出现，不仅会使人们高温中暑的几率变大，还形成光化学烟雾污染，并增加建筑的空调能耗，给人们的工作生活带来严重影响。[3]据统计，近40年来，广州同期气温一直在上升，年平均气温从建国初期的22.0℃升至去年的23.1℃，城区平均气温比市郊平均高出3℃。[4]

目前，室外热环境质量日益受到人们的重视，许多国家都出台了针对小区室外热环境质量的指导性标准。例如，美国颁布的《绿色建筑评估体系（第二版）》中，就明确指出“利用园林绿化和建筑外部设计以减少热岛效应”。[5]我国于2006年颁布的《绿色建筑评价标准（GB/T 50378-2006）》也规定，住宅室外日平均热岛强度不得高于1.5℃。

2 住区微气候研究进展

为了进一步掌握微气候变化的规律，并通过有效的规划、建筑和景观等设计手段来提高室外热环境质量，世界各地的科研人员在不同的领域开展了研究。美国学者B.Bonan[6]利用卫星观测图片，测试了Colorado的一个居民小区，以研究建筑设计对室外温度、风速及相对湿度等环境变量的影响。结果发现，
在夏季炎热时，草地温度比非草地温度低，小区内干燥草坪的气温比灌溉草坪带和住户自己种植草坪附近的气温高。其研究还指出，建筑密度的高低是使微气候产生差异的直接因素之一。在半干旱的 Colorado 居民区，植物选择、浇灌草坪和住房密度对室外热环境的影响重大。

董靓[7]在 90 年代初期研究了重庆的街谷热环境，尝试建立了 WBGT 指标与环境参数的关联式，讨论了环境空间尺度、树阴形态等对街谷热环境的影响。而在 1999 年，国家自然科学基金在工程热物理学科资助的重点项目“住区微气候环境中热物理问题 (59836250)” ，该项目研究取得了对夏季空调环境热物理因素对人群健康影响及其动态热舒适、室内自然通风动态特征及改善室内夏季热环境的途径等若干基础问题的主要成果。

最近几年，李晓锋[8]比较系统地研究了住宅小区微气候的模拟方法。他在保证计算精度、缩短计算时间方面做了许多改进，并建立了一套层次化的模拟体系。

林波荣[9]通过大量现场实测工作，研究了树木、灌木和草地三种绿化形式对室外热环境的影响效果及特征，提出了以 WBGT 和有效标准温度 SET 相结合来评价室外热环境的安全性和热舒适状况。

Liangmei Huang[10]通过现场测试的方法，比较了南京市城镇商业区、湖区、林地以及郊区等 4 种不同性质用地的热岛强度及微气候状况，发现水泥地面对温度的影响非常明显，而树阴及水体能很好的缓解城市热岛。根据测试的结果，热岛强度较大的时刻分别是午夜、13:00－15:00 以及 18:00－21:00。

总的来说，目前对微气候的研究还比较有限，利用现有的手段，如人造卫星、现场实测、计算机仿真模拟等，找到能指导规划、建筑及景观设计的辅助模型，同时定量的分析各影响因子在设计行为中的权重关系，是大家所关心的热点问题。
3 现场实测

华南理工大学亚热带建筑科学国家重点实验室于 2007 年 7 月 19 日～24 日对广州某住宅小区的微气候进行了现场实测。通过测试空气温度、湿度等热环境变量，分析其变化的总体规律，探讨景观设计因子对住区微气候的影响。

3.1 测试小区简介

该住宅小区位于广州市海珠区，占地面积约 22 万平方米，总建筑面积 50 余万平方米。该小区分两期进行建设，一期主要为 8~10 层的低层建筑，于 2004 年初交付使用；二期主要为 15 层以上的高层建筑，于 2005 年底全部交付使用。目前该小区共有住户约 5000 户，分成 40 栋独立住宅。其规划总平面及现场实拍照片如图 1、2。
3.2 测试内容

本次测试主要以定点观测为主，在一期林荫道、主干道以及湖边设置温度、湿度自记仪逐时记录行人高度（距地1.5～2.0米）的空气温度、湿度以及黑球温度。同时，采用流动观测的方法，每隔1小时观测不同点的风速。测试时间从上午10点到下午5点。

3.3 测点布置情况

一期测点共9个（如图3所示），主要考察大面积的水体（人工湖）、树阴以及道路下垫面性质对热环境参数的影响。各测点的位置、树阴遮蔽、下垫面情况及测试参数见表1。
3.4 测试仪器

本次实验采用自记仪记录空气温度、湿度和黑球温度，采用热球风速仪流动观测不同测点的风速。所有自记仪的读数间隔均为1分钟。

空气温度自记仪及湿度自记仪均被放置在用铝箔包裹好的铝合金套筒中，并用三角支架将这些套筒固定在离地1.5～2.0米的高度，如图4、5所示。黑球温度自记仪放置在三角支架的顶端，如图6、7所示。
3.5 城市气象参数

为了更好的比较居住小区各景观设计因子对微气候的影响，根据广州市中心气象台的预报[11]，记录了从7.19～7.24广州市的天气情况，如表3。从表中可以看出，7.21～7.24这几天的天气非常类似。本文中的其余城市气象参数，均来自华南理工大学亚热带建筑科学国家重点实验室的气象站观测所得。

表1 测点设置情况

<table>
<thead>
<tr>
<th>测点编号</th>
<th>位置</th>
<th>仪器高度</th>
<th>树阴遮掩情况</th>
<th>下垫面</th>
<th>测试参数</th>
<th>备注</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>人工湖北面</td>
<td>1.5m</td>
<td>树阴下</td>
<td>灌木</td>
<td>T, W</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>人工湖北面，凉亭旁</td>
<td>1.5m</td>
<td>无</td>
<td>草地及灌木</td>
<td>T, RH, BGT, W</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>人工湖北面，3条人行道的交界</td>
<td>2.0m</td>
<td>树阴下</td>
<td>普通广场砖</td>
<td>T, W</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>人工湖北面，3条人行道的交界</td>
<td>2.0m</td>
<td>无</td>
<td>普通广场砖</td>
<td>T, W</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>人工湖西南面，3条人行道的交界</td>
<td>2.0m</td>
<td>树阴下</td>
<td>普通广场砖</td>
<td>T, W</td>
<td>19日</td>
</tr>
<tr>
<td></td>
<td>人工湖西南面，3条人行道的交界</td>
<td>1.5m</td>
<td>无</td>
<td>水泥地面</td>
<td>T, BGT, W</td>
<td>20-4日</td>
</tr>
</tbody>
</table>

图6 黑球温度自记仪（测点8）
图7 黑球温度自记仪（测点2）
6 人工湖南面,3 条人行道的交界,靠近泳池
   人工湖南面,人工湖与游泳池之间
7 人工湖南面,人工湖北面,住宅楼之间
   人工湖北面,住宅楼之间
8 人工湖北面,住宅楼之间
9 人工湖南面,3 条人行道的交界,靠近泳池

T, W

表2 测试仪器主要参数

<table>
<thead>
<tr>
<th>仪器名称</th>
<th>型号</th>
<th>测试参数</th>
<th>精度</th>
<th>测试范围</th>
</tr>
</thead>
<tbody>
<tr>
<td>热球风速仪</td>
<td>QDF-2A</td>
<td>风速</td>
<td>≤±5%</td>
<td>0.1-30m/s</td>
</tr>
<tr>
<td>热球风速仪</td>
<td>KIMO VTS</td>
<td>风速</td>
<td>≤±4%</td>
<td>0.1-40m/s</td>
</tr>
<tr>
<td>HOBO 自记仪</td>
<td>H08-001-02</td>
<td>空气温度</td>
<td>±0.7℃ (21℃)</td>
<td>-20 to 70℃</td>
</tr>
<tr>
<td>HOBO 相对湿度自记仪</td>
<td>--</td>
<td>相对湿度</td>
<td>±5%</td>
<td>5～95%RH (非结露情况下)</td>
</tr>
<tr>
<td>清华紫光温湿度自记仪</td>
<td>RHLOG</td>
<td>黑球温度</td>
<td>±0.3℃</td>
<td>-20℃～+75℃</td>
</tr>
</tbody>
</table>

表3 城市气象参数

<table>
<thead>
<tr>
<th>日期</th>
<th>天气状况</th>
<th>温度</th>
<th>相对湿度</th>
<th>主风向</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.19</td>
<td>多云</td>
<td>28-35℃</td>
<td>50-80%</td>
<td>南</td>
</tr>
<tr>
<td>7.20</td>
<td>多云转晴</td>
<td>28-36℃</td>
<td>50-80%</td>
<td>南</td>
</tr>
<tr>
<td>7.21</td>
<td>晴转多云</td>
<td>29-36℃</td>
<td>45-80%</td>
<td>东南</td>
</tr>
<tr>
<td>7.22</td>
<td>晴转多云</td>
<td>29-36℃</td>
<td>45-85%</td>
<td>东南</td>
</tr>
<tr>
<td>7.23</td>
<td>晴转多云</td>
<td>29-36℃</td>
<td>45-85%</td>
<td>东南</td>
</tr>
<tr>
<td>7.24</td>
<td>晴转多云</td>
<td>29-36℃</td>
<td>45-85%</td>
<td>东南</td>
</tr>
</tbody>
</table>

4 测试结果与分析

4.1 空气温度

对每天实测的空气温度进行分析，得到各个测点日平均值与最大值(图 8、9)以及各测点空气温度与气象站观测温度的差值(表 4、5)。通过比较可以发现：
自 7.20 起，测点 5 的平均温度始终最高，测点 1 的平均温度始终最低；有树阴遮蔽的测点 (1, 3, 7, 9) 的空气温度低于其它测点；测点 1、2、3 和 7 的温度始终低于气象站的观测温度。

图 8 空气温度日平均值

图 9 空气温度日最大值

表 4 各测点空气温度日平均值与气象站观测日平均值的差值

<table>
<thead>
<tr>
<th>Date</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.19</td>
<td>-0.8</td>
<td>-0.3</td>
<td>-1.7</td>
<td>-0.8</td>
<td>-0.8</td>
<td>0.4</td>
<td>-0.7</td>
<td>0.5</td>
<td>-0.2</td>
</tr>
<tr>
<td>7.20</td>
<td>-0.1</td>
<td>0.6</td>
<td>0.2</td>
<td>0.1</td>
<td>2.7</td>
<td>0.5</td>
<td>0.8</td>
<td>2.2</td>
<td>1.4</td>
</tr>
<tr>
<td>7.21</td>
<td>-0.8</td>
<td>-0.2</td>
<td>-0.1</td>
<td>0.5</td>
<td>2.1</td>
<td>0.5</td>
<td>0.0</td>
<td>1.2</td>
<td>1.5</td>
</tr>
<tr>
<td>7.22</td>
<td>-1.1</td>
<td>-0.5</td>
<td>-0.6</td>
<td>-0.8</td>
<td>1.1</td>
<td>-0.2</td>
<td>-0.9</td>
<td>-0.2</td>
<td>-0.8</td>
</tr>
<tr>
<td>7.23</td>
<td>-0.9</td>
<td>-0.1</td>
<td>-0.4</td>
<td>0.0</td>
<td>2.3</td>
<td>0.4</td>
<td>-0.4</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>7.24</td>
<td>-0.8</td>
<td>0.1</td>
<td>-0.3</td>
<td>-0.2</td>
<td>3.2</td>
<td>0.5</td>
<td>0.0</td>
<td>1.8</td>
<td>0.9</td>
</tr>
</tbody>
</table>

表 5 各测点空气温度日最大值与气象站观测日最大值的差值

<table>
<thead>
<tr>
<th>Date</th>
<th>1</th>
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<th>4</th>
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<th>6</th>
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<th>8</th>
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</tr>
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<tbody>
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<td>-0.1</td>
<td>-0.6</td>
<td>-0.6</td>
<td>-0.6</td>
<td>2.0</td>
<td>-0.6</td>
<td>1.6</td>
<td>-0.1</td>
</tr>
<tr>
<td>7.20</td>
<td>-1.0</td>
<td>-0.1</td>
<td>-1.0</td>
<td>-1.0</td>
<td>2.9</td>
<td>-0.6</td>
<td>-0.6</td>
<td>2.5</td>
<td>1.1</td>
</tr>
<tr>
<td>7.21</td>
<td>-1.2</td>
<td>-0.4</td>
<td>-0.4</td>
<td>3.1</td>
<td>2.7</td>
<td>1.0</td>
<td>-0.4</td>
<td>1.8</td>
<td>1.3</td>
</tr>
<tr>
<td>日期</td>
<td>平均值</td>
<td>最大值</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>6.1</td>
<td>26.6</td>
<td>17.6</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.2</td>
<td>-7.9</td>
<td>-20.9</td>
<td>-23.3</td>
<td></td>
<td></td>
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<tr>
<td>7.21</td>
<td>-2.7</td>
<td>-1.0</td>
<td>-1.8</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>7.22</td>
<td>0.7</td>
<td>-4.3</td>
<td>-5.0</td>
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<td></td>
</tr>
<tr>
<td>7.23</td>
<td>5.1</td>
<td>-4.5</td>
<td>-8.7</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>7.24</td>
<td>10.0</td>
<td>-3.5</td>
<td>-7.7</td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>
4.3 风速

对每天实测的风速进行分析，得到各个测点日平均值与最大值（图 12、13）。通过比较可以发现：位于开阔空间的测点（1, 2, 3, 4）的风速值最大，位于街谷的测点（8, 9）次之，受建筑遮挡的测点（6, 7）又次之；受地形影响而位于角落的测点 5 风速值最小。

图 12 风速日平均值

图 13 风速日最大值

4.4 黑球温度

分析 7 月 21 日测试得到的黑球温度，得到黑球温度的逐时平均值及最大值。通过比较可以发现：3 个测点的黑球温度变化规律相近，都是在中午 12:00 达到最大值，几条温度曲线也接近平行；测点 5 与测点 8 的黑球温度值相差不大，但都远大于测点 2，差值在 4℃左右。
5 结论

通过综合分析比较所测得的数据，可以得到以下初步结论：

1）就7月21日～24日的测试情况来说，测点5的空气温度和黑球温度都最高，而风速则最低。这说明该点的热环境质量非常差。无树阴遮掩、水泥路面以及自然通风条件不佳都是主要的因素。

2）水体蒸发及风的降温作用：沿湖布置的测点的平均温度及最高温度比远离人工湖的测点分别低大约1.3℃和1.8℃。而二者的最高温度差最多可达到2.2℃。
3）由于水体蒸发而导致的温差

i) 有树阴遮阳的测点：平均温差可达 1.8℃

ii) 无树阴遮阳的测点：平均温差可达 1.6℃

4）由于树阴遮阳而导致的温差

i) 靠近湖边的测点：测点 2（无树阴）的平均温度和最高温度比测点 1（有树阴）分别高 0.8 及 0.9℃；

ii) 位于住宅之间的测点：测点 8（无树阴）的平均温度和最高温度比测点 9（有树阴）分别高 0.6℃ 和 1.4℃；

iii) 位于人行道交叉口的测点：测点 4（无树阴）的平均温度和最高温度比测点 3（有树阴）分别高 0.7℃ 和 3.5℃。

5）风环境规律

就风速而言，位于开阔空间的测点（1, 2, 3, 4）>位于街谷的测点（8, 9）>受建筑遮挡的测点（6, 7）>受地形影响而位于角落的测点 5。

6）树阴及水体蒸发对最高温度的作用

i) 延迟最高温度出现的时间：通过对比不同测点最高温度的出现时间可以发现，处于人工湖边的测点普遍比远离人工湖的测点晚大概 1.5 小时；位于树阴下的测点比无树阴的测点晚大概 2 小时；

ii) 减少最高温度出现的频率：通过对比不同测点最高温度的出现频率可以发现，处于人工湖边的测点普遍比远离人工湖的测点少 10%~30%；位于树阴下的测点比无树阴的测点少 18%~36%。
6 致谢

本文的现场测试在国家自然科学基金重点资助项目“湿热地区城市微气候调节与设计”（编号:50538040）的支持下完成。后续的分析及研究工作获得国家留学基金的支持，将在 University of Colorado in Boulder, USA 完成。

参考文献

2. 周淑贞，束炯著. 城市气象学. 气象出版社, 1994
3. 绿色建筑评价标准 GB/T 50378-2006
5. 绿色建筑评估体系（第二版），中国建筑工业出版社，2000.
10. Liangmei Huang, Jianlong Li, Dehua Zhao, Jiyu Zhu. A fieldwork study on the diurnal changes of urban microclimate in four types of ground cover and urban heat island of Nanjing, China. Building and Environment, Volume 43, Issue 1, January 2008.
生态建筑的基本理念与技术示范 — 上海生态建筑示范楼技术集成体系

汪 维 韩继红 刘景立 安 宇

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摘要：生态建筑作为当今世界建筑可持续发展的必由之路遵循“节约能源、节省资源、保护环境、以人为本”的基本理念。本文以此作为出发点介绍了上海市科委重大科研攻关项目“生态建筑关键技术研究及系统集成”的重要成果之一：上海生态建筑示范楼的集成技术体系。展示和探索了符合上海乃至我国发展现状的生态建筑适用技术，以期为我国的生态建筑的研究和推广及上海 2010 世博建筑示范区的建设提供可行的技术借鉴。

关键词：生态建筑，技术集成，技术示范

1. 前言

可持续发展是 21 世纪全球发展战略，树立全面、协调、可持续的科学发展观已成为我国的基本国策。生态建筑遵循可持续发展原则，强调建筑与人文、环境及科技的和谐统一，是当今世界建筑可持续发展的必然趋势。

2003 年 11 月，由上海建筑科学研究院总体负责，上海建筑相关领域 12 个交叉学科团队协同攻关的上海市科委重大科研攻关项目“生态建筑关键技术研究及系统集成”正式启动。作为可持续发展理念的具体实践和探索，该项目针对上海的地域特征和经济发展水平，提出了“节约能源、节省资源、保护环境、以人为本”的生态建筑基本理念，同时借鉴国内外最先进的生态建筑技术成果，通过开展生态建筑集成技术体系的研究、示范和推广，建立具有上海特色的生态建筑集成技术体系，建设具有国际先进水平、体现上海建筑风格的生态建筑示范楼。
2004 年 9 月上海首栋生态建筑示范楼在上海建筑科学研究院科技园区落成，从而标志着由我院领衔承担的上海科委重大科研项目“生态建筑关键技术研究及系统集成”取得了重大成果。示范楼汇集了国内外 60 多家产学研联合体的先进技术研究成果，全面展示了建筑节能、自然通风、自然采光、太阳能利用、健康空调、绿色建材、智能监控、绿色绿化、水资源利用和舒适环境等十大类先进技术，堪称具有当前国际先进水平的生态建筑关键技术集成平台，并为生态建筑关键技术提供了一个测试、实验、技术改进和展示的实验平台，现已作为生态建筑技术产品后续研发的实验平台列入 2004 年国家“十五”科技攻关重点项目“绿色建筑关键技术研究”。本文重点介绍其集成技术体系，以期为我国生态建筑的设计和建造及上海 2010 世博建筑示范区的建设提供技术借鉴。

2. 上海生态建筑示范楼集成技术体系

2.1 示范楼概况（图 1）

2003 年 11 月动工，2004 年 9 月建成，同年 11 月 14 日通过验收。大楼位于上海市建筑科学研究院莘庄科技发展园区内（上海闵行区中春路申富路口），建筑面积 1900m²，钢混主体结构，南面两层，北面三层。一楼东半部约 350m²
的大厅用于生态建筑集成技术展示，示范楼将作为生态建筑关键技术和产品研发的实验平台。

2.2 总体技术目标：

基于上海的经济发展水平，地域气候特征、场址环境特点和建筑使用功能，通过研发并集成国内外最新生态技术及产品，建设具有国际先进水平、体现上海地域特征的生态办公示范楼，总体技术目标达到：

综合能耗为普通建筑的 1/4；

再生能源利用率达到建筑使用能耗的 20%；

室内综合环境达到健康、舒适指标；

再生资源利用率达到 60%。

2.3 集成技术示范

建筑节能综合利用技术

超低能耗围护结构：根据示范楼各种工况，通过能耗指标和节能效果能耗模拟分析，确定最佳的超低能耗综合节能技术系统：

<table>
<thead>
<tr>
<th>序号</th>
<th>应用部位</th>
<th>保温体系主要构成</th>
<th>传热系数 W/(m²·K)</th>
<th>热惰性指标 D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>东外墙</td>
<td>混凝土砌块(90)+298 凯福发泡(60)+砂加气砌块(240)</td>
<td>0.32</td>
<td>4.3</td>
</tr>
<tr>
<td>2</td>
<td>南外墙</td>
<td>EPS 外保温(140)+混凝土砌块(190)</td>
<td>0.27</td>
<td>3.2</td>
</tr>
<tr>
<td>3</td>
<td>西外墙</td>
<td>混凝土砌块(90)+298 凯福发泡(85)+混凝土砌块(240)</td>
<td>0.29</td>
<td>4.3</td>
</tr>
<tr>
<td>4</td>
<td>北外墙</td>
<td>XPS 外保温(75)+混凝土砌块(190)</td>
<td>0.33</td>
<td>3.2</td>
</tr>
</tbody>
</table>
（1）四种复合墙体保温体系（表 1、图 2）

![墙体结构及外保温系统](image)

（2）三种复合型屋面保温体系（表 2、图 3）

生态办公楼的绿化平屋面采用倒置式保温体系，保温层采用耐植物根系腐蚀的 XPS 板和泡沫玻璃板置于屋面防水层之上，再利用屋面绿化技术，形成一种冬季保温、夏季隔热又可增加绿化面积的复合型屋面。

<table>
<thead>
<tr>
<th>序号</th>
<th>应用部位</th>
<th>保温体系主要构成</th>
<th>传热系数 W/(m² · K)</th>
<th>热惰性指标 D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>不上人平屋面</td>
<td>屋面绿化(600)+泡沫玻璃(150)+陶粒混凝土找坡层(100)</td>
<td>0.31</td>
<td>3.2</td>
</tr>
<tr>
<td>2</td>
<td>上人平屋面</td>
<td>屋面绿化(600)+XPS(95)+陶粒混凝土找坡层(100)</td>
<td>0.31</td>
<td>3.2</td>
</tr>
<tr>
<td>3</td>
<td>东向坡屋面</td>
<td>发泡聚氨酯(180)</td>
<td>0.16</td>
<td>5.0</td>
</tr>
</tbody>
</table>
（3）节能门窗（表3，图4）

外门窗采用断热铝合金双玻中空 LOW-E 窗，其中天窗采用三玻安全 LOW-E 玻璃，其表层玻璃具有自清洁功能；南向局部外窗采用充氩气中空 LOW-E 玻璃和阳光控制膜，提高外窗的保温隔热性能。

<table>
<thead>
<tr>
<th>序号</th>
<th>应用部位</th>
<th>窗户类型</th>
<th>玻璃传热系数 W/(m²•K)</th>
<th>玻璃遮阳系数</th>
<th>可见光透过率（%）</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>坡屋面天窗</td>
<td>PET LOW-E 双中空玻璃窗</td>
<td>1.82 (考虑窗框)</td>
<td>0.62</td>
<td>68</td>
</tr>
<tr>
<td>2</td>
<td>各向外窗</td>
<td>LOW-E 中空双玻窗</td>
<td>1.65</td>
<td>0.58</td>
<td>65</td>
</tr>
</tbody>
</table>

图3 屋顶及地面保温系统

图4 Low-E 中空玻璃窗
（4）多种遮阳技术（图 5）

根据示范楼的建筑形式与日照规律，确定多种遮阳技术，以提高外窗的保温隔热性能。 （1）天窗根据节能与采光的要求，外部采用可控制软遮阳技术达到有效节省空调能耗的作用。（2）南立面根据当地的日照规律采用可调节的水平铝合金百叶外遮阳技术，通过调节百叶的角度，即能够阻挡多余光线的照射，达到节能效果；也能使光线进入室内深处，提高舒适性。（3）西立面主要考虑到西晒对室内的影响，根据太阳光入射角度采用可调节垂直铝合金百叶遮阳技术。

<table>
<thead>
<tr>
<th>模拟工况编号</th>
<th>1</th>
<th>2</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>节能效果（%）</td>
<td>–</td>
<td>9.0</td>
<td>42.6</td>
<td>45.5</td>
<td>47.8</td>
</tr>
</tbody>
</table>

图 5 天窗、南立面及西立面遮阳系统实景

采用 DEST 动态分析软件对各种工况条件进行能耗分析，见表 4：其中，工况编号 1：不采用节能措施（对比基准）；
图6 斜屋面太阳能集热器和光电

工况编号2: 采用外遮阳；

工况编号3: 采用外遮阳，采用节能窗（见表3）；

工况编号4: 采用外遮阳，采用节能窗，提高围护结构保温隔热性能（表1~2）；

工况编号5: 采用外遮阳，采用节能窗，提高围护结构保温隔热性能，夜间通风；

通过以上对围护结构的节能措施可将能耗降低47.8%。

3. 太阳能综合利用建筑一体化

3.1 太阳能综合利用建筑一体化

图6 斜屋面太阳能集热器和光电

示范楼设计了斜屋面放置太阳能真空管集热器（150m²）和多晶硅太阳能光电板（5m²），实现太阳能综合利用（图6）。通过集成太阳能热水器、低温地板辐射采暖系统（300m²）和热水型太阳能吸附式空调机组，实施建筑一体化设计，有效解决示范楼冬季采暖、夏季制冷和全年热水供应问题（图7）；在过渡季节，利用太阳能热水强化自然通风。
此外，在斜屋顶下部选用光电转换效率≥14%的高效率多晶硅太阳能光电板，建立5kw光伏电站并采用并网技术实现并网。

4. 节能系统设备

（1）高效、环保、健康新型空调系统

除了利用太阳能、太阳能热水型吸附式空调和采暖复合系统外，针对现行空调系统普遍存在

的霉菌问题、高能耗问题和臭氧层破坏问题，研发热泵驱动的热、湿负荷独立控制的高效、环保、健康新型空调系统：通过避免使用有凝结水的盘管，解决目前空调系统中存在的霉菌滋生问题，同时通过除湿机内盐溶液的喷洒除去空气中的尘埃、细菌、霉菌及其他有害物。

由于该空调系统同时了热泵的冷、热量，并且排风采用全热回收等技术，可以使空调能耗降低20%左右；而且机组可以采用全新风运行，提高了室内空气品质。最后，系统通过使用绿色环保制冷工质（溴化锂溶液等），减少氟利昂制冷剂的使用，减少对大气臭氧层的破坏，体现生态和环保的理念（图8）。
（2）节能照明及其智能监控

选用节能灯具，优化照明方案，并通过设置照度传感器实现智能监控，在确保舒适光环境的前提下，节约照明能耗。

5. 其它辅助节能技术

（1）自然通风设计策略

通过室外气流组织的模拟计算及建筑物外形的风洞实验，下建筑各部分的自然通风效果进行分析，改进和优化建筑外形及房间功能。同时利用面积达 15 平方米的屋顶排风道代替排风烟囱，保证良好的自然通风效果。最后在排风道内设置 7 组加热器，在过渡季节，利用太阳能热水加热流道内的空气，产生热压，提供自然通风所必需的动力，强化自然通风，实现舒适的室内风环境并减少夏季空调运行时间、节约空调能耗（图 9、10、11）。
采用天然采光模拟技术优化中庭天窗、外墙门窗等采光及遮阳设计，设计优化的目标为冬季北面房间可透射太阳光；夏季通过有效遮阳避免太阳直射；白天室内纯自然采光区域面积达到 80%、临界照度 100Lux，在营造舒适视觉工作环境的同时降低照明能耗 30% 以上（图 12、13）。
6. 资源节约、回用技术

6.1. 绿色建材

示范楼 3R 材料（Reduce、Reuse、Recycle）使用率达到 80%，采用大量绿色材料，如墙体采用再生骨料混凝土空心砌块；基础应用了 C20 垫层再生混凝土和 C30 再生混凝土；上部结构混凝土采用了 C40 大掺量掺合料混凝土，可降低水泥用量 60～70%；砌筑、抹灰和地面砂浆采用了再生骨料、粉煤灰等制成的商品砂浆，可减少天然砂用量 25%，水泥用量 15%；选用速生木材加工制成的科技木，既完全保留了木材隔热、绝缘、调温、调湿等所有的自然属性，又避免了天然木材的自然缺陷，同时还可仿制出各种天然珍贵树种甚至更具艺术感的纹理和颜色，大大提高木材利用率和装饰功能；选用回收旧木材用于部分建筑装饰；环保装饰装修材料 100%采用环保低毒产品（图 14、15）。

图 12 天然采光模拟优化
图 13 中庭天窗天然采光效果

图 14 建筑材料的回收和再利用
图 15 再生骨料
6.2 水资源节约、回用技术
选用节水器具；采用ICAST 雨污水处系系统来处理回用全部建筑污水、雨水和实验室冲淋水，处理水量为 20m³/d。系统主要装臵包括调节池、ICAST 反应池、二沉池、中间池、过滤柱及消毒池，并采用自动在线监测仪器对出水水质、ICAST 反应池内的运行条件以及系统设备的运行参数等进行监测，处理合格的中水回用作示范楼冲厕、绿化浇灌、景观水池用水（图 16）、清洁道路和夏季中庭玻璃天窗的水幕降温等，达到节约资源，降低能耗的目的。

6.3 环境保护技术

图 16 景观水系效果图

6.3.1 合理选址规划，保护原环境

6.3.2 尽量减少废水、废气、固体废物的排放；采用雨污水处系技术实现废水的无害化和资源化，
选用洁净生产、无毒无污的绿色环保建筑材料，控制建筑施工过程污染，对固体废物分类收集并进行无害化和资源化处理，促其再生使用。

6.3.3 合理的室外绿化布局配置，改善建筑周边微气候，降低城市热岛效应。

6.4、“以人为本”综合技术

6.4.1 健康、舒适的建筑环境技术

图 17 室内空气污染源种类分

图 18 室内空气污染预评估

（1）室内环境质量控制

通过室内污染浓度分布预评估、环保建材的选用和室内设备的选择及新风量的控制，
确保室内空气品质；通过热环境模拟评估，确定满足热舒适的空调系统运行参数和气流组织、风口的选择；通过室内室外噪声调研和建筑构件隔声模拟，并综合考虑噪声控制与节能、通风、采光之间的协调，提出室内外交通噪声、室内设备房、中庭、管道、电梯等重点区域隔声降噪控制方案；通过光环境模拟分析，将人工照明与自然采光相结合，确定分区照明设计方案。最终通过室内环境综合智能调控系统，实现健康、舒适的室内环境控制目标（图17、18）。

（2）生态绿化及景观水体

示范楼采用生态绿化植物群落配置技术，在平屋顶屋面上设计了九处屋顶花园，在一楼中庭设计一处室内绿化，并结合西墙垂直绿化和室外周边绿化等多种绿化形式，有效改善建筑微环境，并营造视觉舒适。实现夏季建筑外植物群落降温1-2.5℃，夏季屋顶及垂直绿化降低室内温度1-1.5℃，建筑周围植物群落减弱噪音能力达到目1-2dB/2m等生态效益指标（图19）。

![图19 生态绿化配置](image)

a. 屋顶花园  b. 室内中庭绿化
示范楼南外侧设置景观水体，采用景观水质生态修复保持技术，由水生植物净化循环水再生系统保持水质，满足人对“亲水”环境的愉悦需求（图 20）。

6.4.2 建筑智能集成控制技术

以数据采集、通信、计算、控制等信息技术为手段，运用成套先进的智能集成控制系统，包括室内环境综合调控系统及软件，照明及空调节能环保监控系统，安全保障及办公设备控制系统的集成平台和应用软件等，实现大型遮阳百页的转动控制，空调等设备的节能环保监控，照明采光监控，室内空气质量、温湿度、个性化通风等室内环境的动态调节，确保生态建筑运行的节能、舒适和高效（图 21）。

图 20 景观水体生态修复保质（实景）

图 21 室内环境综合智能调控系统
上海生态建筑示范楼的建成，为全面展示生态建筑理念和集成技术体系、引导我国生态建筑的研究和推广应用提供了示范平台。目前该示范楼作为生态建筑技术产品后续研发的实验平台已被列入了 2004 年国家“十五”科技攻关重点项目“绿色建筑关键技术研究”，研究工作已全面开展。通过跟踪实测评价其生态技术集成体系效果，并开展生态新技术、新产品的应用研究，形成适宜推广的适用型生态技术集成体系，为房产商建设生态建筑提供技术支撑；为我国的生态建筑设计和建造及上海 2010 世博建筑示范区的建设提供可行的技术借鉴。

BASIS OF ECO-BUILDING IDEOLOGY AND ITS TECHNICAL DEMONSTRATION
—DEMONSTRATION OF THE INTEGRATED ECO-BUILDING TECHNOLOGIES IN SHANGHAI
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Abstract: Eco-building is the inevitable trend of sustainable development in the worldwide building field nowadays, following the principle of sustainable development, showing the idea of energy & resource saving, environment protecting and human orientation, representing the harmony among building, human, environment and technology. Based on this point, this paper introduces the technical system of the demonstrative eco-building in Shanghai, which is one of the achievements of the grand project, Study and Systematic Integrate Application of Key Technology on Eco-building, sponsored by Shanghai Municipal Science and Technology Committee. Through this, we hope to bring forth and explore feasible eco-technologies that accord with local status quo of Shanghai and even China. We also hope to provide a good reference for both the construction of Expo 2010 site and the sustainable development of building industry in China.

Keywords: eco-building, technology integration, technological demonstration
THE INFLUENCES OF THE WALLS AND DOUBLE-GLAZING ON THE ENERGY CONSUMPTION IN BUILDINGS

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ABSTRACT: The building envelopes highly influence the energy consumption in the buildings, located in the cold regions. In addition, the gradient between indoor and outdoor temperatures is the main factor for heat transfer in these buildings. There are many apartments with extended hollow block walls and one-layer glazed windows in contact with air in Mashad, located in the cold regions of Iran. Hence, there is intensive heat transfer between inside and outside of these apartments. In this paper, the energy consumption in an assumed building in the Mashad with different construction methods for walls and windows is simulated by DeST-h. The results showed that insulated wall and double-glazing windows can decline the amount of consumed energy about 27.7 and 12.2%, respectively. According to appropriate construction cost of insulated wall, it is introduced as a proper alternative. In addition, the influences of the position of a room in a floor on the energy consumption and the amount of energy consumption in different floors are evaluated and compared. These evaluations show that the designer should have especial attention to the position of a room in the building and its stories.

Key words: hollow block; insulated wall; double-glazing; energy consumption; Mashad.

1. INTRODUCTION

As the population in the world increases, the consumption of energy increases and the importance of energy consumption is revealed more and more. By the way, the overuse of energy is an important factor in the environmental pollution and the shortage of energy resources, which can influence all of the countries.

Iran as a developing country has huge resources of fuels and other energy resources such as wind and sun. Hence not only we should replace the fuel energy with the renewable energy resources, but also we should optimize the energy consumption. Sustainable building is a well known method that can save energy and decrease its consumption and it is widely used in many of countries. The residential buildings are the major factor of energy consumption in the most of
cities. The thermal performance of the building envelopes is one of the main factors that affect the energy consumption in the buildings.

Building glasses and walls are two important factors of energy consumption from envelopes. Glasses, similar to other kinds of transparent constructions, are widely used in the modern buildings. For example: It is reported that about 7,500,000 square meters of glass curtain wall have been produced (used) in China in 2001, which is equal to 2/3 of the total production in the world [1]. Until to the end of 2001, 42,000,000 square meters of glass curtain wall were set up in China.

The most of governmental offices in Iran pay great attention to the energy conservation in the building. The relevant departments have issued several documents to require the building industry to innovate the energy conserving wall material and not use of non-energy conserving materials gradually, but the hollow block and non-energy conserving materials are mainly used in building industry and their usage has not changed a lot, because the price of energy in Iran is very low. In order to change this state, the ministry of dwelling in Iran has published new edition of “Iran building national manual” (topic 19: optimization of energy consumption in building) and promoting the innovation of the wall materials and popularizing the energy conserving buildings and request and advise building constructors to use of new materials. Hence, different kinds of new wall's materials appeared in the big cities markets (e.g. Mashad) after the document being issued.

Mashad (capital of Khorasan province) is one of the biggest cities in Iran and it is located in the cold regions of northeastern part of Iran [2]. There are many apartments with extended hollow block walls in contact with air in Mashad. These especial types of residential apartments have evolved in Mashad over last two decades. These apartments have between 4 and 6 stories which are located between one or two stories houses. The Islamic rules have affected on design of these kind buildings.
According to the Islamic architectural rules, these apartments cannot have any view to the one-story houses, which are located in their neighborhood (Eastern and Western parts of apartment). The face of these walls is not important, so often covered by a thin layer of Cement Mortar. Figure 1 shows a southeastern view of an apartment in Mashad with very vast area of walls and windows in touch with air. In the cold regions, the building envelopes and especially their vast area of walls and windows in touch with air have vital role on the energy consumption in this type of residential apartments.

Figure 1: An apartment in Mashad with vast western and eastern walls and vast northern and southern windows in touch with free air.

In this study, the energy consumption in an assumed building in the Mashad (similar to the apartment, presented in Fig. 1) with different construction methods of walls and windows are investigated. In addition, the energy consumption in various stories are evaluated and compared.

2. MATERIALS AND METHODS

In this study, the buildings were analyzed by DeST-H software, which is an annual dynamic energy simulation tool. This software is almost used in China and it can simulate the hourly room temperature, loading of energy by the air conditioning system during a year and some other energy parameters related to the buildings.
The energy consumption in a multi-level building (5-7 stories), located between two stories residential buildings is simulated in this study. The building will be analyzed with the following three different assumptions:

A. Assume that the walls and windows have been built by hollow blocks and single layer of glasses, respectively.

B. Assume that the walls have been built by insulated materials, instead of hollow blocks.

C. Assume that the windows have been built by the normal double-glazing.

2.1 Building information
The building has seven stories, first story (underground) is parking and other six stories are residential apartments. In each floor, there are two apartments. One of them has two bedrooms and the other one has only one bedroom. The total building’s height is 20 m (3.3 m per story). The area of building is about 1421 m², which about 1136 m² of it uses of air conditioning systems. The glazing ratios for southern, northern and eastern sides are 39%, 34.5% and 7.5% respectively and there is no any window in the western side. Figure 2 shows the plan of this apartment. Building position is toward the south direction.

2.2 Materials properties
The materials used for the mentioned three assumed conditions are as below:

Materials used for ceiling and floors are the same for three assumed buildings. Ceiling is including 1.5 cm gypsum mortar, 10 cm reinforced concrete, 20 cm air entrained concrete, thin layer of bituminous coat and 2 cm cement mortar, by the way floors has made by 1.5 cm gypsum mortar, 10 cm reinforced concrete, 3 cm cement mortar and 8 mm parquet floor (solid wood).
A- Block wall building: The walls of this building has been made by hollow blocks (15cm width) with thermal conductivity ($K$) of 0.64 W/(m.ºC) and thin layer of cement mortar (2.5 cm) with thermal conductivity ($K$) of 1.15 W/(m.ºC) in the outside and thin layer of gypsum mortar and plaster for inside [2]. Fig.3 shows the details of hollow block wall.
A normal single glass with thickness of 3 mm, heat transfer coefficient (U) value of 5.7 W/(m²·K) and shading coefficient of 0.93 (DEST-H building materials library).

B- Building with Insulated wall: it has two layer reinforced concrete (5+5 cm), which separated by a insulation layer of polystyrene with 4 cm thickness and the thermal conductivity of 0.047 W/(m·°C) [2]. In addition, the wall has a thin layer of gypsum mortar and plaster for inside. Fig.4 shows the details of suggested insulated wall. The experiences show that the construction cost for hollow block wall and insulated wall is the same.

C- Building with Double glass windows: we just used of normal double glasses with 3+6+3 mm thickness instead single glasses in the windows of block wall building. The U value of normal double glass was 3.4 W/(m²·K) and its shading coefficient was 0.90 (DeST-h building materials library). The construction cost of double glass windows is approximately 10 $/m² higher than one layer glass windows in the previous methods (A & B).
2.3 Mashad Weather data
According to the requirements of the performance approach in the Standard of Design, typical meteorological data should be utilized during dynamic energy calculation procedure. DEST-h weather data library has the weather data of all of the cities in China; but we had no complete weather data of Mashad. Hence we tried to find a city in China with similar meteorological condition to Mashad and we found a city in the cold regions of China [3], that its temperature and latitude were close to Mashad (36°,16’ N), This city is Xi’an (34°,24’ N). In the Fig. 5, the Mean, minimum and maximum temperature of Xi’an and Mashad have been presented [4]. According to the Fig. 5 and Xi’an’s latitude, Xi’an’s weather data, presented in DeST-h (produced by Medpha software and based on 20 years weather data [5]), is utilized for the simulations in this study, instead of Mashad weather data.

![Figure 5: Mean, minimum and maximum temperature of Xi’an and Mashad (1961-1990).](image)

2.4 The conditions of simulation
The energy consumption in the buildings have been simulated under the following condition:

During the air conditioning state, Minimum air change is 0.35 of room air volume per hour for fresh air, and 1800 W.h/day heat is produced by stove and other appliances (internal gains) in the kitchen. Researches show that by decrease of
natural ventilation, the base temperature of rooms in the building with insulated wall declines more than the building with hollow block in cooling load season [6]. Therefore, we use of natural ventilation in the evening (21:00-22:00) of summer.

Other conditions explained in Table 1. The other parameters, not mentioned in the Table 1, are considered as the DeST default.

<table>
<thead>
<tr>
<th>Room with air-conditioning</th>
<th>Living room/Bedroom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room without air-conditioning</td>
<td>Bathroom/Staircase/Kitchen</td>
</tr>
<tr>
<td>Operating mode of Air-conditioning</td>
<td>Living Room</td>
</tr>
<tr>
<td></td>
<td>Bed room</td>
</tr>
<tr>
<td>Internal Heat Gains</td>
<td>Max 26°C-28°C</td>
</tr>
<tr>
<td>Temperature</td>
<td>Min 18°C-16°C</td>
</tr>
<tr>
<td>Air change</td>
<td>0.35 1/h</td>
</tr>
</tbody>
</table>

3. RESULTS AND DISCUSSIONS

According to the explained conditions, some various simulations were performed on the three assumed buildings for the evaluation of the of energy consumption in different buildings.

The results of simulations are presented and discussed in the following parts of this section.

3.1 Total annual energy consumption

The results of simulation of annual energy consumption in the buildings have been presented in the Table 2. This table shows the annual energy consumption for heating and cooling in three assumed buildings (A-C) during a year. Cooling load
season starts on 20th May and finishes on 20th Sep and season of heating load is between 5th Nov. and 5th Apr.

By comparing the results of Table 2, we found that using normal double glass instead of single glass in the windows, annual cooling load decreases about 13%, but if we construct the wall by insulation materials, it just can decrease the cooling load about 4.5%. It means that although insulated wall decrease the flux of energy from outside to inside, but another way of solar energy transfer into the building is the windows.

Table 2: Total and Maximum annual loads of three different assumed buildings (A-C).

<table>
<thead>
<tr>
<th>Building Loads</th>
<th>Block Wall</th>
<th>ND Glazing</th>
<th>Insu. Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual heating load</td>
<td>72688</td>
<td>64078</td>
<td>46209</td>
</tr>
<tr>
<td>(kwh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Cooling load</td>
<td>26960</td>
<td>23458</td>
<td>25749</td>
</tr>
<tr>
<td>(kwh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. of heating load</td>
<td>107.88</td>
<td>99.55</td>
<td>85.74</td>
</tr>
<tr>
<td>(kw)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. of cooling load</td>
<td>120.31</td>
<td>116.33</td>
<td>114.75</td>
</tr>
<tr>
<td>(kw)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results in the heating conditions are completely different with the results of cooling conditions. The amount of decline of heating load by normal double glass and insulated wall are about 11.8 and 36.4%, respectively. The construction cost of insulated walls is equal to hollow block, hence it is necessary to use of insulated wall instead of hollow block wall.

Figure 6 shows heating and cooling loads per square meter of three assumed buildings. According to Fig. 6, the insulated walls can highly decrease the heating load. This means that not only the heating cost and the costs of maintenance of
heating equipments decrease, but also decrease in the consumed fuel is equal to the decease of air pollution.

![Comparison of total annual heating and cooling loads per square meter for different assumed buildings.](image)

**Figure 6: Comparison of total annual heating and cooling loads per square meter for different assumed buildings.**

### 3.2 Maximum of annual energy consumption

Maximum annual heating and cooling loads is another parameter, which is evaluated in this section. The results of simulation show, which both of maximum heating and cooling load decrease by insulation wall more than the normal double glass. Fig. 7 shows the maximum of heating and cooling loads in three assumed buildings. The amount of reduce of heating load by normal double glass and insulated wall are about 7.7 and 20.5%, respectively. By the way, using of the normal double glass instead of single glass in the windows; annual cooling load can be decreased about %3.3 and if we construct the wall by insulation materials it can decrease %4.6 of cooling load.

Decrease of maximum cooling load for insulated wall is very important, because this can help to decrease the pick of electricity consumption in Mashad in summer.
Figure 7: Comparison between maximum heating and cooling loads per square meter for different assumed buildings.

3.3 Energy consumption in different rooms

Although the total energy consumption shows that use of double-glazing windows has better advantages than the insulated walls in the cooling load conditions, but the evaluation of energy consumption in the different rooms shows new results.

Evaluation of average of annual cooling load in two bedrooms shows that the effects of insulated wall are not equal for two different bedrooms. Table 3 shows the average of annual cooling load for Northwest bedrooms in the different floors. The results show that the first and second floors show better results than the other floors and for these floors (First and second floors) the double-glazing method has better results than the insulation method (See Table 3).

<table>
<thead>
<tr>
<th>Floor</th>
<th>Ave. Cooling Load(W/m²)</th>
<th>Block Wall</th>
<th>ND Glazing</th>
<th>Insu. Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>First floor</td>
<td>5.47</td>
<td>4.52</td>
<td>5.16</td>
<td></td>
</tr>
<tr>
<td>Second floor</td>
<td>7.76</td>
<td>6.78</td>
<td>7.46</td>
<td></td>
</tr>
<tr>
<td>Third floor</td>
<td>10.55</td>
<td>9.78</td>
<td>8.79</td>
<td></td>
</tr>
<tr>
<td>Forth floor</td>
<td>10.60</td>
<td>9.79</td>
<td>8.85</td>
<td></td>
</tr>
<tr>
<td>Fifth floor</td>
<td>10.65</td>
<td>9.88</td>
<td>8.90</td>
<td></td>
</tr>
<tr>
<td>Sixth floor</td>
<td>11.76</td>
<td>11.04</td>
<td>9.96</td>
<td></td>
</tr>
</tbody>
</table>
It is necessary to have especial attention to this subject that the building is assumed that has been surrounded by the two stories buildings. Hence, the behavior of first and second floors is completely different with other floors.

However in another bedroom, the amount of annual cooling loads is completely different. Table 4 shows average of annual cooling load for Northeast bedroom. It shows not only for all floors double-glazing have better advantage but also in all of the floors the average of energy consumption for block wall is less than insulated wall.

<table>
<thead>
<tr>
<th>Ave. Cooling Load(W/m2)</th>
<th>Block Wall</th>
<th>ND Glazing</th>
<th>Insu. Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>First floor</td>
<td>11.66</td>
<td>9.43</td>
<td>12.28</td>
</tr>
<tr>
<td>Second floor</td>
<td>12.24</td>
<td>10.47</td>
<td>12.86</td>
</tr>
<tr>
<td>Third floor</td>
<td>13.40</td>
<td>11.83</td>
<td>13.55</td>
</tr>
<tr>
<td>Forth floor</td>
<td>13.43</td>
<td>11.84</td>
<td>13.55</td>
</tr>
<tr>
<td>Fifth floor</td>
<td>13.44</td>
<td>11.89</td>
<td>13.57</td>
</tr>
<tr>
<td>Sixth floor</td>
<td>13.92</td>
<td>12.59</td>
<td>13.98</td>
</tr>
</tbody>
</table>

Evaluation of average of annual heating load in two bedrooms shows that the effects of insulated wall and double-glazing are not similar for different floors. Table 5 shows the average of annual heating load for Northeast bedrooms in the different floors. The results show that the first and second floors give better results than the other floors and for these floors (First and second floors) the double-glazing method has better results than the insulation method (See Table 5). By the way,, insulated wall shows better result than the ND Glazing in Northeast bedroom.
**Table 5:** Average of annual heating load for Northeast bedroom.

<table>
<thead>
<tr>
<th>Ave. Heating Load (W/m²)</th>
<th>Block Wall</th>
<th>ND Glazing</th>
<th>Insu. Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>First floor</td>
<td>31.70</td>
<td>22.19</td>
<td>31.02</td>
</tr>
<tr>
<td>Second floor</td>
<td>29.82</td>
<td>22.69</td>
<td>25.08</td>
</tr>
<tr>
<td>Third floor</td>
<td>36.32</td>
<td>30.18</td>
<td>25.73</td>
</tr>
<tr>
<td>Forth floor</td>
<td>36.50</td>
<td>30.28</td>
<td>25.76</td>
</tr>
<tr>
<td>Fifth floor</td>
<td>36.59</td>
<td>30.37</td>
<td>25.91</td>
</tr>
<tr>
<td>Sixth floor</td>
<td>41.84</td>
<td>35.92</td>
<td>32.24</td>
</tr>
</tbody>
</table>

However, the amount of annual heating loads is completely different in another bedroom. Table 6 shows average of annual heating load for Northwest bedroom. As we see in all of the floors, the average of annual energy consumption for insulated wall is less than double-glazing. Therefore, the amount of energy consumption in a room is highly related to the position of room in the building and neighbor buildings. On other words, use insulation wall for the Northwest bedroom has better advantage than double-glazing to decrease annual energy consumption (Cooling and Heating loads) and for Northeast bedroom that is reverse, it means in Northeast bedroom, double-glazing decrease annual energy consumption better than insulated wall in the assumed building.

**Table 6:** Average of annual heating load for Northwest bedroom.

<table>
<thead>
<tr>
<th>Ave. Heating Load (W/m²)</th>
<th>Block Wall</th>
<th>ND Glazing</th>
<th>Insu. Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>First floor</td>
<td>23.33</td>
<td>20.32</td>
<td>16.83</td>
</tr>
<tr>
<td>Second floor</td>
<td>20.97</td>
<td>18.30</td>
<td>14.19</td>
</tr>
<tr>
<td>Third floor</td>
<td>27.19</td>
<td>24.73</td>
<td>15.39</td>
</tr>
<tr>
<td>Forth floor</td>
<td>27.43</td>
<td>25.01</td>
<td>15.48</td>
</tr>
<tr>
<td>Fifth floor</td>
<td>27.68</td>
<td>25.23</td>
<td>15.74</td>
</tr>
<tr>
<td>Sixth floor</td>
<td>33.27</td>
<td>31.00</td>
<td>22.37</td>
</tr>
</tbody>
</table>
According to the results of Tables 3-6 and their comparison, the simulation of energy consumption is necessary to find the best condition for the walls of each room before of its design.

Results of maximum cooling load in two bedrooms of building with insulated wall show that the improvement of energy performance of higher floors is more than lower floors. It means when a room located beside of neighborhood, or on the other word, in the first and second floors in this study, use of the insulated walls do not have good advantage however for a bedroom, located in the other floors have good advantages. These results for building with double-glazing windows are reverse and with increasing the height, the effects of double-glazing on decrease of maximum cooling load decline.

Figures 8 and 9 show the results of simulation of maximum cooling and heating loads of two bedrooms in different positions for two buildings. The results of maximum heating and cooling load (Figures 8 and 9) show that the lower floors more affected by double-glazing windows more than higher floors because of the buildings, located in its neighborhood. Hence, as the height of building increases, the effects of double-glazing on the maximum heating and cooling loads declines. Evaluation of the results for the building with insulated walls show that mid floors have better influences on maximum energy consumption and this effect is less on the last floor and lower floors.
On other word, however the advantage of energy consumption in Northeast and Northwest bedrooms are completely different (see Figures 8 and 9) but behavior of them in different floors on decrease of cooling and heating load are similar for insulated wall or double-glazing.

4. CONCLUSIONS

1- Use of insulation wall declined the total annual energy consumption more than 27.7% in this method. Because of the equality of the construction costs of hollow block and insulated walls, The insulated wall is an appropriate method toward the sustainable building.
2- Use of double glass for windows, however decreases total annual energy consumption about 12.2%, but increases construction cost.

3- During the design building, it is necessary to notice on neighborhoods and positions in the building for the optimum energy conservation.

REFERENCES


在工程建设活动中我们期待绿色设计，更呼唤绿色思维。这也是社会可持续发展的必经之路。建设活动消耗人类从自然界获得资源的一半，产生约一半的固体垃圾，消耗绝大多数饮用水。中国每年有几十万公顷土地被开发，森林和农田正在被大量占用。随着我国城市化进程逐年加快，建设活动对资源和能源的消耗量也在逐年上升。我们面临的问题、可能的解决方法和所能凭借的现实条件都决定了我们不能简单照搬发达国家既有经验。发展循环经济已成为我国的发展战略。绿色建筑作为建设领域循环经济的具体体现，是建设行业的发展方向。如何科学的实现绿色建筑，需要我们深思。

绿色建筑是指在建筑的全寿命周期内，最大限度地节约资源（节能、节地、节水、节材）、保护环境和减少污染，为人们提供健康适用和高效的使用空间，与自然和谐共生的建筑。所谓绿色思维，是指从人性关怀、资源节约、环境友好的角度，思考人类的建设活动，使城市能在与自然和谐共生的前提下持续发展。它包含了三个要素：首先，一个核心平衡观。即通过分析论证，在技术、政治、经济、气候、人文、资源、需求等方面达到平衡。我们不求在某一方面绝对突出，但求整体效果达到一种最优的均衡。其次，两个全面性，一是时间上的全面性，即审视城市的“全寿命”发展过程，包括规划、开发、建造、运营、维护、更新等各个环节；二是空间上的全面性，即城市及建筑对生态环境的响应从能源方面扩展到全面审视建造活动对全球生态环境和居住者的生活环境的影响。最后是三个基本点，即舒适健康的人居环境、最少的消耗自然资源、最少的影响外界环境。绿色思维将给建筑设计带来观念上，内涵上及方法上的改变。绿色建筑设计讲求创新、平衡之下的“
精宜之道”。所谓“精”，指常规技术的精细化，所谓“宜”是指技术的适宜化。同时要结合集成化的工作模式，数字化的辅助手段，科学化的逻辑判断，持续化的效能验证。

我们曾在“龙岗·体育新城安置小区”这个项目中实践了绿色建筑的设计方法。此项目为政府投资建设的拆迁安置房，建筑造价受到严格限制；为了配合大运会场馆的建设，工期十分紧张；原住居民自用和出租物业混杂的小区，功能需求复杂。如何在苛刻的制约条件下完成绿色建筑设计目标成为一个巨大的挑战。我们运用集成化与精细化的设计，适宜的新技术达到了利用低成本技术实现节能与绿色的目标，同时本项目也获得了2006年国家财政部、建设部第一批可再生能源建筑应用示范项目，现一部分已经峰顶。近年来，我们一直秉承绿色思维设计观，完成了绿色建筑设计与咨询项目约200万平方米。包括深圳振业城，首批中国绿色建筑示范项目，武武汉泰跃金河小区、万科城四期首批中国绿色建筑示范项目，深圳软件大厦，深圳听泉居，杭州城市芯宇，建科大厦——

2006年国家财政部、建设部第一批可再生能源建筑应用示范项目，等等。思维决定行动，观念决定出路。绿色思维必定会给城市建设带来一场创新性的革命！

THE PRACTICE OF INNOVATIVE GREEN BUILDING DESIGN ON THE BASIS OF GREEN CONCEPTION

YE QINg
Dean of Shenzhen Institute of Building Research

In construction activities, we not only prefer green design, but also prefer the green conception. We think that this is the only way to sustainable development.
Construction activities consume half of natural resources, produce about half of the solid waste and use most of drinking water. Each year, hundreds of thousands hectare of land have been developed. Forest and farmland have been largely occupied. Along with the accelerated process of urbanization, the consumption of resources and energy of construction activities is increasing year by year. The problems we faced now determined that we can not simply copy the experience of developed countries. To develop recycling economy has been the development strategy of China. Green building, as the specific representation of recycling economy in the construction field, is the trend of the construction industry. We need to deeply consider how to scientifically realize this goal. Green building means to maximize the resources saving (energy, land, water and materials), protect the environment, and reduce pollution in the life time of a building. This type of building has to provide a healthy, livable, efficient and nature friendly environment to people. Meanwhile, green conception means to consider human (construction) activities from the perspective of caring people, saving resources and friendly environment, so that the city can have a sustainable development in the premise of getting along with our nature. The green conception include three key factors: firstly is the balance conception, which means by analyzing to achieve balance in the aspects of technology, politics, economy, climate, culture, and so on. Maybe we cannot perform the best in each certain aspect, but what we pursue is the best balance of the integrated effect. The second key factor includes two integrations: one is the integration of time, which means to consider the “life time” of a city, covering the process of planning, developing, building, managing and updating, etc. The other one is space integration, which means that the impact of the city or building on natural environment should be considered by a global view. The last key factor includes three basics, which are comfortable and healthy living environment, minimum natural resources consumption, and minimum impact on the environment. In conclusion, green conception will lead to a significant change in building design in the aspects of way of thinking and acting. Green building design requires delicateness and suitability besides of creativity and balance. “Delicateness” means to use the normal technology delicately. “Suitability” means
to use suitable technology. Additionally, it needs to combine with digital tools, scientific decision and sustainable efficiency testing. We practices the green building design in the project of “Long Gang · New Sport town community”. This project is the compensation resident building invested by the government for the farmers whose land has been imposed by the government. The expenses were therefore strictly controlled. To cooperate with the construction of the Universidad Sport Center, we were really lack of time. Furthermore, due to the complicated origins of the tenants, they asked for lots of complex function requirements. How to accomplish this green building design under the conditions described above became a big challenge. At the end, we finished the integrated, delicate design, and used suitable new technology, achieving the green goal of using cost-effective technology to realize energy efficiency. This project became one of the first group of demonstrated projects with using renewable energy, awarded by Ministry of Fiance and Ministry of Construction in 2006. Currently, the fist phase has been finished. During the recent years, we always adhere to green building design and complete about 2 million m2 design and consultancy projects. They are Zhenye Town of Shenzhen, the one in the first batch of green building demonstration projects in China; Tai Yuejin River Community of Wuhan; Dream Town Phase IV, the one in the first batch of green building demonstration projects in China; Software building of Shenzhen; Ting Quan house of Shenzhen; Xinyu of Hangzhou and the headquarter of our company, which is also the one in the first batch of demonstrated projects with renewable energy application, awarded by Ministry of Finance and Ministry of Construction in 2006. In our opinion, what you think decides what you do, and the conception determines the way out. We believe that the green conception will bring a new renovation to the urban planning and development.
STUDY OF THE ORIGINAL ECOLOGY DESIGN IN THE COURTYARD OF TRADITIONAL DWELLINGS IN MEIZHOU

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Abstract: The traditional dwellings with comfortable courtyards provide perfect environment for people in Meizhou because of the design of dwellings’ courtyard possessed idea of the original ecology, which suits for the subtropical architectural climate. We can draw lessons from the traditional idea such as the usage of the original ecological material and effective low ecological technology for the construction of the modern residence environment.

Key words: ecological environment; traditional dwellings in MeiZhou; courtyard

1. PREFACE

The main cause of the development and start of modern environment is that the culture ecological theory satisfies the people spring’s image affection [1], science and technology ecological theory began to display in the busy streets and square in cities and applied in the center square and lawn in front of dwellings afterward from the 1980’s “breathing square” in Japan. The harmony of social environment and nature environment is the final spring need of human being, and the part of need come from the result of science and technology connotation and the country yards distillation. In the trend of modern ecological environment, still can use for reference from so many ecological environment theory in traditional dwellings’ yards in Meizhou, and to display the value of Chinese local environment.
Meizhou locates in mountain area which connects the Guangdong, Fujian and Jiangxi provinces which is biggest center for Hakkas. The ancestors of hakkas escaped from the wars in fertile plain, settled in the mountain area. Build the circle dwellings with the local raw material and keep the traditional normal architecture shape and enforce the defense function, then a new architecture group style come out at the foot of the mountain—Meizhou Hakka’s circle dwelling. Because the function and construction of the circle dwellings suit fort the local produce and life, the style keep stable for long time. Recently, the circle dwellings seldom are built because of the defense function lost its actual meaning and some function can not touch the modern lie. There are so many traditional circle dwellings scattered in mountain with six or seven hundreds of years history. These dwellings were built under the direction of original ecological theory, so the blend of dwellings and environment is perfect, and endow the harmony of the human being and nature.

2. THE INTRODUCTION OF MEIZHOU TRADITIONAL DWELLINGS’ YARDS

The scale of Meizhou Hakka’s circle dwellings is large, in which hundreds of inhabitants live, because of the variety rooms have definite different function, so the yards have. Generally speaking, there are several yards below: first, nearly square patio. Patio is the yard for central room and wing room on the axe in the plane, generally speaking there are two patios for one dwelling. Second, rectangle yard between two wing rooms, 3-6 meters wide belong to sub yards. Third, rectangle and semi circle yard which is front courtyards, the flat floor (called Heping in folk) and the pool (called half moon pool in folk) in front of main gate. Forth, semi-circle courtyards which are back courtyards located between central room and semi-circle rooms. Fifth, other form courtyards, such as the two or more circles form dwellings, the narrowest courtyards between semi-circle rooms.
The circle dwelling yard forms are variety because of their different functions. Not only to close the gates keep the enemy outside and the normal live inside, but also enforce the living temperament and interest, and display the Hakka’s ability to create comfortable living environment from the original environment.

3. THE TRADITIONAL YARDS WITH ORIGINAL ECOLOGICAL FEATURE

Based on the standard of division of Chinese climates, the Meizhou locates in subtropical zone; summer is long, hot and wet all year, the Meizhou traditional dwellings suit for the subtropics climate, even in hot summer, it is cool in the yards because of there are so many features of ecological technology, ecological material and ecological theory.

3.1 The local ecological environment view

The most Hakka live in the mountain, the dwellings on the slope of mountain and near to river in the nature environment among the fresh air. Recently, information come from the poll, all people in the village consider the air is perfect there, half villagers accept the wonderful scene, and 92% villagers are very happy living there. According to No.1 graph, Hakka’s villagers agree on the opinion below: the perfect environment reflects mountains and rivers.

<table>
<thead>
<tr>
<th>Revalue</th>
<th>Percent</th>
<th>Air</th>
<th>percent</th>
<th>Revalue</th>
<th>percent</th>
<th>Revalue</th>
<th>percent</th>
<th>Grip</th>
<th>percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountains</td>
<td>63%</td>
<td>Good</td>
<td>100%</td>
<td>Nature</td>
<td>88%</td>
<td>like</td>
<td>67%</td>
<td>Good</td>
<td>84%</td>
</tr>
<tr>
<td>Rivers</td>
<td>33%</td>
<td>Bad</td>
<td>0</td>
<td>Artificial</td>
<td>12%</td>
<td>Dislike</td>
<td>0</td>
<td>Bad</td>
<td>14%</td>
</tr>
<tr>
<td>No sense</td>
<td>4%</td>
<td>No sense</td>
<td>33%</td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>
Hakka’s people defer to the Fengsui, the Fengsui can effect the architecture’s location, scale, form and so on. Although there are some content of superstition for the Fengsui, the Fensui includes some science nature geographical environment factors such as geology, topographic feature, hydrology, sunshine, climate and landscape. To deal with evaluation of design and get the perfect purpose, and create suitable wonderful environment for long living. Fengsui method is very fashion in the area where Hakka’s people live, not only improves the traditional dwellings to fit in with the needs of original geographical environment but also preserve the original environment for life, finally to touch the need of healthy living. So the Fengsui believe of hakka’a people is the main part of the original local environment.

The Hakka’s local ecological environment applies to main parts of architecture, as the one characteristic—patio display more. For example, there are rectangle space blow floor 20-30cm in the center of the patio on the axle and two wing sub yards called pool, the edge of pool is wide under the eave, the rain from eave pour into pool, through the delivery port of pool into the half moon pool in front of the dwelling. This construction of architecture for drain off water on surface is better than before and the way accords with the Fengsui, Hakka’s people regard water as wealth, the wealth source enter own half moon pool. By the way, the back yard of dwelling is semi-circle higher than other yard about half meter at an incline of about 30 degree, which is paved by pebble as dragon body, the pebble just like the scale called in folk as “Hua tai” for assemble air. There are wood behind wall of dwelling called Fengsui wood to enforce the mountain power. In fact, the front pool and the behind wood have build a perfect environment for dwelling to fight against powerful wind, regulate temperature and safeguard the quality of air.
3.2 The usage of original material

The form of ecological environment based on the usage of ecological material perfectly, the ecological material can be recycled without pollution. The Meizhou circle dwellings’ yards built by the floor, around walls, doors and windows, the scene and quality of air in yards depends on the choice of traditional architecture material.

The Hakka’s traditional dwellings architecture built with local material, generally from artificial clay and pebble, there are so many pebbles in Mei county and Xining for back yards, the pebbles in Dapu county for the center pool in the patio. The pebbles not only have the ability to anti-water, but also to breathe, to regulate the surface heat function target fit in the nature environment numerical value. Walls built by clay and clay bricks; doors and windows circle the yard. The artificial clay rammer walls in Mei county and Xining, and some dwellings built by sun-dried mud brick, the walls in Dapu are built by earth, brick and rock. The door and window are built by wood mostly.

These material just only processed by rammer, piling, carve and so on, have not be changed their own nature function. Some planets have grown up in the roof and cracked walls in so many old dwellings. Sometimes, the material from the old dwellings collapse can recycle without pollution; they all are perfect ecological material.

When the yard becomes the space exchange air with outside, the ecological material as the bridge for the function of exchange, which maintain the inside and yard perfect ecological environment, to enforce the plain natural breath, which is the living environment modern people in cities long for.
3.3 The usage of low original ecological technology

The low original ecological technology for the special social and natural environment, adopt low cost and do small harm to the environment, local traditional region technology is low original ecological technology. The handle of ventilate, sunshine, afforestation, and water display the primitive ecological technology in Meizhou.

Perfect ventilation based on the strewn at random of dwellings and the dwellings’ location forms. The circle dwelling courtyards safeguard the ventilate function, such as the front half moon pool and He ping form a wide flat for the wind, the central hall without walls around for the wind current free. The wing yards both directions of circle dwelling enforce the power of wind.

The circle dwelling not only deal with the perfect ventilation, but also care the sunshine, pay attention to the measure of sunshade. The eave is wider than the corridor under; the eave can protect the people in the corridor from the violent sunshine radiation. To be shade for architecture and part of courtyards, make a cool architecture group in summer for people living in.

The handle of afforestation and water in courtyards do well to the ecological environment. The rain enter into the half moon pool through the system of eave and drain off water in yards supply the planet around for growing. There are so many flowers and plants in flowerpot in the courtyards, the plant make shade, clean air, regulate the temperature, create perfect environment inside and outside of architecture.
4. REFERENCE FROM THE PRIMITIVE ECOLOGICAL COURTYARDS.

The usage of primitive ecological courtyards in Meizhou traditional dwelling blends the natural environment well, and builds the harmony for human being, architecture and environment around. The harmony is the goal of modern people long for, so the usage of primitive ecological theory and technology in Meizhou traditional dwelling is the resource for reference to build modern ecological living environment.

4.1 Reference for the modern ecological living environment.

While the concept of living district is more and more distinct, the demand of design theory deep into farther, the modern ecological living district is the final goal for residents and designers. People are aware of how to build the modern ecological living district is main duty for protect and improve living district, some regulations and laws have been made to settle the relationship between ecological environment and living environment.

How to settle contradiction between the dwelling environment and natural environment, the fundamental way is to conform to the trend of nature. To construct dwelling according to topography and the general configuration of the earth’s surface, to consider the air current and afforestation, to protect natural environment and improve the artificial environment for build harmonious landscape lasted into thousands of years. Of course, the living district ecological environment located in the whole city environment, the demand of city plan for ecological city is higher than before.

4.2 The reference for modern architecture material.

People care more about inner environment besides the area of structure and room layout. Because there are some undegradated and poison chemical materials
in modern environment design, resident pay more attention to the quality of air in room today.

The materials for Meizhou traditional dwellings from the nature, such as the clay, brick, rock, wood and so on, which can be recycle without pollution and have good breath function. There are some confusion for modern people to choose the materials, some harmful or unidentified materials are used for the architecture and ornament because of habit. The important for producing the architecture material is to reduce harm to resident; the design of environment art including the content of living health and sustain development. Making full use of the latest achievement in science and technology to improve sustain usage of sources of energy in modern materials is the trend of modern architecture.

The primitive ecological material is part of modern material science development, the recycled primitive material is special important for the small towns’ development. Some traditional architecture is gone as time pasting, some primitive material still can be used for design of native feature and public works.

4.3 The reference for the modern ecological technology.

The modern ecological technology is the key for modern ecological architecture, the cost of architecture is important factor for ecological architecture choice companying with the development of science. The traditional material is low cost and technology, which satisfy resident’s need of environment. The main features of the traditional dwellings in Meizhou are Peaceful, seclude, pure, fresh and natural. The results from the experiences people got from history. Under use abundantly the local natural resources and not to destroy the nature environment, utilize the system of saving energy in architecture to protect architecture construction, regulate the temperature, and improve the natural ventilate.
The ecological theory not only outstanding the features of culture and region, but also display trusted sustain development under the control of science. The development and innovation of high technology apply to architecture industry and show its strong vitality, but have the same purpose with the low ecological technology. The cost of high ecological technology restricts partly its popularized and applied in the ecological architecture. So it is the essential to blend the practical and economic low ecological technology and theory in Meizhou traditional dwellings with modern high new technology.

5. CONCLUSION

The focus of modern environment art design and architecture design is the relation of inherit and innovation. The blend of two shows how to give the traditional content modern fashion display to build the harmony of tradition and modern. In the international architecture background, how to figure out the native culture feature from and theory in the Chinese modern architecture environment art design is must be dissolved. The key is to dig out the soul of Chinese traditional architecture, put the original ecological theory for the modern architecture environment design for protection of environment, and sustain development and keeping the native culture. In order to construe the Chinese modern architecture environment art design theory and carry out green dwellings plan and city ecological plan’s development, we should not only learn the west’s science, technology material and forms of operation, but also care more about Chinese traditional architecture value, to build harmony of original idea and actual technology. So the Meizhou traditional dwellings’ yards as examples are worthy studying.
REFERENCES


ENSURING THE ECOLOGICAL SAFETY OF THE ENVIRONMENT BY REDUCING THE GROWTH OF THE QUANTITY OF BUILDING WASTE IN BIG CITIES

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ABSTRACT

Different types of waste in populated areas threaten in a catastrophic way the environment. The part of building waste increases quickly. In the countries of Central and Eastern Europe in the last years the application of light polyurethane panels increases sharply in the construction of one-storey and multi-storey buildings – supermarkets, fruit storehouses and refrigeratory warehouses. The author suggests to ensure the ecological safety by reducing the growth of building waste in big cities by building suitable structures for the building elements, made of polyurethane foam. The second important point is the building of specialized depots for the separate collection of the structure materials. The third point is to develop building technologies for recycling and fabrication of secondary products. In this way, the dismounting of the panels of the construction will give the opportunity to collect the structure layers separately by type of the material.

Keywords: ecological safety, reduction, growth of the building waste, panels, separate collection, structure layers, storage.

1. INTRODUCTION

In this paper is reviewed the transformation of ordinary light polyurethane panel structures into ecologically-safe panels.

It is proposed the structure of the panels to be fabricated of sectional elements, so that in the case of wearing out of the panel or expiration of its term of use the layers of this panel to be dismounted separately.
In connection with this the invention “Ecologically safe structure of a panel, connection between panels and a way to produce this panel”, developed by the author in the Civil Engineering Higher School is protected with a patent.

This solution is a basic contribution to the dissertation work of the author named “Ecologically safe structures of panels and connections between them”. [1]

This transformation is required because of the necessity to create ecologically-safe panel structures and their connections. If polyurethane is used, there have to be an intermediate self-sticking layer between the surface metal layers and the insulation. This layer ensures certain cohesion, necessary for the carrying capability of the panels and at the same time facilitates the dismounting of the layers during the separated collection.

Also, there are other possibilities to realize the separated collection of the structure layers:

-all structure layers are inserted into the structure of the panel;

-the structure layers are consecutively mounted into special strengthening stands with suitable configurations;

-the structure layers are fixed form the external side to the sides of the panel and the insulation is situated between them.

There are six basic panel types:

1. Light panels and their connections with spaces for loading the insulation.

2. Light panels, made with “dry” connections. The most common solutions are of the “groove and tooth” type.

3. Panels and connected with the help of bolts, screws and bushes.
4. Panels with stands, ensuring the changeable configuration of the connection, which could be used as a panel side.

5. Panels and hermetic connections between panels.

6. Panels and three-level edge connections between panels.

The solutions from all the six groups are reviewed according to their technical parameters, ensuring the mounting and dismounting of the panels and their connections with the aim to collect separately their structure layers. Also, there are presented the special features of every single solution, which could be transformed so that the separate collection could be carried into effect.

The criteria for the allocation of the panels in the appropriate group are as follows:

- The type of the panel structure;

- The ways of separate mounting and dismounting firstly in the panel and secondly in the wall;

- The configuration of the panel;

- The type of connection between two adjacent panels.

  • The transformation of light panels and their connections, made of polyurethane and other materials into ecologically-safe structures corresponds to the requirements of the laws and regulations;


  a) “The development and implementation of technologies, ensuring the rational use of natural resources”;
b) “technical research and fabrication of products, which are designed so, that their production, use and dismantling do not have or have the least possible part in the augmentation of the quantities or the threat of waste and the pollution with this waste”.


a) “the development and implementation of ecologically-safe technologies, which save primary natural resources”;

b) “the technical recycling and fabrication of products designed so, that their production, use and dismantling do not augment the quantities or the dangerous characteristics of waste and pollution or the influence of these products is maximally reduced”. p.14 [4]

2. The examination of the selected technical solutions, representing the prior level of technology concerning light panels and connections between them shows that the transformation of ordinary into ecologically-safe panels has some special characteristics.

- The transformation of ordinary light panels and their connections into ecologically-safe panels is made in different ways according to the type of the connection between the panels:

- with flat and П-shaped bushes, connected with the surface layers;

- with “groove and tooth”;

- with “two grooves and two teeth”;

- with “four grooves and four teeth”;

- with “straight connection” and “groove and tooth”;
- with “straight connection” and Γ-shaped cotters;

- with “inclined connection”;

- with closing profiles connected to the panels with screws;

- with closing profiles, fixed to metal holders, connected to the panels with bolts and screws;

- front connection with short bushes;

- front connection with a “locking” mechanism;

- front connection with closing profiles, connected with the help of plastic bushes, inserted into openings in the surface insulation of the panel;

- front connection, hermetic, with two feathers;

- with grooves and feathers, fixed to double T-profiles;

- with rabbets;

- with double ‘grooves and teeth”, combined with a double bended rabbet;

- connections between panels with oval “grooves and teeth”; 

-connections between panels and stands with an intermediate bush, made of K-profile with two oval teeth, corresponding to the respective oval grooves in the stand;

-connections between panels and stands in combination with an Y-profile and a Π-shaped bush with inclined walls, ending with oval teeth, corresponding to the respective oval grooves in the stand;

- with a pipe and special parts, set against the pipe;

- with edge joints with closing profiles and insulation, wrapped with aluminium foil;
- with two-channel profiles for connection in two or three plains;

- with three-channel profiles for connection in two or three plains.

As a result of the revealed capabilities of the separated collection of building waste, it is possible to made ecologically-safe structures of sectional walls.

On the basis of the reviewed solutions are suggested different groups according to the way of fabrication of the ecologically-safe structures. The possibilities for separate collection of the structure layers, allowing their recycling and production of new products according to the type of material, are of great importance.

It is highly recommended to apply the following ways of mounting and dismounting of the panels, which allow the separate collection of the structure layers and the parts of the connections:

Type A. Layer mounting of structure layers, fixed to different types of bushes. The connection is with a formed space.

Type A1. Layer mounting of structure layers, fixed to different types of bushes. The connections are “hollow”.

Type A2. Layer mounting of structure layers, fixed to double-wrapped metal plates. The connections are “hollow”.

Type A3. Layer mounting of structure layers, fixed to a feather.

Type A4. Layer mounting of structure layers, fixed with the help of screws.

Type A5. Layer mounting of structure layers, fixed to a double T-profile with the help of screws.

Type (B-B5). Layer mounting of structure panel layers to special plates with different configuration. The insulation is made of solid plates. The connection is “hollow”.
Type (B6-B12). Layer mounting of structure panel layers to special plates with different configuration. The insulation is made of solid plates.

Type (B13-B18). Layer mounting of structure panel layers to special plates with different configuration. The insulation is made of solid plates.

Type B19. Layer mounting of structure panel layers to special plates with different configuration. The panel is fixed to two- and three- channel profiles. The insulation is made of solid plates.

Type C. Layer mounting of structure panel layers to edge profiles, situated in the space of the connection. The insulation is made of solid plates.

Type D. The surface layers and the gills are a whole element. The insulation is made of solid plates, inserted between the gills.

Type E. A panel with a self-sticking layer between the structure layers. The insulation is made of solid plates.

Type F. The structure layers are fixed to the plates of the panel. The panel is hanged to the carrying construction with screws. The insulation is made of solid plates.

Type G. Layer mounting of structure layers with the help of rabbets. There are two II-shaped profiles with rabbets over one of the panel’s diagonals. The insulation is in bulk or it is made of two identical solid plates.

Type H. Layer mounting for fixation of the structure layers to the plates of the panel. The connection is frontal with a “locking” mechanism.

Type I. The structure layers are connected with the help of special holders with screws. The insulation is made of solid plates.
Type J. Gill-panels and layer mounting of structure layers, fixed to special plates. the panels with the additional elements are fixed to stands.

Type K. Layer mounting. The structure panel layers are fixed to special plates and the plates are

set against a pipe.

Type L. Layer mounting. The structural layers are fixed to the plates with screws. There are bushes, connecting frontally two adjacent panels.

2. CONCLUSION
1. As a result of the reviewed technical solutions from the prior technical level in the sphere of light panels were formed 12 characteristic groups of the basic types of ecologically-safe structures of light panels and their connections.

2. They are formed as a result of the condition the structure layers of the wall, the panels and the connections to be collected separately.

3. These 12 groups of ecologically-safe structures could be reduced to the following basic modifications:

-“layer mounting” of the structure layers of the wall to special bushes, double-wrapped plates, feathers and others, which are connected with the floor and the ceiling with screws;

-“layer mounting” of the structure layers of the panel, fixed to plates;

- use of self-sticking layers, situated between the surface layers and the insulation;

- fixation of the structure layers to the plates of the panel, hanged to the carrying construction with bolts;
- fixation of the structure layers to the plates of the panel with the help of front connection and a “locking” mechanism;

- fixation of the structure layers to the plate of the panel firstly with screws and secondly with bushes, which are connected in front position to the panel;

-the structure layers are connected with the help of wrapped profile holders the help of screws.

4. The basic types of ecologically-safe structures are systematized with the help their application, according to the suitable configuration, the materials and the possibilities to mount and dismount the panel structures.

5. Most suitable is the mounting with the help of front panel connections, which allow the replacement of every single panel from the wall if necessary.

6. The most suitable materials for insulation are those in bulk condition, plates of mineral wool or plates of cork. The implementation of polyurethane demands the use of a sel-sticking layer form the internal side of the surface layers.

7. The mounting and the dismounting of the wall panels and their structure layers is accomplished with the help of screws, bolts, wrapped profile holders and others.


3. REFERENCES


GENERAL AND SPECIAL MEASURES FOR PROTECTION OF THE POPULATION IN EXTREME SITUATIONS

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ABSTRACT

In this paper are reviewed general and special measures for protection of the population in extreme situations (based on the experience of the Chernobyl wreck). Here are reviewed specific moments, that must not repeat in case of such industrial wrecks - source of radiation. Also, here are reviewed the medical standards for ecological safety of Ukraine.

Keywords: general and special measures, protection, population, extreme situations, Chernobyl wreck.

1. INTRODUCTION

Extreme situations are unexpected. They appear suddenly and cannot be prognosticated, but the society should take measures to prevent them.

The author is a participant in the medical attendance of the sufferers of the Chernobyl wreck.

In the paper are proposed some basic measures to protect the population and diminish the harmful influence of radiation:

• Preliminary explanatory preparation of the population assigning to the necessary behavior in extreme situations to avoid panic and give first medical aid;

• Building of wide-surface buildings (without bearing) to be used for medical purposes in the areas near big industrial projects. As such objects could be the fruit storehouses and regrigeratory warehouses, whose chambers are suitable for fast reconstruction for medical purposes – as operating rooms and operating blocks in
case of averages. [1,2] These buildings are extremely suitable, because they have hermetic walls and ceilings. It is of great importance to ensure their better protection against radiation – lead facing, facing, made of other high density materials, etc.

- Design and building of sectional multi-wall sanitary filters, ensuring disinfection against radiation of the sufferers before the medical help. It is advisable to develop a catalogue with different filters according to the capacity of the operating room and the operating block. [3, 4]

- Design and building of structural layers of the surrounding constructions, protecting against radiation the medical personnel and the sufferers. The insertion of operating rooms into the spaces of the refrigeratory chambers requires functional connection with the adjacent refrigeratory chambers, which a part of the operating block and the hospital. For this purpose at the stage of design, the apertures for the refrigeratory doors, which are closed at the time when the chambers are used according to their basic function, must be provided. The floors of the chambers must be designed as double constructions with the aim to insert between the two floor layers medical and other installations. The height of these floors could be equal to the height of the concrete platforms. The openings of the installations are closed and are situated near to the walls of the refrigeratory chambers. In this case the walls of the inserted operating rooms are situated very close to the concrete platforms.

- Creation of a developed medical infrastructure, situated in double floors and walls, that is necessary to maintain the operating rooms, the operating blocks and the hospital.

- Creation of a national medical map, including the situation of big industrial objects, as well as the situation of the wide-surface buildings, which must be activated in case of extreme situation.
• Duplication of the roads of access from the place of the average to the wide-surface buildings where first medical aid could be given.

2. SPECIFIC MOMENTS THAT MUST NOT REPEAT IN CASE OF SUCH INDUSTRIAL WRECKS - SOURCE OF RADIATION

1. The lack of a map of the situation of “wide-surface” buildings (buildings without internal bearing), allowing secondary use for medical purposes – operating rooms and operating blocks - in extreme situations.

2. The lack of special medical module blocks, hermetic, with protection against radiation, suitable to be used in extreme situations, intended for the equipment of “wide-surface” buildings.

3. The lack of special sanitary modules intended for the disinfection of the sufferers.

4. The lack of protection against radiation for the medical personnel, exposed to secondary radiation from the sufferers.

5. The lack of suitable transportation for the people of the exposed areas.

6. The lack of specially trained medical teams, ready to work in polluted radiation area.

3. MEDICAL STANDARDS FOR ECOLOGICAL SAFETY OF UKRAINE [5,6,7]

The development of medical standards, concerning ecological safety are very close to the theme of the dissertation work of the author – “Adaptation of the spaces of the refrigeratory chambers of fruit storehouses and refrigeratory warehouses for secondary use for medical purposes (operating rooms and operating blocks) in extreme situations”.

The standards, concerning the following are highly important:
1. Ecological and hygienic safety.

2. Ecological problems of the Chernobyl wreck,

3. Hygienic problems of the regional planning on the territory of Ukraine, influencing the building and exploitation of public buildings.

These standards concern the requirements for:

- the situation of operating rooms and operating blocks in the spaces of refrigeratory chambers on the territory of the country in case of extreme situations;

- the ecological and hygienic safety of the medical personnel and the sufferers of a wreck;

- the safe-keeping and recycling of polluted medical waste in extreme situations;

- the regional planning of medical buildings for giving first medical aid and the situation of the operating rooms and operating blocks on the territory of the country in case of extreme situations.

4. MEDICAL STANDARDS FOR ECOLOGICAL SAFETY IN EXTREME SITUATIONS

It is necessary find a solution for:

1. The ensuring of the ecological and hygienic safety of medical personnel and sufferers in case of a wreck.

2. The safe-keeping and recycling of polluted medical waste in extreme situations.

Now are being developed the state sanitary standards for medical waste regulation by authors from the Institute of hygiene and medical ecology of the National Academy of Medical Sciences. [8]

The above-mentioned medical standards refer to all types of medical waste.
- rules for the collection of medical waste,
- rules for the direction of medical waste,
- rules for the recycling of medical waste,
- rules for the safe-keeping of medical waste,
- rules for the transportation of medical waste.

3. The questions of regional planning the regional planning of medical buildings for giving first medical aid and the situation of the operating rooms and operating blocks on the territory of the country in case of extreme situations.

- There is no special methodic for determination of situation of medical stations for giving first medical aid in case of extreme situation.

- The better concentration of these stations is highly advisable if they concern large industrial territories, complexes and important objects (nuclear stations, etc.).

- According to the level of the industrial wreck could be included medical objects, which are not situated in the mentioned area.

- There must be special hermetic medical modules for emergency operations.

- On the map of the region must be put on record the situation of the hermetic premises, which could be used in case of bacteriological pollution.

- In case of pollution with radiation there must be special premises, protected against radiation, which could be used for medical aims.

5. CONCLUSION

In extreme situations it is of great importance:
-To enhance medical surfaces except the specialized medical buildings. The additional medical buildings could be used in case of destruction or pollution with radiation of the main buildings.

-In these cases it is advisable to use wide-surface premises, where the walls and ceilings are hermetic and gas-impermeable.

-The concentration of medical buildings to be secondary used for medical purposes is crucial. These buildings must be situated near big industrial areas, national infrastructure – airports, railway stations, sport halls, etc.

-The fast arrival to the place where the sufferers could be disinfected and could receive first aid.

6. REFERENCES

In Bulgarian:

[1] Aleksandrova L. “Adaptation of the spaces of the refrigeratory chambers of fruit storehouses and refrigeratory warehouses for secondary use for medical purposes (operating rooms and operating blocks) in extreme situations”. 2004

In Russian:


In Ukrainian:

Group A


Group B


Group C

Standards for medical waste regulation. State sanitary standards. 2.7.00-06.

Note: these standards should be approved by the State sanitary doctor.
ABSTRACT: A combined Life Cycle Assessment (LCA) / Life Cycle Costing (LCC) Study for a 40-storey standard HKHA (Hong Kong Housing Authority) public rental housing block - New Harmony Block (Option 2) (NHB) was completed in 2004. The study was conducted by a consortium comprising of the University of Hong Kong, Department of Architecture, Davis Langdon & Seah Management Ltd., and the Business Environment Council. The objective of the study quantitatively measured following ten environmental impacts generated and life cycle costs incurred from the 155 functional units of the NHB block in the whole building life-cycle perspective, including (1) initial stage including raw material extraction, building material manufacturing and transportation stage; (2) construction; (3) building operation; (4) repair and maintenance, and (5) disposal stage: Energy (MJ); Resource depletion (kg Sb eq.); Water consumption (m3); Waste (kg); Climate change (kg CO2 eq.); Acid rain(kg SO2 eq.); Photochemical smog (kg C2 H4 eq.); Ozone depletion (kg CFC-11 eq.); Toxicity to humans (kg toxic eq.); Toxicity to ecosystems (kg toxic eq.)

The LCA and LCC measurement has been extended to office, hotel, retail, carpark and external work in Pearl River Delta. This paper will briefly discuss the findings from 2004 to 2007.

Keywords: holistic approach, Life Cycle Assessment, Life Cycle Costing, building materials

1. INTRODUCTION

The University of Hong Kong (the greenroom team, Department of Architecture), Davis Langdon & Seah Management Ltd (DLSM), and Business Environmental Council (BEC) completed a combined Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) decision-support tool called Tool for Assessment of Sustainable Construction (TASC). The tool is capable of measuring the following ten environmental impacts and whole-life financial implication of buildings from the whole life cycle perspective, including (1) raw-material extraction, (2) building
material manufacturing, (3) transportation, (4) construction, (5) building operation, (6) repair and maintenance, and (7) disposal stages (Wong et al., 2005):

- Energy (MJ)
- Resource depletion (kg)
- Water consumption (m3)
- Waste (kg)
- Climate change (kg CO2 eq.)
- Acid rain (kg SO2 eq.)
- Photochemical smog (kg C2 H4 eq.)
- Ozone depletion (kg CFC-11 eq.)
- Toxicity to humans (kg toxic eq.)
- Toxicity to ecosystems (kg toxic eq.)
- Capital cost (HK$)
- Recurring cost (HK$) (operational, repair and maintenance cost)
- Disposal cost (HK$)

The tool characterizes, normalizes, and weights environmental impacts of buildings in accordance with ISO 14040-43 standard. The tool can measure a building in terms of:

- All the ten environmental impacts in an aggregated indicator, a notional HK environ-point (HK E-point) - one HK E-point is equivalent to the annual environmental impacts produced by one HK citizen per year (Amato 2006). If a building has a life cycle impact of 5000 HK E-point, it means the life cycle of the building is equal to 5000 no. of HK people’s annual impacts; or

- One of the ten environmental impacts, for example in global warming potency compared with 1 kg of CO2 potency (i.e. kg CO2 equivalent).

This paper will summarize the LCA result of the building archetypes assessed by the tool (see Table 1). The benefit and drawback of the following kinds of indicators in
the comparative life cycle assessment of the environmental sustainability of a building will be discussed at the end of the paper:

(1) The total HK E-points of the building, i.e. equal to how many HK citizen’s annual environmental impacts; (2) HK E-point per construction floor area (CFA); and (3) HK E-point per inhabitant of a building

**Table 1:** The storey height, usage and structure of the assessed building archetypes

<table>
<thead>
<tr>
<th>Assessed buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-storey concrete-framed New Harmony Block (option 2) for public-rental usage in Hong Kong</td>
</tr>
<tr>
<td>40-storey concrete-framed office tower in Pearl River Delta</td>
</tr>
<tr>
<td>28-storey concrete-framed hotel tower in Pearl River Delta</td>
</tr>
<tr>
<td>4-storey concrete-framed shopping arcade in Pearl River Delta</td>
</tr>
<tr>
<td>4-storey underground carpark in Pearl River Delta</td>
</tr>
</tbody>
</table>

2. **THE LCA DATABASE OF TASC SOFTWARE**

To measure the environmental impacts of a building, a unique database was created that measured the detailed material-impacts of 200 materials that can be specified from local or Pearl River Delta’s developers. Previously, such database was not available in Southeast Asia. The resultant database is thus relevant for the Southern China/ HK production region.

3. **DATA INPUTS OF TASC SOFTWARE**

TASC groups a building into building components. TASC allows any combination of building components preferred by user for assessment of their possible alternatives.

TASC mainly built on the following three types of data inputs:
The quantities of building materials used in the building components at initial stage and repair and maintenance stage. The data source could be the bills of quantity or the cost plan.

The repair and maintenance frequency of a building component. The data source could be based on the repair and maintenance data in similar project.

Real bill data or best-estimated data for operational water, electricity and gas consumption. The data source could be the real electricity, gas and water bill of similar project or best-estimated consumption figure based on the engineering assumption on the light power density, the equipment power density, the details of AC plants, the lift and other building services equipments.

TASC can measure the ten environmental impacts and economic impacts of a building based on the data inputs and highlights the environmental and economic ‘hotspot’ elements and functional units of a building from the whole life-cycle point of view.

4. RESULTS OF THE LCA STUDY
There are three possible way to indicate the environmental performance of building archetypes

(1) The total HK E-points of the building;

(2) HK E-point per construction floor area (CFA); and (3) HK E-point per inhabitant of a building

Fig. 1 shows total whole life HK E-points of the assessed building archetypes. Fig. 2 shows the whole life HK E-points/ CFA. Fig. 3 shows the whole life HK E-points per inhabitants of the assessed building archetypes.
The total HK E-pt indicator shows that shopping mall with its huge amount of operational energy consumption has nearly twice more impacts than office archetypes. New Harmony Block (Option 2) has the least environmental impact generated from the whole life cycle.

Figure 1: Total HK E-pt of the assessed building archetypes

The HK E-pt/ CFA indicator shows that the shopping mall has the amount of impacts slightly higher than office and hotel archetypes unlike the large gap in the total HK E-point indicator. It shows that each CFA of office, hotel and shopping mall probably has similar consumption of material and energy in the whole life-cycle. On the other hand, the New Harmony Block (Option 2) and underground...
The carpark has the least HK E-point/CFA. The consumption of material and energy in the whole life-cycle of NHB and carpark might be at the similar low level.

Unlike the total HK E-point and HK E-point/CFA, the HK E-pt/inhabitant or user shows that the shopping mall has less impact than office and hotel archetypes. A hotel archetype has the highest impacts under this indicator. NHB and carpark still have the least HK E-point/user or inhabitant. However, the gap between shopping mall, NHB and carpark is small in compared with the large gap in the total HK E-point and HK E-point/CFA indicator. It might be due to the presence of the large number of users in shopping mall archetypes.

![Figure 3](image)

**Figure 3**: HK-pt/inhabitant or user of the assessed building archetypes

### 5. SUSTAINABILITY PERFORMANCE INDICATORS FOR THE LCA STUDY

To analyse sustainability of the building archetypes, the total HK E-pt and HK E-pt/CFA indicator cannot indicate the sustainability performance of archetypes sufficiently. The building archetypes can have higher number of appliances and lighting because of higher number of building occupancy, for example, the shopping archetype. The total HK E-pt and HK E-pt/CFA indicator cannot reflect the social attraction and economic benefits of the building.
The best indicator is HK E-pt/ inhabitant or user. The indicator can reflect the benefit of increase amenities such as appliance package and increase building occupancy. For example, the shopping mall has great performance on building occupancy although it generated higher impacts/ CFA than office and hotel archetype. But the overall sustainability performance in terms of impact/user is good.

6. CONCLUSION

In all assessed building archetypes, New Harmony Block (option 2) has the best performance in the total HK E-pt, HK E-pt/CFA and HK E-pt/ user or inhabitant indicator. On the other hand, hotel archetype has the poorest performance in HK E-pt/ user indicator. More improvement can be proposed for such archetype, such as the increase of the economic benefits and increased amenities to attract more building occupancy.

To indicate sustainability performance of a project, the indicator in form of HK E-pt is not sufficient in indicating the marketability of the project in matching the needs of the consumers and the increased in building occupancy. Therefore the paper suggests further investigation on appropriate indicator in assessing the sustainability of building archetypes that improves social and economic as well as environmental performance.

7. ACKNOWLEDGEMENT

The authors gratefully acknowledge the support provided by Hong Kong Housing Authority (HKHA) and Davis Langdon & Seah Ltd (DLS) in the above LCA and LCC research projects.

8. REFERENCES


WATER CONSUMPTION IN OFFICE BUILDINGS IN AUSTRALIA

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ABSTRACT: Water consumption in urban environments is a critical issue for a number of countries worldwide. In Australia, a 5 year drought has left many city urban water supplies dangerously low and led to significant water restrictions. Hong Kong similarly has limitations on its water infrastructure that affect the office sector. However, little is known about actual water consumption in the commercial sector.

This paper reports results of three separate studies into water consumption:

Office building water consumption has been benchmarked for locations throughout Australia. Benchmarks have been developed on the basis of water consumption intensity measured in water consumed per m² of net lettable area. These have been implemented as part of a voluntary national water rating system for office buildings which has achieved a significant impact in its first year of operation.

Water consumption for cooling towers has been demonstrated to be a major driver of water consumption in Australian office buildings. The average water consumption per unit area of office buildings more than doubles from the cool temperature to the tropical areas of the country.

Water use in office buildings has been studied in more detail through the collation of water audit data for a number of buildings in Sydney. The results indicate significant potential for improvement in water consumption, with leakage – such as through faulty toilet cisterns, urinals or faulty cooling towers – being responsible for a significant proportion of average water consumption, in spite of five years of increasing pressure to conserve water.

The results indicate that there continues to be significant potential to reduce water consumption in office buildings in Australia. The results from Australia have application in many other countries with similar local or national pressure on water supply infrastructure, including Hong Kong and many locations in China.

Keywords: Water consumption, benchmarking, office buildings

1. INTRODUCTION

Water consumption has become a defining environmental issue for the first decade of the 21st century in Australia with drought conditions causing near-universal restrictions in temperate areas and placing pressure upon infrastructure [1-3].

The built environment, although dwarfed by agricultural water consumption (less than 15% of national consumption versus 65% for agriculture [4]), represents a
major consumer of the potable water that is managed through man-made infrastructure such as dams. As a result, there is significant pressure to reduce water consumption in the built environment to decrease the stress on the potable water infrastructure.

For commercial buildings, there is little knowledge as to what constitutes good or bad performance with respect to water consumption. This lack of knowledge is a barrier that inhibits the ability of the market to respond to poor performance with appropriate actions.

In this paper, the findings of three studies by the authors are collated to provide an overview of water consumption patterns and end-use in Australian buildings. The results are then extrapolated to the international environment.

2. BENCHMARKING ANALYSIS

2.1. Data Collection
Data was gathered via survey. A standard survey form was sent to a range of government and private sector property organisations. The survey form covered key demographic information about the building (size, location) water consumption and also any water conservation measures that have been undertaken. A total of 132 responses of adequate quality were received. This can be compared with the national population of larger office buildings which is of the order of 2000.

2.2. Sample Demographics
The sample buildings were spread across the entirety of temperate Australia. No data was received from tropical regions; a separate tropical region comparison is reported in Section 2.6 of this paper. The spread of data across the states is shown in Table 1 below. Within each state, the samples were heavily biased to the state capital, reflecting the nature of the office population in Australia.

Table 1: Distribution of sample buildings between states
The buildings within the sample ranged from 389 m² to 79,000 m², with a mean building size of 15,700 m² and 10th and 90th percentiles of 2000 m² and 29,000 m² respectively.

**2.3. Water Consumption Data**

The water consumption data showed a strong correlation against the net lettable area of the buildings, as would be expected ($r^2=0.68$ kl water versus m²), and also against climate. For the purposes of this analysis, climate data was represented in terms of cooling degree days (CDD) base 15°C wet bulb. The use of wetbulb rather than drybulb degree days is necessary to gain a good correlation between cooling loads and climate data across the diverse range of climates within Australia. The correlation between cooling degree days and kl per m² had an $r^2$ of 0.25. The effect of this can be seen when looking at individual capital city averages, as shown in Table 2.

Table 2: Average water consumption $w$ by city and climate as represented by cooling degree days (CDD) base 15°C wet bulb.
The indication from the data therefore is that there is a strong relationship between climate and water use. This logically can be accounted for by the water consumption of cooling towers. In this context it is noted that the use of irrigation in the sample buildings was very limited owing to the central city location of the vast majority of the sample. Most buildings within the sample used cooling towers for heat rejection (109 samples). By contrast, the average water consumption of buildings without cooling towers showed no relationship with climate ($r^2=0.002$).

Statistical assessment of the significance of the difference between water-cooled and air-cooled buildings was inconclusive at 95% certainty. This appeared to be mainly due to the relatively small number of air-cooled buildings in the sample and the high variance in the data generally. Inspection of the data suggests however that a larger sample might reveal statistical significance. Other potentially causal factors showed little or no difference in sub-sample medians and certainly no statistical significance.

The data are plotted against climate in Figure 1. In the figure, a number of features can be seen. Firstly, the general increasing trend in warmer climates is evident. Furthermore, there is good evidence that the variance of the consumption increases as the median of the consumption increases. This is an important feature of the

<table>
<thead>
<tr>
<th>City</th>
<th>CDD w (kl/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canberra</td>
<td>80 0.72</td>
</tr>
<tr>
<td>Melbourne</td>
<td>100 0.70</td>
</tr>
<tr>
<td>Adelaide</td>
<td>132 0.70</td>
</tr>
<tr>
<td>Perth</td>
<td>340 0.61</td>
</tr>
<tr>
<td>Sydney</td>
<td>541 1.13</td>
</tr>
<tr>
<td>Brisbane</td>
<td>1043 1.56</td>
</tr>
</tbody>
</table>
data in terms of assigning a “value” to position relative to the median; in essence, the range of realistic consumption is different from one climate region to another. Nonetheless, it is also clear from the data that the potential range of consumption within in any one climate zone is extremely large, typically covering a factor of 5-7 between the lowest and highest consumption.

2.4. Comparison with International Data

Water consumption has received little focus internationally, and this is reflected in the dearth of available international data. A simple web-search reveals that the vast majority of available references are Australian, a perhaps unsurprising reflection of Australia’s position as the driest inhabited continent. The most prominent non-Australian work has been published by CIRIA in the UK [5]. This identifies benchmarks of 0.4 kl/m² for best practice, 0.6 kl/m² for typical practice and 0.8 kl/m² for excessive consumption for offices in the UK. Given the cool nature of the UK climate, these figures can be compared with the data in Figure 1 by looking at the extrapolated intercept of the data trend at the nil cooling degree days point. This figure is 0.65 kl/m², almost exactly corresponding to the midpoint of the CIRIA benchmarks.

This alignment of the data is indicative not only of an alignment of the data but also of a further demonstration of the importance of climate in determining water consumption. If one were to merely compare the median of the Australian data sample (0.91kl/m²) against the CIRIA benchmarks, the indication would be of lesser efficiency. Inspection of Figure 1 indicates that the difference is climate related rather than efficiency related.

This climate relationship is particularly important when considering water consumption figures for tropical and sub-tropical regions, as the climate is more extreme and thus one would expect a larger difference to be present.
2.5. Area or Occupant Normalisation?

A key issue in the derivation of any benchmark is the choice of normalisation. CIRIA provides benchmarks on the basis of both water use per occupant and per unit area, and these two normalisation factors are certainly the logical choices.

In Australia, and indeed in other warm climates, there is a relatively strong reason to choose area as the normalisation factor. This is because of the impact of cooling tower water use which is driven by floor area rather than occupancy. As discussed in the balance of this paper, the water consumption associated with cooling towers is a significant end-use, and this is increasingly the case in warmer climates. Furthermore, the correlation between floor area and occupant number is very strong, making differentiation of these two factors difficult. Where analyses of the impact of occupant density as a secondary variable have been undertaken on the available data, no statistically significant relationship has been able to be derived. This indicates that statistically, at least, floor area is an adequate descriptor of water performance.

Figure 1: Rating bands superimposed on water consumption data as a function of climate.
2.6. Rating Scheme Derivation

The original motivation for the study was to develop a performance based benchmark for water consumption in Australian office buildings. This follows from the success of the Australian Building Greenhouse Rating Scheme (ABGR) in Australia, which has motivated large market changes with respect to operational energy consumption in the office sector [6]. This scheme has been incorporated into the National Australian Built Environment Rating Systems (NABERS) to cover broader environmental issues, of which the current study forms the water component [7]. ABGR and NABERS are administered nationally by the New South Wales Government Department of Environment and Climate Change.

The benchmarking philosophy follows that of ABGR, i.e.

- The benchmark is a five star scale with 1 star = poor, 5 star = excellent and 2.5 star = market median
- The benchmark should aim to cover around 80-90% of the market, with the excluded buildings generally being extremely inefficient;
- The star bands are linear, i.e. the gap between 1 star and 2 stars is the same as 4 star and 5 stars;
- The rating should reflect efficiency rather than absolute consumption and thus requires normalisation for unavoidable issues such as climate impacts.

The application of this philosophy is complicated by the nature of the building population with respect to water consumption; the presence of two strongly differentiated groups, being water cooled and air-cooled, raises the question whether a single scale can fairly capture the entire population. This is further complicated by the fact that an air-cooled building will use fairly much the same amount of water irrespective of climate, while water cooled buildings vary
significantly. The approach that has been taken in response to these challenges is threefold:

1. Only one rating scale is used

2. The rating is set such that a high rating is a challenge for any building, including air-cooled.

3. The 5 star limit has been set as climate independent while the 2.5 star rating has been set to follow the population median.

The results of this approach can be seen in Figure 1. In the figure, it can be seen that the rating bands fit the data well, with the expanding rating scale encompassing the majority of the data throughout all climate zones. The 5 star limit, which is climate independent, is set at 0.35 kl/m², which is partly informed by the data but is also significantly informed by the CIRIA best practice benchmark. The use of a slightly more stringent figure is based on the general philosophy that 5 stars should be a “stretch” target, challenging the market to go beyond best practice.

2.7. Extension to Tropical Climates

One of the weaknesses of the original data set was the lack of data from tropical climates. Australia has a small but significant base of commercial buildings in tropical locations such as northern Queensland and Darwin, where the cooling degree days on the 15°C wet bulb scale range from 2000-3000, significantly differentiating these areas from the temperate and subtropical areas of the country.

Approximately one year after the rating scale was formulated, an additional data collection exercise was undertaken in Darwin, which has the hottest urban climate in Australia at 3011 cooling degree days base 15°C wet bulb. Data were gathered for 11 buildings, comprising 5 buildings with cooling towers, 3 without cooling towers and 3 for which this was not specified by the respondent. This is of course
a fairly small sample but has to be viewed in the context that Darwin has a population of only 105,000 people.

When rated on the NABERS rating scale, the Darwin sample recorded the following results:

- Sample mean: 3.41 (3.5 star rating)
- Sample median 3.18 (3.5 star rating)
- Sample range: 2.24 to 5.80 (2.5-5 star rating)
- Air-cooled average rating: 4.17 (4.5 star rating)
- Water cooled average rating: 2.9 (3 stars rating)

To put this in context, the 95% confidence interval for the Darwin sample is ±0.69 stars, which places the ideal midpoint of 2.25 outside the confidence interval of the sample mean. However, the water-cooled mean (which is essentially what is extrapolated from the NABERS rating at 2.5 stars), is well within the error range. The higher proportion of air cooled buildings in Darwin is therefore potentially a contributing factor in the high sample median rating. Overall, it is considered that the results indicate that the extrapolation is broadly valid but that further data would be required to absolutely confirm this. Furthermore, the potential impact of an expected increased ratio of air-cooled buildings in tropical climates needs further consideration both statistically and in the context of the intent of the rating.

3. END-USE ANALYSIS

In this section of the paper, results are presented of a separate study, conducted on behalf of Sydney Water (the water supplier for metropolitan Sydney) into water end-uses in Sydney. The key foci of this study were:

- The assessment of a locally relevant benchmarks for good practice;
• The identification of key end-uses

• The identification of the economic upgrade potential.

In order to assess these issues, a sample of 31 third-party water audits was selected from work undertaken as part of the Sydney Water: "Every Drop Counts" campaign. The sample cannot be seen to be random as the participating organisations were voluntarily engaged on the program (and thus would be expected to be more engaged with water conservation issues) while the buildings themselves were selected for audit on the basis of their relatively high water consumption. All buildings were sourced within the greater Sydney area.

In each audit, a variety of methods were used to determine water consumption in subcategories, including a significant use of water submetering. The general characteristics of the audit sample are listed in Table 3

<table>
<thead>
<tr>
<th>Item</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Lettable Area (office)</td>
<td>22,613 m²</td>
</tr>
<tr>
<td>Water Use</td>
<td>1.509 kl/m²</td>
</tr>
<tr>
<td>% consumption – cooling towers</td>
<td>27%</td>
</tr>
<tr>
<td>% consumption – amenities</td>
<td>35%</td>
</tr>
<tr>
<td>% consumption – irrigation</td>
<td>0%</td>
</tr>
<tr>
<td>% consumption – retail</td>
<td>4%</td>
</tr>
<tr>
<td>% consumption – baseflow/leakage</td>
<td>31%</td>
</tr>
<tr>
<td>% consumption – other</td>
<td>2%</td>
</tr>
</tbody>
</table>

The median water consumption end-use breakdown is also illustrated in Figures 2 and 3.
A number of features are notable in Figures 2 and 3. In particular:

All buildings in this sample had cooling towers. This is fairly typical for larger buildings in Sydney and indeed much of Australia.

Amenities water consumption averaged 0.5 kl/m². The wide variance in this figure reflects the potential for poor performance of amenities water consumption due to poorly operating urinals, high flush volume toilets and, to some extent, leakage flows that were not separated into the leakage category.
For individual buildings, retail water consumption may be a significant end use. It was found that submetering arrangements for retail generally did not permit exclusion of retail water consumption from gross water consumption. This has implications for the ability of some buildings to be assessed against the NABERS benchmarks.

Leakage is, on average, the second largest end “use” of water in the sample buildings. This is actually a conservative estimate as in some of the audits, leakage water use was allocated to the area of the building causing the leakage. This is both a major indictment and a major opportunity for water conservation practice in this sector.

The comparison of the median water consumption against that in the NABERS sample indicates some routine bias in the audit sample – indeed a t-test indicates that the difference in means is valid to a 99.5% confidence level, even once the NABERS sample has been adjusted to closely match the demographics (location and size) of the audit sample. However, given that the audits were specifically selected because of high water consumption, the presence of a routine bias is not surprising. Indeed, given the high level of leaks reported, it would appear reasonable to assert that the majority of the difference can be allocated to leaks. The data sets align once the average leakage level is reduced to 33% of its original figure. This gives a notional average end-use breakdown that estimates average population end use as shown in Figure 4.
Figure 4: Water end use consumption data adjusted to match the projected population average.

The summation of the flows that are counted within the CIRIA benchmarks (basically amenities and a proportionate share of the leakage flows) is approximately 0.55 kl/m². This is remarkably close to the CIRIA average practice benchmark, indicating good alignment between the data sets across the same sets of end-uses.

4. WATER SAVING POTENTIAL

There is a wide range of technologies and approaches that can be used to reduce water consumption within the office sector. Major items are briefly, but not comprehensively, summarised as follows:

Cooling towers: Reduction of energy consumption, increased cycles of concentration, correction of faulty treatment practices.

Amenities: reduced flow taps, low volume flush toilets, waterless urinals, improved urinal flush controls.

Leakage: Correction of faults causing leakage flows, particularly in mechanisms for toilet flush, urinal flush and cooling tower filling, and also leaking taps. Tracing and correction of other leaks including pipe breakages.

Irrigation: Use of drought resistant plantings, reduction of irrigated area, use of dripper irrigation.

Grey water. Capture and use of rainwater in cooling towers and toilet/urinal flush. Processing of black water (sewage) for use in toilet/urinal flush.

Many of these mechanisms have extensive application in most buildings, but the degree to which any technology is economic varies. In Australia, the cost of water supply is typically only $A1-$A2 ($US0.85-$US1.70) per kl. Thus the water
consumption for typical office building in Sydney would equate to only $1.50-$2.50/m², making significant capital expenditure difficult to justify.

As part of the Sydney Water analysis, the projected savings and costs identified within the individual water audits were assessed in order to allow establishment of a number of benchmarks, i.e.

Median Performance, representing the current median performance within the market

Good practice, representing median performance but with no leaks

Economic best practice, representing implementation of measures with paybacks of up to 2 years

Market leading practice, representing the implementation of all identified measures irrespective of economics

These benchmarks, as applied to the Sydney region, are summarised in Table 4.

**Table 4:** Benchmarks for water cooled buildings in Sydney.

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Value (kl/m²)</th>
<th>NABERS rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>1.14</td>
<td>2.5</td>
</tr>
<tr>
<td>Good practice</td>
<td>1.01</td>
<td>3.0</td>
</tr>
<tr>
<td>Economic best practice</td>
<td>0.84</td>
<td>3.5</td>
</tr>
<tr>
<td>Market leading practice</td>
<td>0.77</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Although no air-cooled buildings were assessed, it is also possible to project similar benchmarks for air-cooled buildings based on the exclusion of cooling towers.
The comparison of the benchmarks with the NABERS rating figures indicates a good level of alignment between the two separate studies both at the median and at the levels of best practice.

5. IMPACTS FOR HONG KONG AND TROPICAL ASIA

The results of this study have focussed on temperate Australia. However, Australia is not alone in suffering water infrastructure issues. Hong Kong, for instance, has areas in which cooling towers are prohibited due to limitations of the infrastructure. Taipei has significant issues with overall water supply. Similar issues should be expected to extrapolate across other high density population centres.

Average water consumption in water cooled buildings in tropical climates is expected to be in the region of 1.6-2.1 kl/m², of which approximately 1.0-2.5 would be expected to be associated with cooling tower water consumption. Furthermore, a high degree of spread should be expected reflecting the impact of both leakage and relative energy efficiency (causing differences in heat rejection and thus evaporative loss), as noted for warmer climates in Figure 1.

From a policy perspective this indicates that the key foci of water savings initiatives should be on the minimisation of leakage and, for water cooled buildings, the reduction of energy consumption. The latter of these aligns well with general energy efficiency policy requirements.

A further emphasis that can be drawn from the Australian studies is that focus on water saving devices in amenities, while important in the medium to long term, should be seen as a second tier of activity after the reduction of leakage.

6. CONCLUSIONS

The results of three separate studies into water consumption in office buildings in Australia have been reported. It has been identified that average water
consumption is strongly climate dependent due to the impact of cooling towers. The derivation of the National Australian Built Environment Rating System (NABERS) rating thresholds has been presented. Separately conducted data collection in tropical Australia has been compared against the temperate-based rating bands and sufficient alignment has been found to justify extrapolation of the scheme into tropical areas.

The results of thirty one water audits of office buildings have been used to derive sub-category benchmarks for water use. Highlighted in this data is the presence of a high level of leakage, estimated to be on average 13% of water consumption of typical buildings in Sydney, but more than 50% in some individual cases. The audit results have been used to derive a range of water consumption benchmarks representing good practice, economic best practice and market leading performance. The results indicate that improvements of 25% are economically viable above and beyond the correction of leaks.

Extrapolating these results to Hong Kong and tropical Asia, the water consumption of water cooling should be expected to be a major end use, while a level of water leaks comparable to that seen in Australia should be expected. This indicates that key policy objectives in this area should relate to the improvement of energy efficiency, in order to reduce cooling tower water requirements, and the elimination of leakage flows.

7. ACKNOWLEDGEMENT
The studies reported in this paper were funded by and with the assistance of the New South Wales Department of Energy Utilities and Sustainability, Northern Territory Department of Planning and Infrastructure and Sydney Water. The assistance of individuals within these organisations and specifically Matthew Clark, Jo Kieboom and Lyndall Pickering is specifically and gratefully acknowledged.
8. REFERENCES


[7] For more information on NABERS see www.nabers.com.au

AN ECOLOGICAL APPROACH TO REGIONAL DEVELOPMENT: SOLUTIONS TO PUBLIC HOUSING COMMUNITY IN HONG KONG

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ABSTRACT: High density cities carry undesirable effect of pollution and congestion which demands immediate attention. With a portfolio of high-rise building accommodating over 680,000 households, the Hong Kong Housing Authority (HA) is exploring new strategies and solutions to create healthy, comfortable and livable environment.

This paper looks at ecological planning focusing on possible solutions for completed and ongoing development constrained by planning densities. The HA’s pioneering attempt to bring transformation to the fabric of Yau Tong /Eastern Harbour Crossing Sites through an Ecological Master Plan featuring the following will be examined:

Provide a long term vision to realize green ribbons linking the ecosystems
Recognise the intrinsic value of biodiversity /natural ecosystems, restore and replenish them
Enable development of long life, loose fit greening technology and biotechnical research
Expand intensive /extensive green coverage and sustainable source of recycled water
Promote ecological concept in garden shopping / hybrid ventilation
Engage the community, empower people and foster participation

Active and passive mitigation initiatives that are involved as part of the theories, strategies and solutions are presented holistically for appraisal and benchmarking

Keywords: health, comfort, livability, ecological, green ribbons, biodiversity, long life/ loose fit technology, biotechnical research, greening coverage, water recycling, hybrid ventilation, community
1. INTRODUCTION

Extremities in density in the built-up environment brings along undesirable side effects of congestion, pollutions, heat island, and visual discomfort. Dominated by highrise buildings, Hong Kong is one of the cities with the highest density in the world. With a population at about 6.94 million and a total area of 1104 square kilometres, the city supports a density of 6420 people per square kilometer mostly concentrated in the built up area [1]. On a net site basis, some of our private or public residential development, it can be more than 5,000 persons per hectare [2].

At 2007, the Hong Kong Housing Authority has a portfolio of about 680,000 public rental flats housing one-third of the population in Hong Kong. The physical size, height and density of the built urban fabric contributed by public and private development poses strong physical impact on the environment which is irrevocable. The 21th century cities in the world demand a strong agenda to confront the challenges posed by rapid urban growth.

Whilst architects, planners, engineers and environmental specialists in the world are mapping out environmental strategies for virgin developments in various scales, equally important is the need to improve and transform the environmental conditions of completed and ongoing development constrained by planning densities. In the context of public housing development, design for comfort, health and livability [3] is the vision for enhanced functionality and efficiency as we migrate from the recovery of SARS (Severe Acute Respiratory Syndrome) in 2003. Solutions are many, this paper focuses on the goals and strategies to replenish and recreate the ecological balance and symbiotic existence between man and nature [4], human and other living system, built form and bio-climate at a regional/community scale.
2. THE ECOLOGICAL MASTER PLAN

The Yau Tong (YT) / Eastern Harbour Crossing (EHC) Sites is a major development occupying an urban site with overall site area of about 14 hectare housing over 80,000 persons featuring a high density Plot Ratio 7.5 [5]. The linear configuration of the development rises above the waterfront along stepping terrain screen off the green mountain side at the back. This is atypical compared to the low density built-environment where rich greeneries from an intermingled landscape network exist. Rather, it is representative of the typical high density topographic development found in other metropolitan counterparts. Planned and built over a series of stages to serve the peak demand of public housing at the turn of the century [6], many opportunities were lost due to the need for rapid urban growth during which the bulk of development along the terrain has been constructed.

The Housing Authority is committed to transforming YT / EHC for ecological responsiveness. In the planning and design of subsequent phases of work from north to south, passive mitigation design features that optimize lighting and ventilation, sunshine, pedestrian comfort, pollution dispersion, energy conservation and water conservation have been adopted. Where applicable, active mitigation, including hybrid ventilation, motorized ventilators, water-cool air-conditioning, reclaimed water have also been employed, mostly at the commercial developments [7]. Most importantly, to tie these initiatives together holistically, and to positively address the impact of density; the associated heat island effect and to reconcile the gap between built environment and nature, an Ecological Master plan for the district has been created to achieve the following themes [8]:

a) Provide a long term vision to realize green ribbons linking the ecosystems between the development and the surrounding country park

b) Recognise the intrinsic value of biodiversity and natural ecosystems, protect, restore and replenish existing fabric
c) Enable development of long life, loose fit greening technology

d) Enable adaptation and sustainable growth through biotechnical research

e) Expand intensive/extensive green coverage

f) Expand a network for sustainable sources of recycled water

g) Promote ecological concepts in garden shopping/hybrid ventilation

h) Engage the community, empower people and foster participation to promote awareness and ownership

Figure 1: High-rise high density development at Yau Tong/Eastern Harbour Crossing Site.
**Figure 2:** The Ecological Master Plan for Yau Tong / Eastern Harbour Crossing

<table>
<thead>
<tr>
<th>Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>EHC 1</td>
</tr>
<tr>
<td>Walled garden</td>
</tr>
<tr>
<td>Roadside Greening</td>
</tr>
<tr>
<td>Slope Greening</td>
</tr>
<tr>
<td>Transplant</td>
</tr>
</tbody>
</table>

**Table 1:** Environmental Greening features distributed amongst various phases of the Development

### 3. GREEN RIBBONS

Green Ribbons have been instigated as a concept to link isolated systems and to form an ecological community in long term. The development at YT/EHC stretches over 1 km in length. It is bordered by the country park at the northern
rim with a big reservoir of biodiversity and habitats for plants and organisms including insects, butterflies and birds.

![Diagram of green ribbons connecting green spaces](image)

**Figure 2:** Green Ribbons linking pocket greenery within the development to the country park along the hillside.

Through intensive/extensive planting, restoration and replenishment of ground cover at slopes and retaining walls; comprehensive structural podium plaza planting; strategic carpet greening of open space, linkages and jump-boards between green pockets within the development and the mountain green are established. Along the ribbon, pockets of greenery are planned at about 100m apart to attract the migration of insects within short flying distance. The novel landscape strategy is an attempt to foster the biodiversity of nature in the residential setting, thereby bridging the physical and psychological gap between people and the natural habitat as a credit for enhancing mental health.

### 4. RESTORATION AND REPLACEMENT

Restoration and replenishment are key strategies that recognize and protect the intrinsic value of biodiversity and natural ecosystems at the disturbed landform. The major development at YT/EHC involved formation of 6 artificial platforms to accommodate over 50 residential towers of up to 30 to 40 stories. To mitigate the visual and heat island effect associated with man made slopes and retaining walls
in between these platforms, every opportunity has been sought to maximize green coverage on the inclined surface. Slope greening using hydro-seeding on soil slope has been adopted comprehensively through out the site. Hard surface such as retaining walls are softened by creepers, colour treatment and introduction of planters. More innovative solutions of bio-engineering planting such as hydro mulching system have been adopted to sustain round-the-year plant growth on the dry, rocky surface originally not suitable for plant growth.

5. LONG LIFE LOOSE FIT GREEN TECHNOLOGY

Innovative concepts are underpinned by the enabling force of technology. The concept of long life, loose fit vertical green panels in the form of thin claddings is developed jointly with the contractor and applied in EHC Site Phases 4 and 5. Recognising that truncated pocket greening at the ground level could not be reconciled by roof greening at 30-40stories above ground, the solution to meaningfully increase greening percentage for pedestrian comfort is to extend on-grade greening to the vertical dimension.

The vertical green panels compose of 1000 x 500mm aluminium trays with 40mm thick proprietary product as the growing media. Plant Species commonly used in HA projects, such as Parthenocissus himalayana, Zephyranthes grandiflora, Lantana montevidensis, Nephrolepis exaltata, etc, are selected for trial. To facilitate ease of operation, networks of automatic irrigation pipes have been introduced to form an integral part of the system. Trial panels have been set up to explore various possibilities of optimizing the design. They have been installed at the roof top of the site office to serve as green roof during construction stage. A total of around 240 nos. of the panels will be permanently erected at EHC Phase 4. Some of these green panels will be installed at the vertical walls of lift tower and rock slopes, others will be installed at roof areas with limited loading allowance.
Figure 3: Green Panels have been set up at the roof of the construction site to work out design optimization.

The research and trial of vertical green panels at YT and EHC is unique for its modular, prefabricated clad-on character purposely designed for long life loose fit and reuse purposes. It is flexible in application, versatile and easily assembled on site and addresses the need for replacement and future maintenance. The thin profile addresses spatial constraints both for new construction and retrofit purpose.

Apart from the clad-on panels, EHC 4 has adopted self-standing vertical green panels to arrive at an integrative green hoarding. Similar to the trial panels installed at the roof of the site office, green hoarding enhances the site environment by providing dust and an element of noise screening. The long life, loose fit concept has been further extended as these large reusable panels are demountable and could be moved to other areas of the site as permanent green walls, or to other construction sites as green hoardings.
Figure 4: Vertical green panels designed to clad onto the external wall and laid flat on roofs of lift tower.

6. BIOTECHNICAL RESEARCH

To ensure long term performance of the vertical green panels, biotechnical research is being conducted to:

a) test out the most optimal plant selection criteria in relation to their performance under different seasons and orientations

b) sustain vegetation growth relevant to the available management resources in housing estates

c) prepare guidelines for the future development and maintenance of the vertical green panel system.

A field site for the technical study has been set up in end July 2007 at the open space of EHC Site Phase1 with four light weight metal structures in north-south orientations to support the green panels. This is a 15-month research project due for completion in early 2009. The research comprises four studies exploring different aspects of the vertical green panel system including plant performance under different watering regimes for individual panels and panel clusters; Species selection; effect of soil thickness on plant growth; fertility persistence of the system and nutrient loss from the panels.

The research should facilitate an optimum vertical green design in terms of technicalities and maintainability; evaluate the environmental effectiveness of vertical green panels at congested urban areas; and establish benchmarking performance based on the current design, for further improvement.
Figure 5: Biotechnical research to test out the plant performance, species selection, soil thickness, fertility persistence and nutrient loss

7. GREENING COVERAGE AND ROOF GREENING

Expanding the targets of intensive/extensive green coverage is one of the fundamentals to materialize an ecological community [9]. Completed phases at YT/EHC developed over the last 10 years have a greening coverage at around 10%. Conscious of the need to enhance green coverage, HA has a standard since 2000 of planting a tree for every 15 built flats.

At YT/EHC, major breakthroughs in greening coverage have been made for projects in the pipeline. Podiums of low rise commercial developments and shopping spines have been fully maximized for intensive or extensive roof greening resulting in a greening coverage percentage of over 40% at YT Phase 4 and EHC Site Phase 6. Roof greening are also applied elsewhere on lift tower, ground floor canopy and intermediate floors of domestic blocks. A green tract [10] provides major enhancement to visual comfort. Roof greening could effectively reduce the surface temperature for 20 - 30°C as compared to hard roof surface. It reinforces building insulation and energy efficiency and lowers the overall heat island effect.
8. **RECLAIMED WATER**

Expanding the network for sustainable source of recycled water will support the expansion of vertical green coverage. The commercial centres at YT ph 4 and EHC Site Phase 6 will work as reservoirs of reclaimed water to irrigate both extensive and intensive greening over these sites. Rainwater will be harvested [11]
from green roofs, concrete roofs, covered walkways and the main pedestrian plaza. Condensate from the commercial centres’ central air-conditioning system will provide huge volume of sustainable water supply. Both sources of reclaimed water will initially pass through a set of break tanks and then stored for re-use. A set of filtration and disinfection treatments maintains the water quality to an international standard. By using the reclaimed water system, an annual reduction in water consumption of 9,263 m$^3$ is anticipated, which equates to 65% of the total irrigation amount required per year.

*Figure 8: Reclaimed water system at commercial development collects condensate water for irrigation.*

Recycling of reclaimed water is also introduced to the domestic development at EHC 5. Apart from collecting rainwater from roof gardens, and taking into consideration the frequent use of household air conditioning in the sub-tropic region, condensate water from air conditioning units of domestic flats will also be collected for irrigation after filtration and sterilization. Subject to the outcome of the trial in EHC 5, the success of the scheme should contribute significantly to the agenda of water conservation at residential settings.
9. GARDEN SHOPPING AND HYBRID VENTILATION

Promoting garden shopping and hybrid ventilation will extend the ecological concept from external to internal environment. The shopping centre at EHC ph 6 is nestled in a luscious garden environment using greening strategies to reduce the centre’s overall CO2 emissions. Intensive greening is provided inside the commercial centre at various levels assessable to users. The garden shopping environment eventually leads to the roof with extensive greening provided to over 40% of the roofed over area of the centre.

Virtual greening is achieved by using a hybrid ventilation system alternating between natural ventilation, free cooling and full-scale air-conditioning. Temperature, humidity, wind and rain sensors would provide signal to activate intake and exhaust openings when the external environment matches the designed indoor comfort conditions. In YT Phase 4 and EHC Ph 6, with a predicted 10% of operating hours per year using natural ventilation, an annual reduction in air condition electricity consumption is approximately 82MWh, which equates to 35,260kg/yr CO2 emission, or the equivalent of planting 1,618 numbers of trees per year to absorb it.

Figure 9: Hybrid Ventilation achieves reduction in CO2 emission
10. COMMUNITY ENGAGEMENT

People of cities are key drivers for transforming cities towards sustainability [7]. We engage the community, empower people and foster participation so as to raise their environmental awareness and instill a culture of environmental protection. In EHC Ph 4, where the trial panels were installed at the roof top of the site office to serve as green roof during construction stage, the vertical green panels together with the growing medium and plants were delivered to the adjoining schools for initial establishment and care in April 2007. They have since been relocated to roof top of the site office in May 2007 after establishment.

As a long term programme, the Green Delight in Estate Programme has been launched with recruitment of public housing tenants as “Green Ambassadors” to spread the green message. Education and promotion programmes by Green Groups on subjects such as estate greening; building up green infrastructure and promotion of green practices are continually cascaded to our tenants. The ultimate aim is to establish a volunteer core group which will gradually own the programme and guide other residents in the promotion of a green lifestyle.

Figure 10: Community engagement involving school student in promoting green culture.
11. CONCLUSION

In embarking on the concepts, strategies and solutions towards an ecological community, we are conscious of the constraints and limits within the confines of a high density fabric that has been half established. This paper demonstrates however that the vision of the ecological master plan together with resolute actions towards restoration, innovation, research, passive and active mitigation, conservation and the active engagement of people are promising notes to nurture and replenish an ecological community. This requires, as illustrated in the paper, conscious review and communication of targets and benchmarks for monitoring and continuous improvements. This paper attempts to increase awareness, generate ideas, provides a framework for action without prescribed solutions. It encourages local and international efforts in creating sustainable high density living environments.

12. REFERENCES


[4] Hong Kong Planning Standards and Guidelines


[10] Lee Hyukjae, Koshimizu Hajime – Creation of a visual continuity through the degree of mixture of green tract of land in re-development areas, SB 05.

DESIGNING FOR SUSTAINABILITY OF BUILDING – HONG KONG CONTEXT

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ABSTRACT: The framework of sustainability for the built environment has been established internationally. Yet, there still exists a gap between the high-level principles and its implementation to achieve the design of sustainable community. To close the loop, indicators that describe the degree of sustainability are required. This paper discusses how such indicators can be established for the unique context of Hong Kong under the principles of triple bottom line, and use a case of Housing Development to demonstrate the concepts. Key elements of the framework include:

Economic Sustainability: Character, Flexibility for Change, Utilization of Completed Piles, Efficient Servicing Strategy
Environment Sustainability: Enhanced Health Environment, Natural Ventilation, Microclimate, Energy Conservation, Enhanced Comfort Environment, water saving
Social sustainability: Connectivity, Amenities, Neighbourhood and context, Culture and community heritage

The case for study is the Hong Kong Housing Department’s Yau Tong Estate Phase 4 Shopping Centre and its neighbourhood. The project symbolizes the commitment of the Hong Kong Housing Department to the environment and the society, and showcases an example of an integrated approach to green building. Numerous sustainable design features, from architectural to system design, are incorporated to support the principles of the Sustainability Framework developed.

Keywords: Sustainability framework, benchmark, indicators, microclimate, economic sustainability, environmental sustainability, social sustainability, ecological footprint.

1. INTRODUCTION
Sustainable development is of fundamental importance world-wide. In Hong Kong, the building industry is becoming the most important development and creates the greatest impact to the environment. A good building environmental design is to protect people and minimise its impact to the environment. From commercial to residential, low-rise to high-rise, public to private buildings, inclusion of environmental consideration into a building design would always bring us a sense of integration of intelligence and consciousness into our environment.

There are three key aspects of the sustainability framework, namely Economic Sustainability, Environmental Sustainability and Social Sustainability (Fig. 1)
Economic Sustainability for a building development includes the identification of economic viability of the development, maximizing economic opportunities, and reducing operation and maintenance cost.

Environmental Sustainability focuses on the effective use of natural resources, optimizing energy efficiency of building systems, and reducing environmental impact to the surrounding environment.

Social Sustainability is related to the consideration of enhancing community coherence, social interaction and cultural enrichment of the development and the neighbouring environment.

To illustrate how the indicators can be established for the unique context of Hong Kong, the Redevelopment of Yau Tong Estate Phase 4 is selected as a case study to demonstrate the concepts.

2. CASE STUDY AT THE REDEVELOPMENT OF YAU TONG ESTATE PHASE 4

Yau Tong Estate Phase 4 is the last phase of the comprehensive redevelopment of Yau Tong Estate. It is located at the junction of Cha Kwo Ling Road and Ko Chiu Road, directly abutting the southern end of the Mass Transit Railway (MTR) Yau Tong Station with the MTR underground tunnels traversing the site. It lies to the west of the existing Lei Yue Mun Plaza across the Yau Tong estate road.
The Development is a shopping centre with a total gross floor area of 44,830m$^2$ (Fig. 2). It is designed to serve the local district with a population of around 80,000 persons at its full occupation. There are also further opportunities to serve the potential future development at Yau Tong Bay, the existing industrial area, tourist attraction at Lei Yue Mun in the vicinity and a larger catchment from beyond through the MTR network. It comprises in essence of –

A public transport interchange (PTI) on Level 1, including four bus bays, one cross border coach bay and two mini-bus bays;

Parking spaces for private vehicles and loading and unloading vehicles on Level 3;

A Community Hall on Level 3;

Retail space on Level 4 to Level 7;

Taxi stands and private car drop-off on Level 4

Common facilities for Yau Tong Estate on Roof Level, including basketball courts, children play areas, etc.;

3. SUSTAINABILITY DESIGN APPROACH

The design of the Development is to embrace and create synergy for a sustainable community focusing on vibrancy, health and social coherence. The design
therefore has been approached with agendas covering economic, environmental and community aspects.

3.1 Economic Sustainability

To maintain competitiveness of the development throughout its life, the design elements introduced to bring retail success and major increase in value are –

3.1.1 Character of a Regional Type Shopping Centre

The sloping nature of the site and its proximity to the existing MTR structures results in a relatively high development cost. To improve the revenue generation and achieve economies of scale, the size of the development has been increased from 27,750m² to an optimum size of 44,830m² thereby generating additional gross annual revenue in the scale of US$5.7M and integrating with of the existing Lei Yue Mun Plaza as a regional type shopping centre with a total size of 60,000 m².

3.1.2 Flexibility for Change

The layout design should have the capacity and flexibility to cater for changes to cope with ever-changing retail trends. A regular structural grid of 8 metres by 12 metres is applied to optimize flexibility and efficiency in retail planning; located the atrium close to the centre of the development to create shops of optimum depths on all frontages; and, aligned route of arcade primarily along the central atrium and connecting bridges thereby maximizing exposure and commercial attractiveness for all commercial tenants.

3.1.3 Utilization of Completed Piles

Foundation works had been completed based on a previously approved layout design. Increase in size of the development of over 60% requires installation of additional foundation. By rationalizing the structural grid to align with the existing foundation as far as practicable and optimizing the use of the spare capacities of existing piles, only less than 20 percent of the building loads is required to be supported by the additional foundation.
3.2 Environmental Sustainability

In response to the global agenda for environmentally sustainable development, the design embodies impetus towards maximizing environmental comfort, resources conservation and mitigating environmental loading on the neighbourhood. The areas for improvement that have been identified are -

3.2.1 Natural Ventilation for PTI and Carpark

The Development has been designed to utilize natural resources (e.g. wind) to provide a healthy environment for the users. For instance, natural ventilation will be utilized at the PTI and carpark with reduced length of PTI’s enclosure through open foyer design and maximized opening on carpark walls. As a result, associated capital and running costs of the mechanical ventilation system can be reduced.

3.2.2 Enhancement of Pedestrian Wind Microclimate

Furthermore, to receive the onshore wind from the waterfront of Yau Tong Bay in the hottest month, a portion of the existing vacant Shopping Spine structure over the MTR station that borders the Level 4 plaza will be removed to enhance pedestrian wind microclimate.

3.2.3 Hybrid Ventilation for Shopping Arcade

Energy conservation is another key theme for the design of the Development so as to minimize environmental impact. To reduce the energy consumption for air-conditioning, hybrid ventilation will be utilized at the shopping arcade. This combines the use of mechanical ventilation in extreme seasons (e.g. peak summer) and natural ventilation in mild seasons (i.e. spring and autumn). Motorized openings will be installed at lower level of the curtain wall for entrainment of cool ambient air. Similarly the same type of openings will be incorporated at the skylights for hot air to exhaust out (Fig. 3).
3.2.4 Use of Water-cooled Air-conditioning System

The design of Yau Tong Estate Phase 4 has also considered the use of more energy-efficient building services systems. Water-cooled air-conditioning system is better than air-cooled air-conditioning system in terms of energy efficiency. In addition, Electrical and Mechanical Services Department (EMSD) is currently promoting the use of water-cooled air-conditioning system in Hong Kong and Yau Tong District is one of the pilot areas. In this connection, water-cooled air-conditioning system is proposed for the Development to enhance energy conservation.

3.2.5 Solar Control

Two key features of the atrium of the Development are the large curtain wall on the northwestern facade and the skylight over the atrium. Although they allow daylight infiltration to reduce energy consumption for artificial lighting, solar penetration at the same time would increase the cooling load of the building. To strike a balance between solar gain, acceptable daylight level, and offering an open view toward the harbour, several measures are studied and suggested to optimise energy efficiency. They include the consideration of high performance glass and vertical fins for the glass wall as well as provision of motorized blind for the skylights.

3.2.6 Green Roof
In Hong Kong, the usability of the open space is largely influenced by climatic conditions, in particular the outdoor thermal environment. The outdoor thermal comfort is affected by the site microclimate, such as local wind speed, air temperature, solar radiation and relative humidity etc. To provide a better thermal environment to public, some phenomena, in particular the urban heat island (UHI) effect should be avoided. To reduce heat island effect and to enhance thermal comfort condition, the current design of the development has achieved 35% of greening.

3.2.7 Water Conservation – Use of Reclaimed Water

The use of reclaimed water would reduce fresh water consumption and generation of wastewater. Condensate from air-conditioning system has been identified as the major source of reclaimed water which could be used for irrigation purpose. Such condensate will be treated with UV sterilization due to risk of human contact.

3.3 Social Sustainability

Upon completion, this development will emerge as the urban living room of Yau Tong area housing more than 80,000 people. Providing a physical environment, space and urban form that responds to the social and cultural need, enhancing people’s access, amenity, comfort and memory map are inherent for a sustainable community.

3.3.1 Connectivity

The project has adopted a universal design concept to achieve maximum connectivity to draw commuters of divergent sources into the heart of retail and leisure at Yau Tong. This include a fully glazed elevated spine to connect to the MTR Station; express linkage to PTI through banks of escalators and elevators, footbridges connecting Levels 5 and 6 to Lei Yue Mun Plaza for convenience, safety and comfort to residents of Ko Chiu, Lei Yue Mun and Yau Tong Estate in their day-to-day commuting; and a pedestrian precinct on Level 4 from the open plaza, through the main atrium onto Ko Chiu Road.

3.3.2 Neighbourhood and context
External space at the public domain of Yau Tong Estate is extremely limited. Through removal of Shopping Spine, decking across the roof of the elevated MTR connection and relocating the existing Refuse Collection Point, a sizable civic and community plaza of 3,600 m² outside the main entrance of the shopping centre is regenerated, with an amount of greening at approximate 35% of the gross area. To sensitively, interface the building entity with the adjacent built fabric and reduce the physical impact on the residential context, the building mass of the development is set back at the estate road level to create a receiving entrance to the plaza.

3.3.3 Community and cultural heritage

Sense of belonging is the driving force behind sustainable community. Community engagement is involved in the evolution of the plaza design. To unveil the heritage and uniqueness of Lei Yue Mun, imagery of rock cutting industry and artifact of historical importance are translated into dynamic architectural form; decks of al fresco dining were created to take advantage of the tourist attraction at Lei Yue Mun.

4. INDICATORS OF SAVINGS

A comprehensive environmental design study has been carried out for the Redevelopment of Yau Tong Estate Phase 4 by Ove Arup & Partners Hong Kong Limited. Performance assessment on the sustainability design for the development has been conducted. Several indicators on energy conservation and reduction in environmental impact have been identified.

4.1 Enhancing Health Environment

4.1.1 Natural Ventilation at PTI

The dispersion behaviour of vehicle exhausts at the PTI has been analyzed under prevailing wind conditions (southeasterly and southwesterly). With mitigated open foyer design, it is illustrated that natural ventilation would be capable of maintaining acceptable air quality for at least 50% of the PTI area according to the
requirement of Environmental Protection Department (EPD) under windy condition.

4.1.2 Natural Ventilation at Carpark

The natural ventilation performance of the Carpark has been assessed based on the criteria as required by Australian Standard AS 1668.2-2002. Based on the design calculation, it is found that natural ventilation alone could satisfy the ventilation requirement of 46% of the carpark area. Consequently, the energy consumption by the mechanical ventilation system and thus greenhouse gases emission can be reduced.

4.2 Energy Conservation

4.2.1 Hybrid Ventilation

Natural ventilation with motorized openings to be installed at low level of the curtain wall and at the skylights will be utilized for the shopping arcade in mild seasons (i.e. spring and autumn), when the climatic condition including the ambient temperature and humidity satisfy the design conditions to meet indoor thermal comfort criteria as required by ASHRAE Standard 55-2004 (Fig. 4 and Fig. 5). The estimated cost saving is approximate US$513 thousand per year.

Figure 4: Acceptable operative temperature ranges for naturally conditioned spaces from ASHRAE Standard 55-2004
4.2.2 Water-cooled Air-conditioning System

Water-cooled air-conditioning system will be utilized for the Shopping Centre. Such system is better than air-cooled air-conditioning system in terms of energy efficiency. Taking into account the air-conditioning period with the utilization of hybrid ventilation, the estimated annual operation cost saving is about US$ 372 thousand.

4.2.3 Solar Control

Several solar control measures for the Arcade including vertical fins, high performance glazing for the northwestern curtain wall and motorized blinds for skylight were considered.

Table 1 shows the matrix for comparison of solar performance for different fin and glazing options for the northwestern curtain wall. As much as 25% of annual solar heat gain can be reduced.

External motorized blinds controlled by timer or weather sensors was also proposed to reduce solar load for the Arcade. The blinds, being made of fabric materials, can filter a significant amount (up to 60%) of solar radiation while at the same time allow diffuse daylight infiltration to the Arcade.

Table 1: Comparison of solar performance for different fin and glazing options for the northwestern curtain wall.
### Annual Solar Heat Gain Reduction at the shopping arcade (compared to single glazed clear glass with no fins)

<table>
<thead>
<tr>
<th>Glazing Option</th>
<th>Fin Option</th>
<th>No fins</th>
<th>1m fins at 2.5m interval</th>
<th>1m fins at 1.25m interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single glazed, clear glass</td>
<td>-</td>
<td>10%</td>
<td>21%</td>
<td></td>
</tr>
<tr>
<td>Double glazed, clear glass</td>
<td>9%</td>
<td>12%</td>
<td>22%</td>
<td></td>
</tr>
<tr>
<td>Low-e double glazed</td>
<td>19%</td>
<td>20%</td>
<td>25%</td>
<td></td>
</tr>
</tbody>
</table>

### 4.3 Enhancing Comfort Environment

Green roof has positive effect on building environment, especially in thermal aspect. Planted roof would reduce the roof surface temperature, thus enhancing both outdoor and indoor thermal comfort. Fig. 6 shows the surface temperatures of a hard roof of a public housing block and a planted slope. It can be observed that the temperature difference could be up to 30°C. Green roof would also increase thermal insulation such that thermal loading for the building could be reduced. In general, green roof can reduce the cooling load for the floor underneath by around 15% [1].

![Figure 6: Comparison of temperatures of hard roof and surface covered with plantation](image)

The image shows a comparison of temperatures of a hard roof and a roof covered with plantation, highlighting the difference in surface temperatures between the two conditions.
4.4 Water Conservation – Use of Reclaimed Water

Condensate from air-conditioning system will be reclaimed for irrigation purpose for water conservation. The amount of reclaimed A/C condensate would adequately cater for irrigation at Levels 1, 3 and 4, podium roof, as well as the soft landscape on L4 open plaza. Assuming the amount of water required for irrigation to be 2 L/ m² / day, the estimated annual cost saving for fresh water consumption is approximate US$2,400.

5. ECOLOGICAL FOOTPRINT

5.1 Definition of ecological footprint

The ecological footprint is the predominant methodology used to highlight the impacts of consumption within the context of ecological limits. The methodology has been increasing in popularity since its initial publication by Wackernagel and Rees in the 1990’s [2]. The footprint is a means of measuring a population’s level of consumption by calculating the notional and direct land area needed to support them with the resources they consume and absorb the wastes they generate. The ecological footprint is measured in global hectares (gha) which means that the land can be located anywhere in the world and is representative of a standardized unit of average global productivity. In this manner the ecological footprint reallocates the environmental impact to the end user no matter where in the world the impact takes place. Ecological footprint calculation can take either a bottom up [3] or top down [4] approach, or use a combination of both.

Independent of the methodology used to conduct an ecological footprint study, one of the most important messages that it conveys is that we only have one planet with a finite land area therefore clearly demonstrating that we are constrained by ecological limits.

Different from traditional environmental indicators, such as the Kyoto climate change targets, for which impacts are measured within a defined boundary such as a country, the ecological footprint takes into account all impacts on a population no matter where in the world the impacts are taking place. The ecological footprint is
therefore taking a consumer rather than territorial approach in measuring environmental impacts.

5.2 Integrating the Ecological Footprint into the Design Philosophy

The average footprint in rural China currently stands at 1.6 global hectares per person (gha/capita) and that of an individual living in Shanghai is already around 7gha/capita. For a country that is urbanizing rapidly like China it is important to make effort to reduce the impacts by all new cities. In 2001, Hong Kong's Ecological Footprint was 6.1 gha/capita or 2.2 times the world average [5]. If the situation remains unchanged, we would need at least 180 times the existing land and sea area we have to support our current lifestyles.

Olgyay and Herdt [6] proposed two indicators on measuring ecological footprint for buildings, namely Index of Building Sustainability (IBS) and Index of Efficiency in Sustainability (IES). The IBS reflects the fraction of the annual carrying capacity of the project’s land that is consumed by a building. On the other hand, IES is the quantity of land required to meet a sustainability goal. These two metrics can be applied to assess both construction and operation impacts. Smaller indices mean less impact to the environment. These indices could be used as indicators to architects and / or building designers to design high performance building with minimal impact.

Energy consumption by air-conditioning plays an important part in ecological footprint as it involves the use of fossil fuel. In 2004, approximate 36% of total energy was consumed by commercial buildings, from which 28% (equivalent to 29,021TJ) was due to air-conditioning [7]. And the study by Panizo [8] stated that fossil fuel energy consumption accounts for approximate 20% (equivalent to 1.25gha/capita) of the total ecological footprint for Hong Kong. It may be concluded that the ecological footprint for fossil fuel consumed by air-conditioning in commercial buildings is 0.13gha/capita.

Through optimizing the design of the Yau Tong Estate Phase 4, the energy consumption by air-conditioning has been reduced through the utilization of natural ventilation and water-cooled air-conditioning system. With a combined
annual energy saving of approximate 25TJ for air-conditioning, 0.00011gha/capita of land could be conserved. These measures not only reduce the demand on fossil fuel but also reduce the generation of greenhouse gases.

6. CONCLUSION

Indicators for different aspects of the sustainability framework including Economic, Environmental and Social was established for the unique context of Hong Kong and demonstrated using the case study of the Redevelopment of Yau Tong Estate Phase 4 of Hong Kong Housing Department.

The sustainability design approach for the case study was illustrated. Performance indicators for enhancing health and comfort environment as well as energy and water conservation were identified. This project symbolizes the commitment of the Hong Kong Housing Department to the environment and the society through an integrated approach to green building design, from architecture to building systems.

Ecological footprint, which accounts the impacts of consumption by a development within the context of ecological limits, has also been incorporated into the design philosophy of Yau Tong Estate Phase 4. With the utilization of natural ventilation and water-cooled air-conditioning system, energy consumption by air-conditioning has been minimized. As a result, the generation of greenhouse gases is reduced with reduced demand on fossil fuel.

7. REFERENCES


A STUDY ON THE IMPROVEMENT OF THE “INDOOR ENVIRONMENT QUALITY” WITH ASPECT OF HEALTH IN TAIWAN

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ABSTRACT: Read these notes carefully all the way through and follow them as precisely as possible. This document explains how to prepare a paper for submission to the SB07HK conference. It also includes the instruction for submission and some other information. This document can also be used as a template if you are using MS-Word. Text in red gives some overview on layout and should absolutely be deleted in your paper version.

Keywords: Health Building (HB). · Indoor Environment Quality (IEQ). · Post-Occupancy Evaluating Method (POEM). · Building Doctor System.

1. INTRODUCTION

Many hazardous factors may potentially exist in the indoor environment of buildings, which present many risks to the health of the habitants. In a broader definition, people spend 90% of their time on average staying in the indoor environment. Thus, the quality level of indoor environment will definitely cause impact to people’s health. Inferior indoor air quality may cause discomfort and harm. Moreover, it may spread the contaminated mass to more people and offer a media space for the diffusion of contamination source. The health of general public will be seriously influenced.
2. RESEARCH METHOD

2.1 Targeted space
This study adopted the standard operation process in improving the quality of indoor environment, which was created by previous studies. The actual quality of indoor environment was measured in order to understand the problems associated with the inferior quality, to draft measures of improvement and to undertake practical improvement work. Through confirming the goal of improvement, designing and planning, constructing and re-inspecting, it was concluded that the advancement of indoor environment quality was ultimately reached and the improved performance was assessed as well.

2.2 indoor environmental items
Prior to the indoor on-site comprehensive environmental test, an on-site test planning was drafted. The comprehensive environmental test items were roughly divided into five portions including sound, light, warmness, air and electric-magnetic.

2.3 Tables
Tabular presentation of data is an easy way of condensing many items.

Tables must carry numbers in the text (Table 1) and caption.

3. INDOOR ENVIRONMENT QUALITY ADVANCED TEST RESULTS

3.1 Selection from initially inspected cases
Considering the factors including indoor sound, light, warmness and air, it is expected that the indoor quality to health can be advanced after the improvement, the best improvement results can be gained and two items of improvement can be easily performed.

3.2 Questionnaires to users
The improvement to indoor environment must eventually aim at the assurance of user’s health. Hence, it is necessary to collect the information on the indoor use status, the degree of complaints to indoor environment and the symptoms caused by indoor environment. As such, the questionnaires were drafted prior to initial inspection and the survey was conducted focusing on four key points.

Taking the implementation of 2006 research project for example, the results of the survey are described as follows: A total of 500 copies of questionnaires were mailed, 321 copies of them returned, of which 292 copies were valid. Examining the features of the samples, from the structure of sex, the percentage of male (40.34%) is lower than the female’s (59.66%); from the structure of age, primarily in the range of 30 to 39 (33.22%), followed by 40 to 49 (31.56%), 20 to 29 (17.94%), 50 to 59 (12.96%), and the percentage of the age above 59 (2.66%) and below 20 (1.66%) are rather low; in the status of smoking, a high percentage of up to 85.33% of the users do not smoke, current percentage of smokers is 8%, 6.67% of them already quit smoking; in addition, 85% of the users maintain normal living condition (85.02%) and balanced meals (84.23%). However, as high as 68.62% of the users are under pressure. Probability take place in the indoor personnel's discomfort symptom. in figure 1. 

3.3 Survey of users’ reaction to indoor environment problems
The project included the diagnosis and physical improvement of the indoor environment. For diagnosis, three different stages were implemented, including self inspection, the preliminary walk-through, and the detailed inspection of the building from a healthy environment standpoint. For environment measurement, there were components of indoor acoustics, illumination, thermal comfort, air quality and electromagnetic field. The process for conducting physical improvement started by setting the goals of improvement, and followed by planning, design, construction, and re-assessment after completion. It is also the purpose of this study to establish a reference manual for future projects of this kind.
Ranking the influence to human health by the items of indoor environment, the sensitivity to the air in the environment is the highest (22%), followed by sound (14%), warmness (13.5%), light (12.9%) and electric-magnetic (12%), these factors also draw a lot of attention, as shown in figure 2. Referring to this result, it can be concluded that while performing survey for cases, the visible environmental factors shall be specially watched or more items shall be added for inspection. Synthesize in its room the bad reason of environmental quality is counted.

<table>
<thead>
<tr>
<th>Project</th>
<th>Factor</th>
<th>Unit</th>
<th>Datum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustics environment</td>
<td>Sound Level</td>
<td>dB(A)</td>
<td>Office: 56 (IEI)  Museum: 56 (EPA) Show room: 45</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>House: 50 (IEI)</td>
</tr>
<tr>
<td>Illumination environment</td>
<td>Illuminance</td>
<td>Lux</td>
<td>Office: 750 (CNS)  Museum: 500 (CNS) Hospital: 750 (CNS, JIS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Naturally room: 1/3 (IEI)  House: 1/3 (IEI)</td>
</tr>
<tr>
<td>Thermal environment</td>
<td>Temperature</td>
<td>°C</td>
<td>Machinery ventilation: 22 ~ 27 (ASHRAE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Natural ventilation: 25 ~ 28 ( Summer) 20 ~ 26 ( Winter) (ASHRAE) (PMV-C) (PMV-C)</td>
</tr>
<tr>
<td></td>
<td>Relative humidity</td>
<td>%</td>
<td>40 ~ 70 (ASHRAE)</td>
</tr>
<tr>
<td>Air environment</td>
<td>Wind speed</td>
<td>m/s</td>
<td>Machinery: ≤0.35 (IEI)  Naturally: ≤0.5 (TW-EPA)</td>
</tr>
<tr>
<td></td>
<td>PM$_{10}$</td>
<td>µg/m$^3$</td>
<td>150 (TW-EPA)</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>ppm</td>
<td>9 (TW-EPA)</td>
</tr>
<tr>
<td></td>
<td>CO$_2$</td>
<td>ppm</td>
<td>1000 (TW-EPA)</td>
</tr>
<tr>
<td></td>
<td>HCHO</td>
<td>ppm</td>
<td>0.1 (TW-EPA)</td>
</tr>
<tr>
<td></td>
<td>TVOC</td>
<td>ppm</td>
<td>3 (TW-EPA)</td>
</tr>
<tr>
<td>Electronic environment</td>
<td>Electronic</td>
<td>V/m</td>
<td>10kHz ~ 100kHz: 87 (TW-EPA) 50Hz ~ 60Hz: 4170 ~ 5000</td>
</tr>
<tr>
<td></td>
<td>Magnetic</td>
<td>µT (1000nT)</td>
<td>12kHz ~ 200kHz: 4.6 ~ 6.25 (TW-EPA) 50Hz ~ 60Hz: 83.3 ~ 100 (TW-EPA)</td>
</tr>
</tbody>
</table>

Table 1: This indoor environment of research assesses the datum.
Figure 1  Probability take place in the indoor personnel’s discomfort symptom.

Figure 2  The user counts every environmental factor attention degree.
4. DISCUSSION OF THE IMPROVEMENT TO INDOOR ENVIRONMENT QUALITY

4.1 Improvement techniques for indoor environment problems

Improve technology for indoor environmental question and The problem happens to click and improve the way. In Table 2.

4.2 Overall Evaluation

Aiming at subtropical environment and the differences of climates in north, central and south Taiwan, this study discussed the indoor environment quality issues frequently occurred in each building features and planned appropriate improvement methods, further suggested items and content to be worked based on the individual condition.

In the process of the improvement, it is necessary to continuously communicate and coordinate with construction group and management unit responsible for the

Figure 3  Synthesize in its room the bad reason of environmental quality is counted.
improvement. During the period of improvement, the area under work is still being normally used, to avoid the impact it is necessary to plan the working time to the shortest. The time of work shall be arranged to accommodate the time of use, in order to take care of the maximum benefit for users. In addition, the waste produced from the work shall be reduced in order not to cause impact to the building and the benefit of users. The related operation guideline for construction control plan shall also be observed.

5. CONCLUSION AND RECOMMENDATIONS

The overall indoor environment quality in Taiwan’s buildings was investigated and inspected, and the comprehensive conclusion is as follows:

(1) Creating a wave of “green building design” for the existing private buildings.

(2) Establishing indoor environment quality research and test process.

(3) Drafting improvement techniques based on the specific conditions in each building.

(4) The diagnostic result of indoor environment showed that the air environment was the primary problem.

(5) Preparing a simple evaluation manual.

6. REFERENCES


[3] Indoor Air, Concentrations of airborne culturable bacteria in 100 large US office buildings from the BASE study, 2005


Table 2: Improvement techniques for indoor environment problems

<table>
<thead>
<tr>
<th>Environmental factors</th>
<th>Frequently occurred problems</th>
<th>Recommendations for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sound</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External noise</td>
<td>Transportation noise,</td>
<td>Adding building sound-proof</td>
</tr>
<tr>
<td></td>
<td>Construction noise,</td>
<td>(Increasing thickness of external wall &amp; floors)</td>
</tr>
<tr>
<td></td>
<td>Vibration noise,</td>
<td>Air-tight doors and windows</td>
</tr>
<tr>
<td></td>
<td>Large gatherings</td>
<td>Floating structure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adopting damping type material</td>
</tr>
<tr>
<td>Internal noise</td>
<td>Air-con equipment noise,</td>
<td>Adopting low noise equipment</td>
</tr>
<tr>
<td></td>
<td>Walking vibration noise,</td>
<td>Routine maintenance of equipment</td>
</tr>
<tr>
<td></td>
<td>People talking</td>
<td>Adding anti-vibration mechanism</td>
</tr>
<tr>
<td></td>
<td>Audio devices noise,</td>
<td>Adding noise-proof cover</td>
</tr>
<tr>
<td></td>
<td>Echo noise</td>
<td>Pipe lines noise-proof</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Advancing building sound absorption feature</td>
</tr>
<tr>
<td><strong>Light</strong></td>
<td>Insufficient lighting,</td>
<td>Natural light</td>
</tr>
<tr>
<td></td>
<td>Uneven distribution of light</td>
<td>Coordinating with the building direction</td>
</tr>
<tr>
<td></td>
<td>Dazzling light</td>
<td>Light introduced from two sides to reduce the depth of light</td>
</tr>
<tr>
<td></td>
<td>Lighting fixtures high power consumption and low efficiency</td>
<td>Sufficient window size</td>
</tr>
<tr>
<td></td>
<td>No labeling on lighting switches</td>
<td>Glass with high light pervious feature</td>
</tr>
<tr>
<td></td>
<td>Heavy afternoon sunlight</td>
<td>Proper external shading</td>
</tr>
<tr>
<td></td>
<td>Insufficient area to introducing light</td>
<td>external planting</td>
</tr>
<tr>
<td></td>
<td>Introduced light too deep</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inferior lighting mood</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High reflective-type glass</td>
<td></td>
</tr>
<tr>
<td><strong>Warmness</strong></td>
<td>Hot and humid</td>
<td>Building body</td>
</tr>
<tr>
<td></td>
<td>Stagnant air flow</td>
<td>Building direction, coordinating with external environment</td>
</tr>
<tr>
<td></td>
<td>Improper type of air outlet,</td>
<td>Structure and thickness of roof and external wall</td>
</tr>
<tr>
<td></td>
<td>causing air strikes</td>
<td>Way of opening windows and air-guiding &amp; shading settings</td>
</tr>
<tr>
<td></td>
<td>No labeling on air-con</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indoor heat source cannot be drained.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ineffective insulation to outdoor heat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High humidity, causing dew</td>
<td></td>
</tr>
<tr>
<td><strong>Air</strong></td>
<td>Outdoor pollution sources (Transportation, factory emission)</td>
<td>Isolating and filtering external pollution sources</td>
</tr>
<tr>
<td></td>
<td>Indoor pollution sources (Decoration material, pets, plants, air-conditioners)</td>
<td>Adopting certified green material</td>
</tr>
<tr>
<td></td>
<td>Insufficient external air</td>
<td>Proper window opening, air-guiding and shading settings</td>
</tr>
<tr>
<td></td>
<td>Indoor air short circuit</td>
<td>Layout of air outlet and inlet to avoid short circuit</td>
</tr>
<tr>
<td></td>
<td>Improper setting on air-con air inlet and waste air outlet</td>
<td>Positive and negative pressure space control</td>
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<tr>
<td></td>
<td>inefficient air exchange</td>
<td>Real-time CO2 monitoring system</td>
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<td></td>
<td>Old air-con system</td>
<td>Introducing flash external air</td>
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<tr>
<td></td>
<td>People smoking</td>
<td>Routine cleaning and sterilization of air-con equipment</td>
</tr>
<tr>
<td><strong>EM</strong></td>
<td>Electric-magnetic field generated from office equipment</td>
<td>Reducing the generation of pollution sources</td>
</tr>
<tr>
<td><strong>Biological</strong></td>
<td>Sources of bacteria (Human, animals, plants ….)</td>
<td>Controlling pollution source – regional emission</td>
</tr>
<tr>
<td></td>
<td>Indoor temperature and humidity too high, offering a bio-hotbed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Condensed, peeling-off and mildew on walls and ceilings</td>
<td></td>
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<tr>
<td></td>
<td>Water and dust accumulated in air-con pipes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maintaining proper distance while operating and avoiding long time use</td>
</tr>
</tbody>
</table>

Theme B: Creating a livable, healthy and environmentally viable cities
SKY WOODLAND FOR URBAN POWER TRANSMISSION SUBSTATION IN HONG KONG

Y.H. CHOI¹, ANTHONY IP², JOHN HO³ AND C.Y. JIM⁴

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²(2 Acting Senior Project Engineer of CLP)
³(3 Vegetation Manager of CLP)
⁴(4 Chair Professor of Geography of The University of Hong Kong)

Name of Organisation: CLP Power Hong Kong Limited, and The University of Hong Kong

ABSTRACT: CLP Power Hong Kong Limited generates and supplies reliable electricity to over 2.2 million customers in its supply area. It owns about 210 transmission substation buildings. Many green initiatives have been incorporated into recently built substations. This paper introduces a green building initiative Sky Woodland, at Sham Mong Road Substation on a building of 7 m tall for completion in mid 2008. This pioneering pilot project contributes both environmental and scientific research value, aiming at exploring the viability and effectiveness of creating an intensive green roof on the top of a substation building. Native tree species have been chosen for tree form, foliage, seasonal colours and attractive flowers. They will be planted closely to establish a crown interlocking effect and to emulate a natural woodland. Sapling or standard trees of about 2 ~ 4 m in height will be planted to reach a medium final height of 8 ~ 10 m. Specially designed drainage, water storage and soil layers will provide a suitable substrate to support woodland growth. Environmental monitoring will be conducted to evaluate the wide range of benefits to both the public and the company, such as pleasant green landscape for the site and surrounding residents, reduction of air and indoor temperature, improvement of air quality, and extending the life span of the building roof. The challenges of the project include tree selection against occasional typhoon damage, landscape design, tree transplanting and establishment, building load bearing capacity, and protection and the separation of building provisions. The valuable experience could facilitate future green roof installation of the company and other local developments.

Keywords: green building, green roof, native woodland, electricity substation, sustainable development.
1. BACKGROUND

Trees play a vital role in maintaining a healthy environment by converting carbon dioxide in the atmosphere into oxygen, cooling the air temperature and removing gaseous and particulate air pollutants. However, each year in different parts of the world many woodland and forest areas are converted to other land uses. Hong Kong, being one of the most modern cities in the world, has an exceptionally compact urban environment crowded with tall buildings. High air temperature, high levels of atmospheric carbon dioxide and other pollutants are commonly found on the street due to the busy metropolitan activities and the proximity of tall buildings. Trees can improve the local environment of Hong Kong by improving the air quality and lowering the air temperature on streets during the hot summer season. However, there is not much space left for trees among the densely-packed buildings and roads of the city. Flat roof on the concrete building provides a good opportunity for growing trees within the crowded urban area.

CLP Power Hong Kong Limited (CLP) generates and supplies reliable electricity to over 2.2 million customers in Kowloon, the New Territories, Lantau and most of the outlying islands in Hong Kong. It operates about 210 number of 132kV transmission substation buildings all over its supply area. Many green initiatives have been incorporated into the recently built substations. In June 2006, CLP announced the launch of the Sky Woodland project. This is a pilot project to provide a woodland on the roof of a building inside Sham Mong Road Substation (Figure 1). The project is one of the environmental initiatives of the company and will be completed in mid 2008. It is jointly designed and developed by CLP and Professor C.Y. Jim, Chair Professor of Geography of the University of Hong Kong.
2. PURPOSE OF THE PROJECT

A number of initially 2 ~ 4 m high trees of various native species will be planted on the roof of the new building. The Figure 2 shown here is the vision of the model for Sky Woodland. The proposed woodland on the building roof will form a thick canopy covering the whole flat roof within 3 ~ 4 years. As the green roof is located among the high rise residential and industrial buildings, it will greatly improve and enhance the visual comfort of the community.

This pioneering pilot project contributes both environmental and scientific research value, aiming at exploring the viability and effectiveness of creating an intensive green roof on the top of a substation building. The data collected and experience gained from this development can greatly enhance the successful development of other green roof projects within CLP Power as well as other local developments. Its aim is to demonstrate and promote the practice of green rooftop in Hong Kong and its applicability to neighboring regions.
3. BENEFITS OF SKY WOODLAND

Benefits of this project are summarized as follows:

**Environment**

- improves air quality by filtering and absorbing, and absorbs air pollutants in the urban environment
- reduces the indoor/outdoor temperature
- decreases the quantity of the surface rain water discharge run-off
- improves the quality of rain water discharged into the municipal drainage system
- improves the view for the public especially for residents living in the surrounding high-rise buildings
- reduces the carbon dioxide content in the atmosphere

**Energy Conservation**

- reduces the power consumption by reducing the solar heat absorbed by the building. It is estimated that the roof woodland can reduce as much as 50% the air conditioning power consumption in the hot summer and approximately 30% power consumption for the whole year

**Economic**

- increases the rental value and the property value of the surrounding community owned buildings in the vicinity
- helps to protect the waterproof layer and the structure of the building roof, reduces life cycle costs and reduces wastage. In general the life span of the
The waterproof layer is about 10 years. With a woodland on the roof, the life span of the waterproofing layer may be lengthened to 20–30 years.

**Continuous Improvement**

- The valuable experience could facilitate future green roof installation of the company and promote green roof adoption in other local developments.

**4. CHALLENGES**

Since the green roof is a new concept to Hong Kong, the Sky Woodland will meet many challenges during different stages of the project as highlighted in the following:

**Planning**

- Site selection like availability of space, means of access, etc.
- Acceptance of stakeholders
- Impact to the company’s corporate image
- Selection of technical environmental parameters to be monitored
- Government approval

**Design**

- Tree species selection and protection measures against occasional typhoon damage
- Landscape design
- Tree transplanting and establishment
• Building load bearing capacity
• Protection and separation of building provisions
• Blending with the local environment
• Soil composition for healthy growth of trees
• Irrigation system with water conservation provision
• Drainage and sub-surface drainage facilities
• Effective monitoring system

**Operation**

• Minimum maintenance resources
• Safety issue of the operating personnel
• Protection of Damage to the water proofing material on roof
• Pest control
• Monitoring the performance of the project

**Disposal**

• Impact onto the existing building upon removal of the woodland
• Methodology for removal and disposal of materials from the obsolete woodland

5. **RISK ASSESSMENT**
In order to manage the potential risks of this project, a risk management process had been carried out to identify the relevant risks and associated mitigation measures. Some of these risks and the corresponding mitigation measures are listed in the following Table 1.

**Table 1: Assessment of the major risk items**

<table>
<thead>
<tr>
<th>Risk Items</th>
<th>Impacts</th>
<th>Risk Mitigation Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety of the operation and maintenance personnel</td>
<td>Personal injury and safety</td>
<td>▪ Establishing a database of risks identified for each project</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Ensuring the operation and maintenance personnel to familiarise with means of access and escape from the woodland</td>
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<tr>
<td></td>
<td></td>
<td>▪ Good housekeeping</td>
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<td></td>
<td></td>
<td>▪ Clear indication of escape route</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Convenient access route to the woodland</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Parapet wall with sufficient height</td>
</tr>
<tr>
<td>Impact on the environment</td>
<td>Affecting the existing habitat</td>
<td>▪ Grow trees of native species,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ No water accumulation on the roof to prevent the growth of pests</td>
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<td></td>
<td></td>
<td>▪ Use of organic pesticides</td>
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<tr>
<td>Impact on the company image</td>
<td>Loss of asset</td>
<td>▪ Establish a database of the project development for continuous improvement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Simple sustainable design that can show the company’s continuous effort of ‘care for the environment’</td>
</tr>
<tr>
<td>Project does not achieve the target</td>
<td>Less benefits than expected</td>
<td>▪ Maintain a database for plant selection, growth of plant species, temperature of the building, climatic condition under the tree crowns, water consumption, quality of surface runoff, etc. for roof woodland</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Review the records periodically for continuous improvement.</td>
</tr>
<tr>
<td>Specific requirements of different government departments</td>
<td>Increase of cost and project development time</td>
<td>▪ Design shall address concerns of all related government departments.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Streamline the design and submission processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Early submission to government departments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Communication with government officials</td>
</tr>
<tr>
<td>Damage to the water proofing material on roof</td>
<td>Water seepage can damage facilities and the building</td>
<td>▪ Careful design of water proofing system and selection of plant species</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Selecting an effective root barrier to protect the water proofing layer on roof</td>
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<tr>
<td></td>
<td></td>
<td>▪ Adequate monitoring of the construction works</td>
</tr>
</tbody>
</table>
6. CIVIL ASPECTS OF THE DESIGN

The Sky Woodland is located inside Sham Mong Road 132kV substation at the western city skirt of Kowloon. This substation is located among the high-rise residential buildings (Figure 3) and is one of the green substations which have been developed in the recent years. The substation possesses a streamlined metallic roof and a colourful external wall that is blending well with its surrounding environment. The woodland is located on the roof of an equipment building situated next to the main substation building. Ten to twenty trees will be grown on the roof with an area about 100 m².

The building structure for the roof woodland will be able to bear the dynamic and static loading of soil and plants. Different soil layers are provided to support vigorous tree growth. An subsurface plastic-sheet drainage system will discharge excess water effectively, prevent water accumulation and growth of mosquitoes and other pests. A sturdy root barrier at the bottom of the green roof will protect the waterproof layer and the building structure.

The irrigation system of the landscaped roof comprises a rain sensor, irrigation controller and automatic water spray system. The rain sensor will stop water supply to the irrigation system during the rainy days. This irrigation controller will monitor the water spray cycle for different tree types. The automatic system will be more effective than the traditional watering method by manual water taps and hoses. The system maximizes the irrigation efficiency and mitigates water wastage.

This is a pioneering pilot project to investigate various technical aspects for providing an intensive green roof in the local urban environment. Environmental monitoring will be conducted to evaluate the wide range of potential benefits to both the public and the company, such as the reduction of air and indoor temperature, improvement of air quality, improvement of water quality of the surface run-off, and extending the life span of the building roof. Other relevant technical parameters such as the solar radiation, wind speed, rate of rainfall,
humidity, water content of the soil layer, ambient air temperature, quality of water
drain from the soil layer on roof, etc. will also be recorded and analyzed to yield
useful findings to inform the design of other green roof projects.

![Figure 3: Sham Mong Road 132 kV Substation and neighboring Residential
Buildings](image)

7. WOODLAND DESIGN

The Sky Woodland will be composed of small- to medium-sized of local trees
species primarily. The tree pattern will be made of two biomass strata. The main
features include:

- thick soil layer of 1 m to permit healthy root development
- heavy standard trees as planting materials
- small- and medium-sized tree species
- less costly plant species
- less maintenance need
Trees with small size will be planted amongst the medium-sized trees. Trees with seasonal colour change will be added to the plant palette. The design is to introduce natural ecological elements of a native woodland into the bustling urban area. The expected views of this green roof when the trees reach their final dimensions are shown in Figure 4.

8. CRITERIA FOR TREE SELECTION AND PREPARATION

Native tree species have been chosen for tree form, foliage, seasonal colours and attractive flowers. They will be planted closely to establish a crown interlocking effect and to emulate a natural woodland. Sapling or standard trees of about 2 ~ 4 m in height will be planted to reach medium final height of 8 ~ 10 m. Trees with special significance to Hong Kong will be selected with the first priority. Examples like *Aquilaria sinensis* (Incense Tree) that is related to the origin of the name of Hong Kong. Trees with the following characteristics will be selected for the Sky Woodland:

- good tree form
- availability of heavy standard tree in the local nursery market
- height of 2 ~ 4 m at the planting stage, ultimately attaining a final 8 ~ 10 m
- displaying vivid seasonal colour changes
- requiring relatively less care
- ability to resist the gale force wind, and insect and pest infestation
- no aggressive root root system to avoid damaging the roof structure

During the establishment of the Sky Woodland, trees will be transplanted from the nursery to the roof of the building. The transplantation process will inevitably
cause a certain degree of injury and stress to the tree. As far as practicable, hardy tree species which are suitable for transplanting shall be selected for the project.

9. OPERATION, MAINTENANCE AND RESOURCE OPTIMIZATION

In order to maintain the Sky Woodland and the premises, it is necessary to consider optimization of resources required during the design stage of the project. The Sky Woodland design shall comprise of different layers (Figure 5). The soil type for growth of plants will be about 90% decomposed granite and 10% fully matured
organic compost by weight for top soil layer and 95% decomposed granite and 5% organic compost by weight for the subsoil layer. The physical and chemical properties of the soil layers shall enable healthy growth of trees. Tree species shall be carefully selected to avoid extra effort of pruning, fertilization, undue water demand, and pest control. Design for the tree tie shall be strong enough for the tree to stand against typhoon strength winds. It is necessary to avoid tree falling as that may cause damage to the building, electrical plants and adjoining properties or injuries to people.

![Diagram of green roof layers]

**Figure 5: Details of the green roof layers**

Data measurement and collection facilities are incorporated in different soil depths and the building structure. The data will be collected and analyzed for design improvement for future rooftop woodlands in Hong Kong.

Automatic irrigation and illumination systems will be employed to decrease the associated maintenance efforts and costs. Natural organic pesticide materials and technologies including the bug spray which is refined from the Bitter Azedarach, and the Pyrethrum which refined from the natural Chrysanthemum; will be used for pest control in the woodland.
10. CONCLUSION AND WAY AHEAD

This Sky Woodland is a pilot project for exploring the viability of this innovative green initiative in Hong Kong. Post-project review and continuous monitoring will be carried out to identify rooms for improvement regarding the design, construction, operation and maintenance modules. The associated database will be regularly updated and reviewed. The latest technology, such as the root ties in the soil, will be reviewed and implemented. A state-of-the-art plant management system will be developed to manage the rooftop plants inside the substation.

Other green initiatives about plantations within properties of the company will also be implemented in the future. New experimental modules for green planting on external walls will be explored so that the substation with the roof space fully occupied by electrical equipment can also adopt an alternative green design. New ways for irrigation, pruning and vegetation care without the need for scaffolding erection will be explored. Growing plants on other areas such as slopes adjacent to the substation buildings would also be further enhanced.

With the continuous development of green initiatives in the power transmission system, CLP aims to provide a reliable and environmental friendly power supply to customers in Hong Kong in a sustainable manner.
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COMPACT CITY STRATEGY OF BANGKOK MEGA CITY

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2Graduate School of Policy Science, Ritsumeikan University, Kyoto, Japan

ABSTRACT: The objectives of study encompass 3 aspects. First is to analyze the Bangkok Mega City Model in 3 sub areas around the "New International Airport; Suvarnabhumi". Second is to analyze the compact city policy to measure factors of the compact city based on affordable transportation costs related to household income, job-housing balance, and facilities. Third is to analyze household commuting travel by the modeling displays with visual simulation. The results show that the compact city strategy can shed light on the lifestyle of residents in mega city. Moreover, the study reveals the patterns of urban structure of Bangkok Metropolis are closed to the compact city concept that means the residents utilize urban structure around the area of residences that are not more than 20 km distant. It intends to show the necessity of urban policy to pursue "a compact city" in the Bangkok Mega City.

Keywords: Compact City Policy, Mega City, Bangkok Metropolitan Regions

1. INTRODUCTION

The mega city is also known as one of the most rapidly growing and increasingly populated cities, in addition to having the largest scale of urban infrastructure in the world (MIT: 2000). Bangkok Metropolis is considered as one of the world’s 21 mega cities (Guest: 2000). It has a rapidly increasing population, which will increase to 10.5 million, and also the surrounding areas will increase by millions. This means that an additional 1.5 million people will live in the Greater Bangkok Area, and a million people will be located in the surrounding provinces. Populations and built up areas as of 2001 are showing urban sprawl (see Figure 1 and Figure 2). What we witness today requires new concepts and strategies for the management of this “urban world” - especially for the largest human agglomerations. All the specific problems of this century’s development appear most obvious in mega cities that cause population migration, changes in regional patterns and fast growing cities. Moreover, the character and spatial distribution of mega cities of the 21st century has been called the age of urbanization, during
which period an increase of 50 percent in population occurred in towns and cities. The effects of urbanization are not the same world wide, but differ regionally. Whereas the situation in the industrialized countries of the world is also challenging, it is still under control. We have to face the fact that the inferior situation in the mega cities of the developing countries is escalating and in many cases is out of control. Hence, development of the sub centers concept was selected as the solution to the problems of Bangkok Metropolis. 9 sub centers iii were developed in Bangkok Mega City. The sub centers within the jurisdiction of Bangkok Mega city are for travel time and metropolitan structure, for improving the quality of the mega city life view of the current state of urban problems, and for discussion of ideal urban infrastructures from the standpoint of realizing the desirability of the paper proposed for land use planning policy.

In recent years city planners, developers and policymakers have increasingly looked towards designing a more ‘compact city’ in order to achieve a more sustainable urban form. There are many perceived benefits of the compact city over ‘urban sprawl’, which include: less car dependency thus lower emissions, reduced energy consumption, better public transport services, increased overall accessibility, the re-use of infrastructure and previously developed land, a rejuvenation of existing urban areas and urban vitality, a higher quality of life, the preservation of green space, and the creation of a milieu for enhanced business and trading activities. (Thomas and Cousins, 1996)

However, the major findings of US mega city research found that denser and more mixed land use are associated with less automobile use for improving sustainability, and more creation of pedestrian areas in order to support the development of a “health city”, but there is a limitation for Asian mega cities. Bangkok Mega City also has been experiencing rapid increase in automobile use and empirical studies in the high-density context have been scarce. Hence, the studies will show that the process of urbanization presents enormous challenges for government, social and environmental planners, architects and inhabitants of the
city. There are three points as followings; (1) What urban population should be realized to mega-city growth, (2) How compact city policy and sub center policy should guidelines be for the mega city, and (3) How the urban population commute in order to carry out urban activities in the mega city.

**Figure 1:** Bangkok metropolis growth in 2001

*Source: Research team, August 2006*

**Figure 2:** Built up area around Suvarnabhumi Airport
2. OBJECTIVE OF THE STUDY

This paper tries to seek a better understanding of the mega city as an introduction of how the quality of life of the residents will proceed if urban reconstruction cannot be achieved by the compact city policy. The objectives of the study encompass 3 aspects.

To analyze commuting behavior of The Bangkok Mega City Model in 3 sub areas around the "New International Airport; Suvarnabhumi". These are Bang Kapi, Bang Plee, and Lat Krabang sub areas.

To analyze the compact city policy in order to measure factors of the compact city based on affordable transportation costs related to household income, job-housing balance, and facilities.

To analyze household commuting behavior by the use of modeling displays created with simulation software which integrates an existing system using the Sketch Up, Maya, 3D Max, Flash, and Premier programs, and also including visual simulation.

3. DATA COLLECTION

The study methods employed travel surveys of 4 residential areas in 3 sub centers (Bang Kapi area, Lat Krabang, Rom Klao Housing Project, Bang Plee New Town Project, and Bang-Chalong Housing Project) (278 samplings). A household travel survey was compiled by authors in August 2006, which was employed to investigate the urban structure and the commuting pattern of residents who travel downtown and commute to work. The surveys were expected to have some effects on people, such as affordable transportation costs related to household income, job-to-housing balance, and to facilitate in the change of the urban structure to the new development of 3 sub centers. Descriptive statistics were also analyzed within
this study with the intention of exploring the different characteristics of Bangkok’s commuting behavior and in more detailed daily travel investigations among the participants of this survey. The questionnaires consisted of questions about individual travel behaviors, participation in activities related to commuting, and social relations or routines likely to influence travel behavior. The main survey included questions about the distance traveled by each method on each day during a week. In addition, the study utilized simulation software integrating existing systems such as Sketch Up, Maya, 3D Max, Flash, and Premier programs, which also used visual simulation to facilitate the modeling, display and evaluation of the proposed alternative environment.

4. LITERATURE REVIEWS

Williams (1990) argued that compact cities were explained with 4 aspects, as following: (1) to be efficient for more sustainable modes of transport. The population densities are high enough to support public transport and to make it feasible to operate. Also, because compact cities are high density and mixed use, the theory is that people can live near to their workplace and leisure facilities. Hence, the demand for travel is reduced overall and people can walk and cycle easily. (2) To be a sustainable use of land by reducing sprawl. Land in the countryside is preserved and land in towns can be recycled for development. (3) In social terms, compactness and mixed uses are associated with diversity, social cohesion and cultural development. Some also argue that it is an equitable form because it offers good accessibility. (4) To be economically viable because infrastructure, such as roads and street lighting can be provided cost-effectively per capita. Many planners and policymakers believe that “sustainable communities are places that exhibit a compact urban form.” (Beatley, 1995) However, there is debate about the very definition of a ‘compact city’, and in particular what policies need to be undertaken to achieve urban compaction, let alone whether these particular policies in fact do contribute to sustainability. According to (Breheny,
2001) “policies of urban compaction involve the promotion of urban regeneration, the revitalisation of town centers, restraint on development in rural areas, higher densities, mixed-use development, promotion of public transport and the concentration of urban development at public transport nodes.” Researchers such as Gordon and Richardson (1997) have renounced many of these policies as being uneconomic, and against the wishes of the general population who have characterized the twentieth century by a rejection of inner city living, and the invention of suburbia. The nature of intensification is also important; while development in mixed-use town centers is usually perceived to have a positive effect, especially if landscaping and urban design improvements are subsequently implemented. Infill housing developments in residential suburbs are frequently perceived as being of poor quality and therefore having a detrimental effect on the environment and sustainability in general. A model of an existing context is built to a consistent quality, and developers/architects are required to “plug-in” their model of a proposed development and various alternatives at the same level of detail, accuracy, and visual quality as the existing contextual model. Besides, the so-called activity-based approach (Jones, 1990) is a useful conceptual framework for the travel activities study. Nearly all travel activities are derived from the need or wish to fulfill physiological needs (eating, sleeping), institutional needs (work, education), personal obligations (child-care, shopping) and personal preferences (leisure activities) (Vilhemson, 1999). This may be true to some extent about holiday and leisure trips, but the activity-based approach is, in our opinion, still fruitful in order to understand and analyze daily life travel behavior. In Bangkok, the road, rail and waterway networks provide full coverage of Bangkok. The ‘solution’ to the unsustainable nature of cities throughout the world has been frequently referred to as making these cities more ‘compact’, to make better use of the resources currently available. The element of a mega city related to transportation and traffic pollution concurs with the idea that when a city grows in size, homes and workplaces become further apart and the shape of the city and land-use structure will change.
5. POPULATION, URBAN ECONOMIC AND URBAN GROWTH

In brief, trends in population growth in the Bangkok Metropolitan Region (BMR\textsuperscript{iv}) increased to 3.3, 6.6 million and 10.0 million in 1960, 1980 and 2006 respectively (see Table 1). Thus, the BMR represented a high percentage of the total population of Thailand in 2006. Annual population growth in the BMR has been slowing down and turned negative between the years 2000-2006 from 4.5 percent per annum during 1960 - 1970 to –1.0 percent per annum during 2000 – 2006. According to the Department of City Planning, BMA, the built-up area had expanded by nearly 10 % per annual year from 1993 to 1995. Depicted by the aerial photography in 1995, there were about 39% of the built-up areas in the BMA. Subsequently, there has been no statistical significance in the increase. The built-up area is 700 km\textsuperscript{2}, out of a total of 1,568 km\textsuperscript{2} of the city’s administrative area. However, during the same period, the population density \textsuperscript{v} of Bangkok Metropolis expressed 4,001 – 7001 inhabitants per sq.km in 2006 (Bang Kapi), 1001-4000 inhabitants per sq.km in Lat Krabang and 500-1,000 inhabitant per sq.km in Bang Plee (see Figure 3). The level of urbanization expressed to change in urban sprawl is as follows: (1) residential population declines in the central area, (2) commercial and office buildings are to be found in areas such as Petchaburi, Rama I, Rama IV, Sukhumvit, Asok-Ratchadapisek, Victory Monument and Central Plaza, (3) suburban residential developments expand in Eastern and Northern corridors, (4) areas within a 10 km radius from the center have vertical extension and (5) areas outside 10 km have horizontal extension. Unplanned urban sprawls are currently in progress. They cause not only traffic jams, but also various problems relating to the urban living environment. Various problems include the mixing of conflicting functions, such as cluttering of residential and industrial areas which is potentially hazardous to residents, lack of sufficient provision of public services and resultant deterioration of the living environment. However, the majority of economic and social activities are still located in Bangkok Metropolis and its vicinity. In addition, Table 2 indicates a real household income in the BMA of 18,800 Baht and BMR of
18,000 Baht per month in 2000. Moreover, the employment structure in Bangkok varies greatly across its area. Secondary employment structures such as commercial, financial and service sectors play an important role as major sources of employment. In the vicinity of Bangkok, the production sector was still the major source of employment in 2000 (see Table 3). Thus, urban sites are generally initiated primarily by the private sector. This is thought to be one of the reasons why the road network is poorly devised in built-up areas, and this situation causes pertinent congestion in town.

Table 1: Total population of the BMR and its growth rate classified by province in 1980, 1988 and 2006 (Unit: 1,000)

<table>
<thead>
<tr>
<th>1. Province</th>
<th>Total population (millions)</th>
<th>Annual growth rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bangkok Metropolitan Area</strong></td>
<td>2.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Samut Prakan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonthaburi</td>
<td>1.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Pathum Thani</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Samut Sakhon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nakhon Pathom</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Vicinity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total BMR</td>
<td>3.3</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Sources: *National Statistical Office (NSO); National Economic and Social Development Board (NESDB). ** The Bangkok Metropolitan Authority, as of December 16, 2006

Table 2: Real household income in 1995 (unit: baht/ month)

6. COMMUTING MODE IN GREATER BANGKOK

There are three modes of transport for commuting employed in Greater Bangkok. These are private vehicle, public transport, and non-motorized vehicle. All types are variably employed. The areas of Greater Bangkok are linked to the center by a set of roads radiating northwards and southwards to Nonthaburi and Samut Prakan provinces, and eastwards and westwards to Chachoengsao and Nakhon Pathom provinces respectively (see Figure 3).

Table 3: Employment structure of BMR In 2000 (unit: baht/month)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangkok</td>
<td>21,000</td>
<td>18,800</td>
<td>-2.19%</td>
</tr>
<tr>
<td>Nakorn Pathom</td>
<td>15,100</td>
<td>13,500</td>
<td>-2.22%</td>
</tr>
<tr>
<td>Nonthaburi</td>
<td>27,100</td>
<td>24,200</td>
<td>-2.44%</td>
</tr>
<tr>
<td>Pathum Thani</td>
<td>17,700</td>
<td>15,800</td>
<td>-2.25%</td>
</tr>
<tr>
<td>Samut Prakarn</td>
<td>15,200</td>
<td>13,600</td>
<td>-2.20%</td>
</tr>
<tr>
<td>Samut Sakorn</td>
<td>13,000</td>
<td>11,600</td>
<td>-2.25%</td>
</tr>
<tr>
<td>BMR</td>
<td>20,100</td>
<td>18,000</td>
<td>-2.18%</td>
</tr>
</tbody>
</table>

Table 3: Employment structure of BMR In 2000 (unit: baht/month)

<table>
<thead>
<tr>
<th>Name of Province</th>
<th>Primary</th>
<th>Secondary</th>
<th>Tertiary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangkok</td>
<td>1.90%</td>
<td>34.70%</td>
<td>63.40%</td>
</tr>
<tr>
<td>Nakorn Pathom</td>
<td>41.20%</td>
<td>31.90%</td>
<td>26.90%</td>
</tr>
<tr>
<td>Nonthaburi</td>
<td>18.10%</td>
<td>39.70%</td>
<td>42.30%</td>
</tr>
<tr>
<td>Pathum Thani</td>
<td>14.40%</td>
<td>59.50%</td>
<td>26.00%</td>
</tr>
<tr>
<td>Samut Prakarn</td>
<td>7.80%</td>
<td>65.00%</td>
<td>27.20%</td>
</tr>
<tr>
<td>Samut Sakorn</td>
<td>15.60%</td>
<td>62.20%</td>
<td>22.20%</td>
</tr>
<tr>
<td>BMR</td>
<td>7.60%</td>
<td>41.20%</td>
<td>51.20%</td>
</tr>
</tbody>
</table>

Source: URMAP estimates(2000)
Within the BMA, private cars and motorcycles (44.7%) and public transport systems (42.4%) are chiefly employed for journeys. Among the public transport systems, buses have an outstanding share of 72%. This fact indicates mass transportation as a striking feature of transportation within the BMA. There are various commuting modes in place in the BMA. In terms of approximate contribution of passengers per kilometer traveled, city buses are the largest contributors. This transport mode thereby contributes significantly to either improvement or degradation of the urban air quality in Bangkok. Improvement of urban air quality would be accomplished with appropriate policies on city buses. In the same fashion, private cars are the biggest contributors in terms of vehicle-kilometer traveled. This indicator signifies that private cars play an important role in the improvement of urban air quality in the Bangkok Metropolitan Area. The passenger-kilometers traveled and vehicle-kilometers traveled of different transport modes in 2005 are shown in Table 4.

Table 4: Mode of transport to work trip in greater Bangkok
<table>
<thead>
<tr>
<th>Description</th>
<th>Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus</td>
<td>72.0</td>
</tr>
<tr>
<td>Railway</td>
<td>0.4</td>
</tr>
<tr>
<td>Surface</td>
<td>4.2</td>
</tr>
<tr>
<td>Other (taxi, etc.)</td>
<td>23.4</td>
</tr>
</tbody>
</table>

**Source:** BEIP 1997, JICA

**Table 6:** Passenger-kilometer traveled and vehicle-kilometer traveled per year for various transports modes in Bangkok in 2005

<table>
<thead>
<tr>
<th>Transport Mode</th>
<th>Capacity (Passenger)</th>
<th>Number of Fleets</th>
<th>Vehicle-kilometer Traveled per Year</th>
<th>Passenger-kilometer Traveled per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxies</td>
<td>4</td>
<td>53,000</td>
<td>286,200,000</td>
<td>572,400,000</td>
</tr>
<tr>
<td>Tuk-tuk</td>
<td>3</td>
<td>7,500</td>
<td>20,286,000</td>
<td>40,500,000</td>
</tr>
<tr>
<td>BTS Sky train</td>
<td>1,000</td>
<td>40</td>
<td>2,032,380</td>
<td>1,728,000,000</td>
</tr>
</tbody>
</table>

**Source:** BEIP 1997, JICA
Table 5 and 6, it is apparent that city buses and private car users are potential shareholders in the issue of alleviating congestion problems and air quality issues. Prior to taking this action, expansion of excellent but affordable public transport and integration of all public transport modes with smooth transit systems are indisputable to compensate for the comfort that has been sacrificed by private cars users. The elevated light rail and the subway have shown encouraging signs that some car uses have changed to these transport modes. This is very visibly indicated by popularity of the park and ride facilities near some railway stations. Therefore, the park-and-ride system needs more promotion and expansion to attract more car users to mass transit systems.

7. RESULTS AND DISCUSSIONS

7.1 Activities and Travel in 3 Sub Areas
This study of activity-based approaches is based on the work day and holiday behavior for leisure trips by analysis of daily life travel behavior and also analysis of the relationship between residential locations, urban facilities, and the location of the activity, trip distances, activity participation and journey frequency in the 3 sub-areas. For some facility types, the results almost always show that commuters choose the closest facility because the various facilities are more or less equal (such as post offices) or have regulated catchment areas (such as social security
offices). Conversely, symbolic differences within each facility category may make people travel beyond the closest facility, other recreational facilities, many types of shops and not the least, workplaces. Furthermore, there are a number of features other than proximity that are also important when choosing among facilities. Figure 4 shows the relationship between the residents and workplaces and the amount of distance traveled for 5 workdays. It indicates that the distance from residence to workplace of commuters was around 40-50 km on average. The relationship of cost of travel and distance were significantly related to each other. Moreover, the distance is less significantly related to the time duration

![Figure 4: Average, expected travel distances (km.) over 5 days
Source: Survey by research team, August 2006](image)

7.2 Trip Frequencies in Sub Areas
Trip frequency analysis was based on data from the daily travel investigation. In particular, a close interdependence of activity participation could be expected. However, because of the possibility of combining several activities such as shopping at different locations and thus making several journeys in connection with the same activity, on average, the travel diary respondents made 3 journeys per day during the investigated week days and during the weekend. Clearly, the respondents have, on average, made 3 journeys per day. The total number of
journeys appears to be influenced by the urban structure. The effect of local area density on the number of journeys at the weekend is more difficult to explain, but it might reflect a tendency found among residents of dense, inner city areas to reduce the number of shopping and visiting trips carried out at the weekend. However, some theorists have assumed that “distance decay” will, by and large, also have an effect on the number of days per week that the workplace is visited, since information technology and improved communication have made it possible for an increasing number of employees to do some of their work from home. Location of the residence in hierarchy relation centers in the metropolitan area has some influence on the frequency of participation in different activities. With more visits to typical “urban” facilities like cinemas and restaurants among inner city dwellers, while residents of outer suburbs go to other provinces more frequently, and spend more time on recreation.(See Table 7)

Table 7: Number of residents and urban structural characteristics of dwellers grouped into 3 sub areas near Suvarnabhumi Airport

<table>
<thead>
<tr>
<th>Urban structural factor</th>
<th>Number of residents for traveling to downtown (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Less than 20 km.</td>
</tr>
<tr>
<td></td>
<td>21-30 km. 31-40 km. 41-50 km.</td>
</tr>
<tr>
<td>Distance from residence to downtown BKK (km.)</td>
<td>14.39 16.19 24.46 44.96</td>
</tr>
<tr>
<td>Distance from residence to closest second order urban center (km.)</td>
<td>55.04 44.96</td>
</tr>
<tr>
<td>Distance from residence to closest urban rail station (km.)</td>
<td>30.58 69.42</td>
</tr>
<tr>
<td>Local area population density (dwellers/ (rai)</td>
<td>18-20 18-20 18-20 18-20</td>
</tr>
<tr>
<td>Local area workplace density (jobs/(rai)</td>
<td>3:1 2:1 2:1 2:1</td>
</tr>
<tr>
<td>Distance from residence to closest grocery stores</td>
<td>500 m</td>
</tr>
</tbody>
</table>
Number of grocery stores within 1.5 km. Distance of the dwelling

<table>
<thead>
<tr>
<th>Distance from residence to closest primary school</th>
<th>200</th>
<th>-</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from residence to closest kindergarten</td>
<td>1 km</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Distance from residence to closest daycare</td>
<td>500 m</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Distance from residence to closest post office</td>
<td>500 m</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Proportion of residence with a green recreational area at least 5 rai within 1 km. distance</td>
<td>1:1</td>
<td>1:1</td>
<td>1:1</td>
</tr>
</tbody>
</table>

Source: Survey by research team; August 2006

The following Figure 5 shows daily commuting and traveling that demonstrates the visual activity by using 3D graphical program presentation. This figure aims to describe the activity through urban facilities like convenience shops, workplaces and the other facilities around their residential area. Residents in 3 sub areas, Bang Kapi, Lat Krabang and Bang Plee use the nearest urban facilities to their homes and commute around 41-50 km to their workplaces. In daily life, travelers start from home and take breakfast around their residential area and take a bus to the railway station, which is a distance of 12 km, and trip-duration is 30 minutes. After spending 30 minutes on the bus they switch to various other modes of transportation, such as taking the fastest way by sky train, Bangkok Mass Transit System (BTS) or subway, Mass Rapid Transit System (MRT) that takes only 10-30 minutes of travel to the vicinity of their workplace, then they go to their place of work on foot, which takes less than 10 minutes, so it can be assumed that the shorter distance may take a longer time and the longer distance may take a shorter time if they use an appropriate mode of transportation. At lunch time people will go for lunch near to their workplace for about 5-10 minutes and 10-20 minutes for doing other activities and participating in other urban services also situated near their workplace. After finishing work they will go to department stores for relaxation, other venues for recreational activities and then back home by using the transportation modes mentioned above.
7.3 A Behavioral Model

This is a simplified behavioral model of the residential urban structure and other social conditions, which individuals are assumed to influence daily through traveling distances, accessing facilities, and participating in activities. This is correlated with the location of the activities, frequencies of activity participation and locations of the facilities. The location of residences relative to various centers and facilities combined with the transport-infrastructure on the relevant stretch determines how accessible these centers and facilities are from the dwelling. There are also mutual influences between the urban structural situation of the dwelling (location relative to various centers and facilities and local transport infrastructure) and the individual and household characteristics. The study implies that urban structure, in addition to its direct effects, may influence active participation and travel behaviors indirectly via car ownership, transport attitudes and some other variables. From Figure 6, it was found that the average distance of holiday travel falls in the range of 21 – 30 km, while travel time was 30-60 minutes on average. The majority of respondents used bus and/or train as the major mode of travel.
Theme B: Creating a livable, healthy and environmentally viable cities

Daily-life Traveling Distances

Through Urban Facilities

Urban structure around Residential Inc.

Walk from home to bus station 10 min.

Take 30 min on bus to Sky Train Station (BTS).

Various Center combined with the transportation

Short distance But take long time

Walk for lunch 5 min.

Walk for Banking 10 min.

Drop in Department store for shopping

Urban service fully around workplace

Compact City Ideal

253
Figure 5: Daily life commuting traveling

Source: Research team, December 2006

Figure 6: Distance and time of travel for respondents 3 sub areas
It was found that residents in the study area go shopping, watch movies, meet family and friends, do social work and also other activities that are less than 20 kilometers distant from their homes. This means that they are satisfied with going out to other places around their residential area. In addition, they are also satisfied doing the aforementioned activities, spending less than 30 minutes and spending at least 7 Baht to go shopping, watch movies or meet family and friends. They also spend around 300 baht on shopping, 159 Baht on watching movies, 1,800 Baht meeting family, 500 Baht meeting friends and other activities, 250 Baht on social work and 3,500 Baht traveling to other provinces (see Table 8).

Table 8: Cost spending of commuting travel to social function of residents in study areas (Baht)

<table>
<thead>
<tr>
<th>Cost of travel (Baht)</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shopping</td>
<td>7</td>
<td>300</td>
<td>46.99</td>
<td>59.019</td>
</tr>
<tr>
<td>Movie</td>
<td>7</td>
<td>159</td>
<td>40.00</td>
<td>47.476</td>
</tr>
<tr>
<td>Meet cousin</td>
<td>7</td>
<td>1,800</td>
<td>209.96</td>
<td>415.773</td>
</tr>
<tr>
<td>Meet friend</td>
<td>6</td>
<td>500</td>
<td>89.76</td>
<td>129.379</td>
</tr>
<tr>
<td>Other province</td>
<td>80</td>
<td>3,500</td>
<td>851.32</td>
<td>803.358</td>
</tr>
<tr>
<td>Help social</td>
<td>50</td>
<td>250</td>
<td>133.33</td>
<td>104.083</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
<td>500</td>
<td>124.17</td>
<td>159.837</td>
</tr>
</tbody>
</table>

Figure 7 shows the percentage of Bangkapi sub area residents’ use of distance and time spent commuting and doing social functions. It shows that when residents usually go out to do social functions, they travel less than 20 kilometers and spend less than 30 minutes traveling. Except for some activities, they may travel further
and for a shorter time, to meet family or friends more than 50 kilometers, but they spend less than 30 minutes. This relates to the chosen mode of transportation. Table 9 shows the cost of travel to do social function in the Bangkapi sub area. The minimum cost of commuting in Bangkapi to go shopping, watch movies, meet family, meet friends and other activities were 7, 8, 75, 14, 270, 29 baht respectively.

Figure 7: Distance and time of commuting travel in Bangkapi sub areas

Source: Survey by research team, August 2006
### Table 9: Cost spending of commuting travel to social function of residents in Bangkapi sub area (Baht)

<table>
<thead>
<tr>
<th>Cost of travel (Baht)</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shopping</td>
<td>7</td>
<td>200</td>
<td>67.00</td>
<td>77.454</td>
</tr>
<tr>
<td>Movie</td>
<td>8</td>
<td>50</td>
<td>21.50</td>
<td>19.485</td>
</tr>
<tr>
<td>Meet cousin</td>
<td>75</td>
<td>300</td>
<td>158.33</td>
<td>123.322</td>
</tr>
<tr>
<td>Meet friend</td>
<td>14</td>
<td>150</td>
<td>83.50</td>
<td>56.883</td>
</tr>
<tr>
<td>Other province</td>
<td>270</td>
<td>3,500</td>
<td>897.86</td>
<td>1,021.945</td>
</tr>
<tr>
<td>Help social</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>29</td>
<td>20</td>
<td>20.00</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Team survey, August 2006

Figure 8 shows the percentage of residents’ distance against time spent commuting to social functions in the Lat Krabang sub area. The satisfaction of Lat Krabang residents to do social functions, go shopping, watch movies, meet family, meet friends and the other activities is correlated with distance of less than 20 kilometers and of time less than 30 minutes. Table 10 shows the cost of commuting to social functions of residents in the Bangkapi sub area. The cost for commuting to meet friends is 6-100 baht less than the other activities such as meeting family at 30-1,800 Baht and shopping at 7-100 Baht.
Figure 8: Distance and time of commuting travel in Latkrabang sub areas

Source: Survey by research team, August 2006

Table 10: Cost spending of commuting travel to social function of residents in Bangkapi sub area (Baht)
Figure 9 shows the percentage of residents’ distance traveled and time spent commuting to do social functions in the Bang Plee sub area. The results for social functions in Bang Plee show that the residents are satisfied with doing this activity near their homes, and this minimizes time and cost. The distance shown for shopping, watching movies, meeting family, meeting friends, going to other provinces, doing social work and other activities are less than 20 kilometers and time is less than 30 minutes, and the minimum cost is around 7-80 Baht and the maximum cost is around 150-2,000 Baht (See Table 11).

<table>
<thead>
<tr>
<th>Cost of travel (Baht)</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shopping</td>
<td>7</td>
<td>100</td>
<td>37.94</td>
<td>26.016</td>
</tr>
<tr>
<td>Movie</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Meet cousin</td>
<td>30</td>
<td>1,800</td>
<td>379.17</td>
<td>703.821</td>
</tr>
<tr>
<td>Meet friend</td>
<td>6</td>
<td>100</td>
<td>68.67</td>
<td>54.271</td>
</tr>
<tr>
<td>Other province</td>
<td>200</td>
<td>2,800</td>
<td>914.29</td>
<td>933.503</td>
</tr>
<tr>
<td>Help social</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Other</td>
<td>14</td>
<td>500</td>
<td>184.67</td>
<td>273.396</td>
</tr>
</tbody>
</table>

Source: Team survey, August 2006
Figure 9: Distance and time of commuting travel in Bang Plee sub areas
Source: Survey by research team, August 2006

<table>
<thead>
<tr>
<th>Cost of travel (Baht)</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shopping</td>
<td>7</td>
<td>300</td>
<td>42.92</td>
<td>61.078</td>
</tr>
<tr>
<td>Movie</td>
<td>7</td>
<td>150</td>
<td>52.33</td>
<td>58.078</td>
</tr>
<tr>
<td>Meet</td>
<td>7</td>
<td>1,200</td>
<td>156.19</td>
<td>307.195</td>
</tr>
</tbody>
</table>
8. CONCLUSION

The study is to try to find a guideline compact policy for newly developed aero metropolis points of view are not only based on job and housing balance but also on technical points of view measured by activity and functionality. These are important when considering the quality of life in mega cities. Although government policy attempts to develop some new connections between structures of the city and various dimensions of poverty representing quality of life through mega housing projects for low income people, the low income people still meet the problems of which points of view are, for example, considerations of the meaning of cities as fields of transportation, as well as those for securing urban spaces suitable as a rearing environment for children where such children can come into contact with nature.

The results found that the low income residents enjoy living there, and having their workplace near their living area (not more than 20 kilometres distant). Meanwhile upper middle income groups still work in the CBD, commuting a distance of 41-50 km. For holiday activities, most of them prefer to stay home rather than participate in holiday shopping around residential areas. Moreover, the project location is far from the public transportation project. The study reveals that patterns of the urban
structure of Bangkok Metropolis are close to the compact city concept. That means the residents utilize urban structure such as grocery, kindergarten, day-care center, school, post office, etc. in and around the area of their residences or not more than 20 km distant. In addition, the residents’ time for daily life travel and distance for accessibility to urban facilities, activity participation, and local activities was related to the efficiency of the transport infrastructure. This implies that the urban structure directly affects the travel behavior through car ownership and transport attitudes. Hence, the compact city policy in BMR is to be planned in urban land use for sustainable development. There are three aspects which must be emphasized in Bangkok Mega City as follows:

Resizing of urban redevelopment projects. The number of large-scale urban redevelopments should be reduced from now on, while a large number of small-scale unit area development projects should be promoted.

Building of a network structure should now be formed by transferring its functions to Bangkok Metropolis vicinity areas,

Promotions of mega city policies from the standpoint of residents, such as the division of mega city areas into unit areas under separate administrative zones, which will enhance the quality of daily life.

The BMA’s policy has solved these problems and the future of mega cities, with view over the growth stages of those cities. The role of the mega city, however, with large-scale urbanization, has had a toll in lifestyle terms, with Bangkok sacrificing affluence and healthy living. A network structure has now been formed by transferring the functions to Bangkok Metropolis vicinity areas, while promoting compact city policies from the standpoint of residents, such as the division of mega city areas into unit areas under separate administrations as places for everyday life....

The conclusion of study shows (1) the problems facing Bangkok mega cities have to be solved to a significant basis. (2) The low income quality of life has to be
improved but access and approach are still problems. (3) There is inadequate low income housing due to such high land prices around the restructured city. (4) Mega cities create urban sprawl, which is not beneficial to the environment or the national economy.

9. RECOMMENDATIONS
This study is definitely required to include some measures of the urban living environment. However, the examination of the Compact City concept could provide the guideline for policy development and for coming mega cities in the future. However, city or urban plans should be promoted as small scale urban redevelopments in each sub center, connected with each other by mass rapid transportation (BTS or MRT). Moreover, Bangkok Sustainable City conditions should consist of the most efficient social structures and balance of urban areas to rural areas. Also, the security of social equity should be taken into account. Finally, indicator measurement will determine the success of the Compact City Policy which will be measured by indicators of quality of life and saving of energy.

To this end, it is necessary to accumulate detailed data by promptly formulating an observation system. The study proposes the following:

(1) Shift from rapid-growth-type urban policies and land planning to policies suitable for a mature society.

(2) Creation of urban environments as scenes of living and fostering children.

(3) Creation of a network of medium-to-small sized cities in order to promote nation building on a basis of decentralization.

(4) Establishment of a wide-area policy to make and enforce offices exceeding local municipalities in mega city areas.
10. ACKNOWLEDGEMENT

The paper reports part of the finding of Compact City Simulation Strategy in Bangkok Mega City, Thailand studied in 2006. The study was carried out with a grant provided by the Center of Excellence of Ritsumeikan University. Thanks area also due to the Faculty of Architecture and Planning for kind assistance in the conduct of the study and the students of Urban Environmental Planning and Management year 4, Miss Chonthicha Thamasith for preparation of the document until the completed study.

11. REFERENCES


i study areas; such as Bangkapi, Lad krabang, and Bang Plee

ii The term “mega-city” is frequently use as synonym of words such as “super-city”, “giant city”, “conurbation”, “megalopolis”, “world city” and so on

iii Sub center policy was proposed by BMA as a measurement of urban development policy.

iv BMR= BMA+ Vicinity(Bangkok Metropolitan Region) BMA= Bangkok Metropolitan Administration, Vicinity including, province of Nonthaburi, Pathum Thani, Samut Prakan, Nakhon Pathom and Samut Sakorn

v Population density of Nonthaburi, Samut Prakan, Pathum Thani, Samut Sakhon, and Nakhon Pathom; 723, 362,266, 697, and 285 population per sq.km are respectively.

vi Private Vehicle is personal car, motorcycle, taxi, hired motorcycle, motor tricycle-texti (Tuk – Tuk). Public transport is all kinds of buses (they operated by public and private). Non – motorized mode is all kinds of transport without engines such as walking or bicycling.
THE REDEVELOPMENT OF KWAI CHUNG ESTATE

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ABSTRACT: Kwai Chung Estate in the Western New Territories of Hong Kong, was built in the 1960s at a time when the population was increasing rapidly and when there was a severe shortage of safe and secure housing. The original estate was home to 22,000 people in 42 seven storey “walk-up” Mark II and III blocks, with shared toilet and washroom facilities. They were built at a time of urgency to cope with the needs of shelter for the masses when Hong Kong was emerging to a post-war industrial city. When they were built, they were a great improvement for those who were re-housed but by the late 1980s the estate was in poor condition, with an aging population and the basic living shared toilet and washroom facilities no longer met accepted standards. The estate was identified for redevelopment under the Housing Authority’s Comprehensive Redevelopment Programme.

Keywords: Kwai Chung Estate, redevelopment, planning

1. INTRODUCTION

After the Second World War, the Hong Kong government decided to develop the New Territories districts to accommodate the influx of new immigrants from mainland China. At that time, many people in Hong Kong were living in crude squatter settlements on hillsides, on boats in Typhoon shelters or in overcrowded tenements. Consequently they were vulnerable to fire and other natural disasters. Tsuen Wan New Town, including Kwai Chung, was one of the first industrial new towns developed in the 1960s and Kwai Chung Estate was one of the earliest ‘Resettlement’ Estates, built when public housing was still mainly an emergency housing programme struggling to cope with a growing demand and to address the chronic shortage of safe and secure housing for people on low incomes. Public housing of that time was built with very rudimentary standards of accommodation, by comparison with the modern comprehensive estates that are built today. For homeless people and squatters, the shelter and security provided in Kwai Chung estate was a huge improvement on their previous living conditions.
However, by the late 1980s the Estate was in very poor condition and with an aging population. Prosperity and education had improved dramatically from the 1960s, and consequently public expectations went beyond the desire for simple shelter. The non self-contained accommodation of the type provided in the early estates was no longer acceptable.

2. THE OLD KWAI CHUNG ESTATE

Kwai Chung Estate is located in Upper Kwai Chung district, in the Western New Territories of Hong Kong and provided homes for 22,000 people in 42 Mark II and Mark III blocks of reinforced concrete construction. These buildings were some of the earliest forms of public housing in Hong Kong and were eight storey walk-up blocks with single room flats and shared toilet and washroom facilities. Each flat was designed as single room with no partitions and no water supply. Flat size was about 14-21 sq. meters to accommodate 4-6 persons (2.3m² per person).

The old estate had no proper public transport facilities, shops were scattered under the blocks, and road network split the estate into small irregular sites and made access difficult. Car parking spaces were insufficient and not well planned to segregate from pedestrians within the Estate. Local open spaces were also isolated and uncoordinated with minimum soft landscape work and recreational facilities. The whole Estate were only planned and built to meet the housing demand with minimum provision of facilities.
With the formation of the new Hong Kong Housing Authority (HA) in 1973, public housing estates moved into a new era where more comprehensive and self-contained estates were planned each with its own public transport interchange, purpose built schools, shopping and market facilities and a wide range of housing and social welfare support services provided by both the Housing Authority and NGOs to cater for the diverse needs of a more complex community.

When compared to the standards of housing in the new estates of the time, Kwai Chung Estate fell far short. In 1988, the HA introduced its Comprehensive Redevelopment Programme (CRP) and Kwai Chung Estate was then identified for redevelopment under this programme.

3. THE OBJECTIVES

Planning for redevelopment commenced in early 1990. The objectives were to improve the standard of accommodation for the population, rejuvenate the community, optimise redevelopment potential, improve the road network, pedestrian access and public transport facilities, and provide modern and comprehensive shopping, social, recreational and community facilities for residents. Regeneration of ageing districts serving the people living in the area and retaining and rejuvenating community identity, is the main goal of redevelopment.

4. THE NEED FOR REDEVELOPMENT

Since the public housing programme had began in the 1950s, standards had risen significantly. Space standards in particular had increased from 2.3m$^2$ per person to 5.5m$^2$ by the late 1980s. That period had been characterised by an ever growing
demand for housing and gradually changing eligibility criteria which exacerbated demand still further. Increased demand meant making better use of the land available and as a consequence development densities were rising. In the 1980s, development to over 2,500 persons per hectare became the norm.

Figure 2: The dilapidated building blocks (left) and the market stall (right)

Larger flats and more flats in each new site meant that buildings were increasing in height from the seven storey walk up designs of the 1950s to buildings of over twenty storeys in the 1960s and 1970s and to 35 storeys in the early 1980s. By the time that the CRP had been announced, the Housing Authority was planning even higher blocks of 39 storeys with even larger flats.

From the formation of the Housing Authority in 1973, and the adoption of the higher standards of facilities, the planning and design of more comprehensive estates naturally brought with them far greater site planning constraints.

The condition of the buildings in Kwai Chung Estate had deteriorated badly, maintenance demands were growing, and the blocks had no lifts which were causing greater problems for the aging population. Non self-contained flats with shared toilet and washroom facilities had been phased out in new estates from the late 1960s and conversion of this type of building into self-contained units was not practical when considered alongside the demands of rising standards, increasing production and greater development densities.

The old estate also had no planned public transport facilities, and the existing streets split the estate into small irregular sites and made access between them difficult. Car parking spaces were insufficient and not well planned nor segregated from pedestrians. Local open spaces were also isolated and uncoordinated with
minimum soft landscape work and recreational facilities. Shops and other support services were scattered under the blocks and were a world apart from the new comprehensive shopping centres that were being built in new estates.

5. THE PLANNING AND DESIGN CONCEPT

The redevelopment was planned in phases. The CRP concept was to enable the Housing Authority to redevelop its older estates more speedily and more efficiently. It allowed a larger scale of redevelopment compared to the slower and relatively inefficient “pump primer” approach that had been tried in the late 1970s and early 1980s, when individual blocks were built in older estates. One of the main principles of the CRP was to recognise that communities had been established in older estates and hence redeveloping around those communities was seen to be an essential component of the success of the programme.

The redevelopment of Kwai Chung was therefore based on the need to re-house as many of the existing residents as possible in the same estate and if that was not possible, then in the same district. The CRP therefore relied on the construction of large reception estates to enable the first groups of residents to be moved out and allow the redevelopment to proceed.

What we now regard as the parameters essential to achieve sustainable development goals, were also the key parameters at the time of the planning of the redevelopment of Kwai Chung Estate.

The following approach on social, environmental and economical considerations was used:

5.1 Social considerations

5.1.1 Minimising Social Disruption to Residents

Under the CRP, an overriding principle has been to maintain some of the characteristics and essential components of the community by in-situ
rehousing, reprovisioning and retention of facilities. 7,000 tenants were eventually rehoused in the new estate whereas other tenants moved to housing estates in the neighbourhood. Essential facilities, such as temporary car-parking and a market, were to be built in advance, adjacent to phase 1 and maintained throughout the redevelopment period.

Efforts were also made to retain and integrate an existing religious shrine, schools, youth centre and the premises of the local *Kai Fong Association* [Neighbourhood Community Association] in the master layout plan of the new Estate.

![Figure 3: Existing school and factory building (top left), the Kai Fong Association [Neighbourhood Community Association] (top right) Youth Centre (bottom left), religious shrine (bottom right), retained in the neighbourhood of Kwai Chung Estate.](image)

Kwai Chung estate was over 25 years old and consequently had established communities with important social networks already in place. The elderly residents in particular, wished to stay in the estate because of these long standing networks and because of their association with the various complementary social welfare services which provided care where required and regular opportunities for them to conveniently meet friends.

5.1.2 Establishing a Civic Hub
The design concept adopted a “civic hub” design approach which has been strategically located and provided with essential facilities to create a focal point in the estate. This ‘civic hub’, together with the podium garden acting as a natural meeting point, provides multi-faceted estate facilities, easily accessible for residents to meet and socialise.

The central ‘civic hub’ comprises of a 3-storey central air-conditioned commercial centre with a total floor area of 5,800 sq. meters, an air-conditioned market with stall area of 800 sq. meters, 744 car-parking spaces, 112 light goods vehicle parking spaces, 75 motorcycling parking spaces. A covered public transport interchange is now centrally located along with the educational and social welfare accommodation; kindergartens, a day nursery, clinics and Residential Care Home for the Elderly, as the supporting facilities for the convenience of the public.

5.2 Environmental Considerations
5.2.1 A Green and Healthy Living Environment

In the planning of the original Kwai Chung Estate, which was essentially part of a programme for fast track emergency housing, there was no clear theme for the planning of play and recreation, with no provisions for sheltered seating nor formal planning of passive and active recreation. Though there had been estate improvements over the years, the estate lacked green spaces and external areas were fragmented and predominantly concrete paved with play and recreation facilities which fell far short of the standards of new estates.

A large housing estate such as Kwai Chung, has a significant impact on the district as a whole and hence play and recreation spaces for the district were planned in consultation with the Leisure and Cultural Services Department (LCSD) of the Hong Kong Government and with the local District Council. Two sites have been specifically designed in consultation with the LCSD as local open spaces for the use of the residents of the district and will be under their management upon completion. Landscaping, play and recreation within the estate follows the HA’s
comprehensive guidelines and they have been built at-grade (in phase 5) and at podium level (in phase 3 and 4) and are all linked to other estate facilities and domestic buildings.

The overall area of open space has been increased in the redevelopment from about 4.8 ha to 6.5 ha. An area has been excised in consultation with the Government and a playground has been re-provisioned, as a District Open Space. About 30% of the estate area has been landscaped with over 100 old trees retained and about 150,000 new trees and plants provided in the new Estate. Green features, including a bamboo garden, planting on the podium and a well landscaped noise barrier, are provided.

![Figure 4: Landscaped garden in Kwai Chung Estate](image)

The open spaces in the estate have been strategically located and integrated with the main pedestrian circulation networks. Active and passive recreation areas, including badminton courts, basketball courts, volleyball courts, table tennis tables, children’s play areas, and a Tai Chi court, have been provided as part of the overall landscaping design of the estate. These open spaces, together with the main podium plaza, provide greatly improved opportunities for the residents day to day recreational needs and for formal planned community activities.

### 5.3 Economic Considerations

#### 5.3.1 Optimising Site Potential
The HA has routinely formulated its design briefs in close consultation with Government but over time the supply of land has become more difficult. In the late 1990’s there was a critical shortage and demand for flats for rent and flats for sale had been increasing dramatically. The Government set annual production targets for both the public and private sectors, with 50,000 flats per annum required of the public sector.

Steps were taken to maximise the development potential of new HA developments and there was a gradual alignment with private sector practices. Phases 3 and 4 of the redevelopment were designed with a podium to accommodate the new transport interchange, a new modern shopping centre and car-parking for estate residents and for shoppers. Residential blocks were built over the podium with recreation space and landscaping on the podium decks, thereby increasing the number and size of flats and at the same time dramatically improving the extent and standard of the estate facilities.

The redevelopment has optimised the site potential, with a plot ratio of 5.5 providing 430,000 sq. metres domestic gross floor area. The number of new flats in the redevelopment has increased from 8,850 to 14,543 and population from 22,000 to 40,000, yet still allowed for an impressive upgrading of the whole estate and hence a much improved living environment. The flats are also generally larger and to a much higher quality than those in the existing estate. The mix of flat types and flats sizes has been more finely tuned to fit the profile of the estate residents, with flat sizes ranging from 17 sq. metres to 47 sq. metres, to cater for changing demographic needs, suitable for 1 person, and families up to a household size of 6 persons.
5.3.2 Improving Pedestrian Accessibility, Road Network and Transport Provision

The old housing sites were fragmented, with level differences and consequent accessibility difficulties. The sites were small and split by the local road network and so did not allow sufficient development opportunities. The space required for some of the improved and more comprehensive estate facilities required larger sites and this, along with the need for clear and simple communication links through the estate, provided the opportunity to simplify and realign the road layouts, thereby improving the traffic flow, and at the same time allowing the optimisation of the development potential of the housing sites.

The redevelopment has created a predominately vehicular free environment for the residents, with a well planned pedestrian network with footbridges and lifts which provide above grade connections throughout the estate between domestic blocks, schools and the “civic hub”. A link has also been provided to the Tai Wo Hau MTR station so that there is now a quick, efficient and convenient link to Kowloon and Hong Kong Island and the KCRC and West Rail connections to the New Territories.
6. IMPLEMENTATION

6.1 Social Aspects

6.1.1 Local Rehousing

Under the CRP, the redevelopment was to allow for in-situ rehousing, reprovisioning of open space and retention of existing facilities and features as far as possible, so was to be implemented in stages. As a first step, residents on the site of Phase 1 were to be moved to a new reception estate in Kwai Shing Estate and then the construction of new blocks on the site began, which would eventually re-house people from other parts of the estate and trigger the overall redevelopment of the estate in a planned and sequential manner. Phase 1 of the redevelopment was completed in early 1998. Of the 22,000 original tenants of Kwai Chung Estate, 7,000 were eventually re-housed in the new Estate.
6.1.2  Retention of Existing Heritage and Communal Buildings

The existing religious shrines, youth centre, schools and *Kai Fong Association* [Neighbourhood Community Association] were essential local heritage and communal buildings which had to be retained. The layout of the new estate has been designed to accommodate these existing buildings and temporary arrangements for vehicular and pedestrian access to these locations was provided to maintain proper functioning of activities during the redevelopment.

6.1.3 Continuous Updating of Development Parameter to Meet the Social and Policy Changes

During the last 10 years of the redevelopment programme, there were substantial changes in the development parameters of the project in response to adjustments in the Hong Kong government housing policies, such as intensification of development potential, introduction of quality Initiatives, the cessation of the construction of flats for sale through the Home Ownership Scheme (HOS), the corresponding later conversion of the two completed HOS buildings in phase 7 into government departmental quarters, and enhanced design features to emphasise the identity of the Estate.

In February 1998 the government began to look at the opportunities for increasing the land supply for housing by redeveloping suitable old HA factory sites. Adjacent to the old Kwai Chung Estate, there were four 7-storey factory blocks completed in the mid 1960’s. In the 1990s, these factory buildings were under
utilised and in 1999 they were selected for redevelopment to become part of the new Kwai Chung Estate. Relocation of the affected factory tenants was to be resolved before redevelopment could be started, so special ex-gratia allowances were made to assist the affected factory tenants to re-establish their businesses in private sector accommodation.

6.1.4 Housing for the Elderly

From the start of the housing programme, family structures have changed where family sizes have declined and populations of the older estates have aged. There are more single elderly people in the older estates and this particularly vulnerable group required positive planning. The HA had been extending its support services for the elderly since the early 1970’s, but because of the high housing demand, accommodation for elderly was only provided on a shared basis. By the late 1980’s the demand was acute and the HA built more self-contained small flats for 1 to 2 persons in its main new residential block of the time, the Harmony block, and though a step in the right direction, this still did not cater for the demand.

To try to address this problem more effectively and improve standards, new blocks of small flats were designed to be linked to the main residential blocks and make use of their lift and utility services. These Annex blocks, as they became known, were to become the most common way of addressing the need for small flats. In the mid 1990s the HA embarked on a programme of specific developments for the elderly with self-contained small flats for single persons and couples, providing recognised accessibility standards and allowing for appropriate support services to be provided by the NGOs. These buildings were known as “Small Household Developments” and a programme of 25 such projects was launched in 1995 with flats of 17m$^2$ to 22m$^2$ for single persons and couples, built up to 20 storeys in height.

One such block with 240 self-contained flats was built in Kwai Chung by arranging a site swap with the LCSD for a small but under-utilised playground.
across the road from Kwai Chung Estate. A footbridge was built to the estate for access to essential services and as part of the new pedestrian footpath network. This block became the second stage of the redevelopment and was completed in late 1999.

Later housing for the elderly in the final redevelopment of the estate was provided in 17m$^2$ flats in the 40 storey residential blocks as part of the standard flat mix along with family flats, and in Annex Blocks in phases 3 and 5 of the estate.

This redevelopment project has therefore had to respond as new policies and priorities have evolved in the community during the design and construction programme spanning two decades.

6.2 Environmental Aspects

6.2.1 Layout Design

The design of the estate and the disposition of the buildings, has made use of environmental studies to model the local wind environment and traffic noise nuisance in the area to help to plan the estate facilities more effectively. The domestic blocks are located away from the noise sources as far as possible; some blocks located adjacent to the public roads are on the podium, which serves as a noise shield to minimize the impact of traffic noise. Noise barrier walls at appropriate locations along estate boundaries are also provided as noise mitigated measures.

6.2.2 New Construction Technology

At the time of the initial planning of the Comprehensive Redevelopment Programme (CRP) and the decision to include Kwai Chung Estate in the programme, the HA embarked on a major programme to improve construction efficiency and quality. Though standards had improved as the public housing programme had evolved, between the 1960’s to the 1980’s there was actually little
change in the way that buildings were built, despite the considerable increase in height of buildings, from 7 to 35 storeys.

Construction was very labour intensive with in-situ concrete construction and a reliance, to a large extent, upon semi-skilled or unskilled labour. Quality of construction was a major concern because housing production targets were increasing and hence the stock of housing, along with a growing management and maintenance responsibility. In addition, efficiency, construction waste, working conditions and site safety were also important factors that needed to be addressed.

New initiatives with prefabricated construction techniques had been tried over the years and by the late 1980’s the HA embarked on a completely new approach for the design and construction of its residential buildings using modular design concepts and prefabricated construction techniques. This work started with pre-cast concrete components and was later extended into the fitting out of flats, with dry construction lightweight concrete partitions, door assemblies and kitchen fitments. The intention was to reduce wet trades, reduce the reliance on unskilled or semi-skilled site labour and introduce factory production as far as possible. This has ultimately had the benefit of improved construction quality, less waste and cleaner and safer construction sites.

Precast elements include facades, staircases, refuse chutes, bay windows, features to emphasise the identity of each phase and carpark floor slabs, account for approximately 30% of concrete works by volume. The contribution of the building contractors and sub-contractors in the development of these techniques was also a major factor with over 30 awards on safety, environmental, and construction management obtained by the contractors during construction period.

Prefabrication has been developed more extensively in the last project at the Kwai Chung Flatted Factory site, where pre-cast concrete components have made up over 60% of construction volume by also including structural elements. These
processes have had a major effect on the Hong Kong construction industry and have led to the development of a flexible and responsive pre-cast concrete components industry, initially in Hong Kong but latterly in southern China, which is now benefiting the private sector.

An advanced refuse collection technology, was also implemented in the Estate, the Automatic Refuse Collection System (ARCS). ARCS enables collection and handling of domestic refuse in a totally concealed environment where the refuse is automatically extracted by vacuum to the centralised containers to minimise nuisance caused by spills and smell. The system is one of the largest ARCS in Hong Kong and can handle a capacity of about 34 tonnes of refuse per day with 2 to 3 nos. of 10-tonne capacity containers for daily storage.

6.3 Economical Aspects
6.3.1 Continuous Provision of Basic Facilities

In order to maintain basic facilities such as retail premises, car parking and transport facilities for the residents and the public in the vicinity, Housing Department had made use of the site planned for a district open site adjacent to phase 1 to provide a temporary market and carparking to maintain every-day
facilities. The new road network was also constructed in stages and remained in-use throughout the 4 years reconstruction period.

6.4 Continuous Community Engagement

A continuous dialogue with local residents is an important part of the redevelopment process. After public consultation at planning stage, efforts were made to seek local comments during and after completion. A Resident’s Survey was carried out after occupation to obtain feedback and the findings showed that over 80% of the residents were satisfied with the estate as a whole, in particular, with the planning and design of blocks and estate facilities.

Continuous improvement is also on going after in-take. A working group formed by Members of the Kwai Tsing District Council, a representative from the Incorporate Owners of the nearby HOS court, and representatives from Housing Department conducted regular meetings over about 2 years to work out common objectives for improvements. A lift tower and footbridge were eventually planned, and are now under construction, to serve Kwai Chung Estate, Tai Wo Hau Estate, and the schools.

In order to promote public participation in “greening”, a Community Participation Scheme was launched in mid 2007 in the new estate. The Scheme is to provide young plants to the participants to be grown at home or school and to be transplanted in the estate after approximately 6 months. The idea is to engage the community in the longer term to enhance commitment to the well-being and upkeep of the estate and will be part of a series of activities to be arranged to generate more interaction and dialogue with the local community.

Figure 10: Community Participation Scheme
7. THE STAGES OF THE REDEVELOPMENT

7.1 Stage 1

The first stage comprised of three 39 Storey Harmony Blocks with 2,400 flats which were completed in 1998. These blocks are adjacent to the larger of the two planned District open spaces (due for completion in early 2008) which was formerly used as a temporary car park and market until the car parking facilities in phases 3 and 4 were completed in 2005.

7.2 Stage 2

The second stage was the construction of two New Cruciform Blocks (NCB) in phase 7, originally intended for sale and the Small Household Development for the elderly. The NCB were fully fitted apartments, larger than flats for rent, with 10 flats per floor, rather than 20 flats per floor for typical rental housing. Prior to completion, the HA cancelled its flats for sale scheme and they were eventually transferred to Government for use as disciplined services quarters and are now managed by Government.

7.3 Stage 3

The third stage shows the intensification of production that was necessary towards the late 1990’s when phases 3 and 4 were developed with a podium design for the “Civic Hub”. The shopping centre, public transport interchange and car-park were built beneath the podium and residential blocks built above with social welfare facilities and landscaping, with passive and active recreation facilities to cater for all ages. Social welfare and housing support services were therefore located at the main above grade pedestrian access levels connecting phases 3, 4 and 5.

The residential buildings were five 40 storey modified New Harmony One blocks, and two 30 storey Annex Blocks, to provide an increased number of small flats for single persons and couples. This stage also demonstrates a new direction for the
HA, where an effort has been made to give the estate an identity of its own. Though standard building types are an efficient and cost effective way of building mass housing, there were concerns that public housing estates were becoming monotonous and were not contributing positively to the urban landscape. Consequently, design teams modified the detailing of the buildings and developed unique colour treatment for each site within an overall colour theme.

7.4 Stage 4

The fourth and final stage was for the construction of five 40 storey New Harmony One blocks and two 30 storey Annex Blocks with an increased number of small flats for single persons and couples, predominantly for the elderly. This stage also demonstrates the Housing Authority’s drive towards greater identity for its buildings, with more modelling on the facades than those in phase 3 and 4 and a different, though sympathetic colour scheme. There is also extensive high quality landscaping with a landscaped plaza and a Bamboo Garden which has proved to be very popular with residents.

![Figure 11: Master Layout Plan of Kwai Chung Estate](image)

8. THE COMPLETED ESTATE

The redevelopment has allowed for more effective land use and enhanced traffic flow in the area. Residents are now living in modern self-contained flats with a much improved estate environment, a high standard of landscaping, and ample sitting out areas for the elderly and play facilities for children. Key facilities were
maintained during the redevelopment and out of the original 22,000 tenants, 7,000 were eventually re-housed in the new estate.

Figure 12: Residential blocks on the podium in Kwai Chung Estate Phases 3 and 4

Pedestrian access has been improved by footbridges, escalators, lifts and a comprehensive covered walkway system. There is a connection to the nearby Tai Wo Hau MTR station, for convenient and quick access to Hong Kong and Kowloon. A public transport interchange is now at the core of the estate, with a range of shopping, social and community facilities, which have created a new focal point. There are greatly enhanced recreation facilities and new district open spaces to serve the wider area.

Figure 13: Landscape garden in Kwai Chung Estate

9. ACHIEVEMENTS AFTER COMPLETION

In drawing up the plan for redevelopment in 1992, the Housing Department realized that demographic changes, environmental awareness, demand for better social services and community facilities, preservation and improvement of open
spaces, rationalization of the public transport network were issues that had to be addressed in order to revitalize the estate.

*Figure 14: Commercial centre (left) in Phases 3 and 4 and residential buildings (right) in Phase 5.*

The redevelopment has regenerated the area with its ‘civic hub’ concept, the preservation of mature trees, religious shrines, and schools and revitalised landscaping and recreation and play facilities in the estate and district. The completed estate has successfully improved the environment of the district as a whole which encourages social interaction of residents and has fostered a renewed community identity and a vibrant community, providing for the needs of a diverse group of people, with a greener, healthier and more comfortable living environment.

*Figure 15: A vibrant community in Kwai Chung Estate*
After 12 years of work and close attention to local interests, Kwai Chung Estate has been one of the largest CRP projects with homes for 40,000 people.

10. ACKNOWLEDGEMENTS

The redevelopment of Kwai Chung Estate was a long term project with the contribution of a large number of individuals and organisations.

This paper required the cooperation of many individuals who generously shared the information of the estate, old and new. We are grateful for the support from the project management team, planning team, landscape team, Housing Management team and of course, the building contractors, including China State Construction Engineering (Hong Kong) Ltd., Hip Hing Construction Co. Ltd., Yau Lee Construction Co. Ltd. who provided information on construction technology. Special thanks to ARCA Ltd. for contributing photographs for the Paper.

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11. REFERENCES

ABSTRACT: The Hong Kong Housing Authority provides affordable and sustainable public housing for those in need. In order to achieve our vision for sustainable housing, we integrate environmental, aesthetic and customer concerns in all of our designs. This approach is an integral part of our Strategy for Sustainable Construction. The HA has been working towards the broader sustainability of Hong Kong by providing housing for about 29% and 17% of the population in subsidised rental flats and flats for sale, respectively. A key mission is to provide affordable quality housing and healthy living environments and so improve the quality of life for a considerable portion of the community. Sustainable housing will prolong building life cycles, engage our community and build efficiently through an environmentally aware approach. To achieve our vision we try to balance the environmental, social and economic needs, and formulate housing policies accordingly.

Identifying Sustainability Priorities

As a government agency, we have adopted the view of the HKSAR government on sustainable development which states ‘full integration of the needs for economic and social development with that to conserve the environment’ and have taken this into consideration in identifying our priorities:

Environmental Priorities

In line with the Green Management Practice of the HKSAR Government and the Clean Air Charter, we are committed to reducing energy and paper consumption. We have committed to utilizing better construction methods to decrease our environmental impact and footprint. As part of the ‘Green Delight in Estates’ programme, environmental ambassadors have been trained to help raise environmental awareness in the estates.

Social Priorities

We aim to make our estates better places to live, so that our tenants enjoy a quality environment which focuses on safety and health. We are prioritizing the needs of potential customers by providing public housing to those who need it most.

Economic Priorities

Cost-efficiency is vital to us and we try to achieve this through a variety of measures, including the listing of some of our assets and implementing management measures to sustain the useful life of our existing buildings. We also continue to ensure the best use of existing resources by reducing flat vacancies and enforcing better tenancy controls to avoid the abuse of public housing.

Engaging Stakeholders

In order to meet our vision for sustainable housing, we try to balance the economic, social and environmental needs and formulate our operational policies accordingly. We know that clear communications play an essential role in our activities, ensuring that our stakeholders are fully informed of what we do, while also giving them an understanding of, and ability to respond to our initiatives to help ensure their success. Next we need to engage our stakeholders on all fronts, our staff, our business partners and contractors, as well as tenants.

With the active support of management, policies on sustainability are systematically implemented throughout the Housing Authority and communicated to staff, service providers, suppliers and contractors alike. Addressing sustainability concerns is embedded in our planning, design, tendering and contracting procedures and our guidelines for our staff and external stakeholders. Implementation of our policies and processes are regularly checked and monitored. We also provide
training and promotional events to ensure that competency levels meet our needs. Last but not least, we have been engaging our tenants, property services experts and concerned parties in the community to raise awareness of sustainability issues in Hong Kong.

The paper will examine all measures undertaken by the Housing Authority to promote concepts of sustainability in public housing and thereby contribute to sustainability in Hong Kong as a whole.

Keywords: public housing, sustainability, stakeholder engagement

1. INTRODUCTION

The primary role of the Hong Kong Housing Authority (HA) is to provide subsidized public rental housing to low income families who cannot afford private rental accommodation. The public housing programme has evolved to meet public expectations, from an emergency housing programme in the 1950’s, into the more sophisticated public housing services that we provide today, covering planning, design, construction, management and maintenance. Over the years, we have been working to ensure the implementation, maintenance and sustainability of an effective housing programme that will not only meet Hong Kong’s requirements but also contribute towards a stable and happy community. The improvements we make are a direct response to public demand as society has prospered and as public expectations and the demographics of Hong Kong have changed. At the end of March 2006, about a third of Hong Kong’s population was living in 682,300 public rental housing flats.

One of our key missions is to provide affordable quality housing and associated healthy living environments thereby improving the quality of living of many people in Hong Kong. This, we believe, in turn allows our tenants to contribute more effectively to the community and the local economy. In a broader perspective, we are contributing to the broader sustainability of Hong Kong. In order to achieve our vision for sustainable housing, we have been continuing to strive for achieving better designs which integrate environmentally friendly, user friendly, functional and cost effective considerations. We have put this vision into action through our Strategy for Sustainable Construction, and have adopted the HKSAR government’s
view on sustainable development and have taken this into consideration in identifying our sustainability priorities.

2. IDENTIFYING SUSTAINABILITY PRIORITIES
Sustainable development has always been our driving force for the provision of affordable public housing as we progressively explore ways to improve our performance in a balanced manner - environmentally, socially and economically. Sustainable development requires the full integration of the need for economic and social development with those of conserving the environment. We have to find ways to increase prosperity and improve the quality of life, while reducing overall pollution and waste, reducing the environmental impact of our activities and helping to preserve common resources and in doing so, create a sound basis for future generations. We cannot achieve this alone. We need to engage our stakeholders and work in collaboration with them, and to ensure that we will ultimately achieve our sustainable development goals.

2.1 Environmental Priorities
Given our high-density, high-rise environment with enormous political, technical, time and cost constraints, we must design, construct and manage for better environmental performance for the benefit of our tenants and the community at large. We are committed to properly managing and reducing our consumption of resources in our day to day activities, in particular the reduction of waste, and in reducing energy consumption. We also are committed to finding and utilizing better construction methods to decrease our environmental footprint and reduce the overall impact of our development, occupation, management and maintenance processes.

2.2 Social Priorities
The HA aims to make public housing estates a better place to live, and to ensure that our tenants enjoy a quality living environment with a focus on safety and
hygiene. We are working at prioritizing the demands of potential customers according to our policy pledges by providing public housing to those who need it most. We seek to provide a safe and healthy living environment for tenants, as well as working environment for workers who are engaged with our construction, maintenance and property management services.

2.3 Economic Priorities
Cost effectiveness is critical to the HA because decisions on any aspect of the housing programme from design, through construction, to operations and maintenance will have an impact on the public purse. Cost-effectiveness is being achieved through a number of measures, including the listing of some of our assets and implementing management measures to sustain the useful life of our existing buildings. Management measures to get the best returns out of the HA resources are constantly reviewed. Enforcing better tenancy controls to reduce the abuses of public housing, more efficient maintenance services and hence upgraded assets via the Total Maintenance Scheme and reducing vacancies in flats, are all very important areas.

3. ENGAGING STAKEHOLDERS: OVERARCHING POLICIES AND SYSTEMS
Our vision on sustainable housing can only be achieved through working with people. In order to meet our vision for sustainable housing, we strive to balance the economic, social and environmental needs and concerns of all our stakeholders. Our stakeholders include planners and designers, building and maintenance experts, property services experts, tenants, users and workers, as well as the community at large. To help achieving this balance, we have formulated our policies on sustainability which are systematically implemented throughout the HA and communicated to our tenants, suppliers and contractors. Measures to address sustainability concerns are embedded in our operating policies, planning and design guidelines, tendering and contracting procedures, and tenancy agreements to guide our stakeholders on all fronts. Implementation of our policies and systems
are regularly checked and monitored, and measured against established targets. We also provide training and undertake promotional events to ensure that staff and contractor competency levels meet our needs and also to raise the awareness of our tenants.

### 3.1 Partnering with the Industry

The developments in the way that we work, both in our construction and our property management operations have only been possible with the cooperation of our business partners. As we develop new initiatives in line with best practices for implementation, we engage our business partners to participate in the process so that we can ascertain that they are practicable, and that they also own the decision.

The Housing Authority has been one of the key players in driving improvements in the industry, such as spearheading best practice in site safety, health & environment, working conditions, protection of wages etc. The dialogue with the industry and the efforts to promote partnering in the industry are critical to the success of these initiatives in the delivery of housing services. Through regular liaison meetings or ad hoc groups, we tap the expertise of our business partners to develop the policy framework and operational details.

Since 2001, we have been running project partnering workshops in all building and piling contracts plus some maintenance contracts to foster more effective communication and cooperation amongst team members, including contractors, subcontractors, project staff and consultants. With six years’ experience, many project stakeholders have reported better communication and understanding of each other, problems solved more promptly on site, less paper work, smoother progress and improved quality of work. Partners have become more proactive in working towards achieving common project objectives, including quality, site safety, environmental and customer service performance.
3.2 Communication with Residents

The HA vision for sustainability is to benefit all of our stakeholders. Clear and ongoing communications play an essential role in HA activities, ensuring that stakeholders are fully informed of HA plans, while also giving them an understanding of, and ability to respond to initiatives to help ensure their success.

Launched in 1995, “Estate Management Advisory Committees” (EMAC) serves as a very useful vehicle for tenants to contribute towards better management of our estates, acting as bridges between HA and the residents (Photo 1). Serving as an advisory body, they make suggestions on day-to-day management issues and help to assess the performance of contractors and to allocate funds for minor improvement works. In 2005/06, more than 260 issues of the half-yearly EMAC newsletter were produced, keeping the two million public housing tenants in touch with important housing issues as well as local estate news.

Photo 1: Event Organized by EMAC Played a Vital Role on Stakeholder Engagement

The “Housing Channel”, launched in 2004, has been extended to cover over 850 residential blocks in close to 130 estates. Video programmes on housing-related matters are broadcast on Liquid Crystal Displays monitors installed in the ground floor lift lobbies of residential blocks. The channel enhance communication between the HA its tenants and keeps them informed of new services and developments within their estates. Over 50 videos on housing related matters were produced, including topics on developments in the Review of Domestic Rent Policy, the Total Maintenance Schemes, the Rent Assistance Scheme, the promotion of green practices in estates, and even news and weather information.
4. ENGAGING STAKEHOLDERS: IN PURSUIT OF ENVIRONMENTAL SUSTAINABILITY

4.1 Planning and Design for Environmental Sustainability

Planners and designers play a crucial role in the “embryonic stage” of our estates during the upstream planning and design work, which will ultimately affect the downstream construction and occupation phases throughout the life of the buildings. It therefore follows that we must positively engage this group of creative stakeholders and aligns their thoughts with our corporate vision and values.

4.1.1 Adopting Micro-climate Studies

Since 2004, all our designs for new estates micro-climate studies have been required to assess the performance of the estates by applying computational fluid dynamics techniques. Our designers are able to refine the scheme design to maximize the advantages of the form, orientation and disposition of buildings and thereby optimize performance of local wind patterns, the natural ventilation to buildings and dispersion of pollutants, day-lighting standards, thermal comfort, and provide a basis for improved energy efficiency in occupation.

Photo 2: Micro-climate Studies for Upper Ngau Tau Kok

The studies will help us to provide a healthier, more natural and more user-friendly living environment for our tenants and the community. We have already applied these micro-climate modelling techniques on 26 projects. The first project of its kind, Upper Ngau Tau Kok Phases 2 and 3 which is due for completion in 2008, has been assessed under the Hong Kong Building Environmental Assessment Method (HK-BEAM) and has achieved the provisional top-level Platinum Rating.
4.1.2 Providing Environmentally Responsive Building Facades

Building on the micro-climate studies, we have conducted research into the detailed design of the facades of our buildings to further improve the building performance. External façade designs have been customized to address orientation and sun-penetration concerns to provide better thermal comfort, reduce glare or afford more natural lighting, depending on the location of each flat. We are now trying out these environmentally responsive façades ideas in a few pilot projects in the Eastern Harbour Crossing Site Phases 3 and 4, in Eastern Kowloon, which are scheduled for completion in 2008 and 2009.

4.2 Building for Environmental Sustainability

The construction stage of a development can have the greatest impact upon surrounding developments and if not properly managed can lead to complaints and delay to projects. To minimize the possible impact, we have required our contractors, through comprehensive contractual provisions, to develop “green building practices” and they in turn cascade the message down through the supply chain to workers on site. We conduct rigorous site inspections and have implemented thorough Performance Assessment Scoring Systems to monitor the performance of contractors to ensure that they meet their obligations by strict compliance with specified environmental standards.

4.2.1 Application of Precasting and Mechanized Construction Methods
Since the late 1970’s, our designers and builders have experimented with various mechanized forms of construction to improve built quality, to improve efficiency, and reduce the use of labour-intensive and skill-sensitive wet trades on site. Mechanized construction techniques can make the process simpler, safer, quicker and cleaner. These techniques became mandatory contractual requirements in the 1990’s and our teams have worked with our contractors to perfect the use of large panel formwork systems, pre-cast concrete and other pre-fabrication techniques for a wide range of building components (Photo 2). We now have a pilot project where we have increased the extent of pre-casting and prefabrication from our usual 20% of the concrete work, to approximately 60%, through the use of pre-cast concrete shear walls, stairs and lift cores as well as volumetric units for bathrooms, kitchens and staircase cores. Social, economic and environmental benefits have followed, most notably the improvements in site safety, reduction of waste, quality benefits and the reduced impact on the environment.

*Photo 3: Increased Use of Pre-cast and Prefabricated Elements in Building Construction Works*

4.2.2 Applying Hard Paved Construction for Building and Piling Works

A further enhancement to reduce the impact of our works and improve conditions at site level has been the requirement for temporary paving in all of our
construction sites. We have specified hard paved construction for use in all our building and piling contracts since June 2005 where the practice has provided a healthier and cleaner site with much better dust control, material storage and handling and more effective control of surface water runoff.

Photo 4: Hard Paved Site at Eastern Harbour Crossing Phase 4

Some builders have gone further by the use of re-usable precast concrete slabs instead of in-situ concrete. This has been shown to be very effective, not only in minimizing the environmental impact but also in improving site safety, and gradually changing the behaviour and culture of the workforce where more clean and green working practices are becoming the norm.

4.2.3 Applying Hydraulic Crushers for Demolition and Jack Piles for Piling Works

Demolition and piling works are usually noisy and dusty activities which have the greatest impact on the community. We have been working with the industry to reduce noise emissions, and introduce efficient, safe and environmentally friendly demolition and piling techniques. Since 2001, we have carried our trials of hydraulic concrete crushers in demolition works rather than traditional pneumatic breakers. In 2004 we published guidelines and specifications to facilitate their use by project teams for demolition works close to noise sensitive receivers, such as domestic buildings, schools and hospitals. For our piling works, a comprehensive study was conducted in 2003, and after consultation with the Hong Kong Buildings Department, the use of jack piles, a new type of more environmentally friendly piling technique was endorsed.

4.3 Green Living in Practice

Through education campaigns and outreach programmes in conjunction with green groups, we have collaborated with tenants, staff and service providers to reduce domestic waste, promote schemes to save energy and water, and clear hygiene black spots. Working with our tenants will help to ensure a clean and green living environment has been shown to be effective.
4.3.1 Domestic Waste

In 2006 to 2007, residents of HA estates generated 0.74 kg per person per day compared to 0.82 kg per person per day in 2003. Waste recovery has also been a concern, both from the perspective of recycling and for disposal of potentially toxic waste such as used rechargeable batteries. With our residents continuing to make significant contributions to environmental protection by using the recycle bins provided in each block. Recovery rates for recyclables in the past year have been increased. In total, 12.36% of paper, 28.31% of aluminium cans and 6.19% of plastic bottles were recovered for recycling from our estates in the past year.

4.3.2 Estate Landscaping and Greening

Landscaping and planting schemes in public housing estates have long been an HA priority (Photo 3). In 2005/06, HA professional teams and the Horticulture Team have continued their efforts to improve the standards of landscaping, both in the planning of new developments and in improvements to existing estates. About 4,100 trees, 527,400 shrubs and 92,000 annuals were planted during the year. For 2005/06, we set ourselves five targets on greening works, which have all been achieved, on green treatment to newly formed slopes, upgrading of the existing landscape facilities in selected estates, promoting the benefits of a green environment in estates with the Estate Management Advisory Committee. Theme gardens have also been set up to enhance awareness of greening, with Rhododendron Gardens at Lei Muk Shue Estate and Nam Shan Estate and every year we organize tree planting days on selected estates to help to raise awareness of our efforts and achievements.
4.3.3 Green Delight in Estates

In 2005 we launched a long-term community environmental programme, called “Green Delight in Estates” to promote environmental awareness among our tenants through a series of educational and community activities (Photo 4). Various activities are being organized in conjunction with local green groups where they have designed and implemented green initiatives for some 30 estates in 2005/06. The programme was extended to a further 30 estates in 2006/07 and will be progressively rolled out to all public rental housing estates. A tenants survey conducted at the end of the first year concluded that the programme has raised the environmental awareness of our tenants. The green groups are working with us in vigorously promoting new waste reduction and recycling campaigns amongst our tenants. We are also starting energy saving awareness campaigns with the green groups and the Electrical and Mechanical Services Department to promote conservation measures for our tenants.
5. ENGAGING STAKEHOLDERS: IN PURSUIT OF SOCIAL SUSTAINABILITY

Social sustainability enhances the well-being of people. The low rents in public housing represented a subsidy to low income families. The housing programme promoted social stability, economic prosperity and fostered harmony in the community. The HA cares for residents and users in assuring a safe and healthy living environment, enhances social cohesion through community participation and communication, and cares for the well-being of workers providing services to us. These interrelated measures all contribute to the well-being of the community as a whole.

5.1 Engaging the Community

Comprehensive design approval processes, and a mature feedback system, have all contributed to the process of matching estate planning and design with tenants and community needs. For the community needs to be properly addressed, we consult Government Departments as a start and then District Councils. Depending on circumstances, the Legislative Council and the Estate Management Advisory Committees in public housing estates and relevant Non Governmental Organizations may be involved. Public and media briefings on new proposals and a range of communal activities; meetings with residents groups, art promotions and
exhibitions, all play an important part in securing public support to HA development proposals in this era.

5.2 Healthy Life Styles and Obligations to Neighbours
Healthy life style has become a great concern of Hong Kong society after the SARS crisis in 2003. High density, high rise living, imposes some obligations on all of us. Our behaviour will directly affect our neighbours and our recognition of our obligations builds a more harmonious relationship between residents in the estates and the estate management teams.

Clean Neighbourhood Campaigns are organized in public rental housing estates every year to promote overall cleanliness through awareness and educational activities. In parallel, we introduced a Marking Scheme to address the unsociable behaviour of some residents that impacted directly on hygiene and therefore on public health in estates. Infringements of accepted public hygiene standards such as littering, spitting, urinating and defecating in public areas, allowing mosquito breeding by accumulating stagnant water, smoking in public lifts, illegal hawking of cooked food, throwing rubbish and objects from height will attract severe penalties. For serious threats to estate hygiene, we adopt a zero tolerance policy and allot demerit points to offenders. Offenders will receive verbal and written warnings, and eventually termination of their tenancies if 16 demerit points or more are accumulated within a two year period.

In October 2005, this marking scheme was further reviewed in response to feedback from residents and the public. In the case of throwing objects from height, the penalty imposed will be commensurate with the seriousness of the action, where injury to a person will result in immediate termination of the offender’s tenancy.

5.3 Developing a common W-trap system for drainage works
The outbreak of SARS in 2003 was a shock to Hong Kong and the region and led to the re-appraisal of some well-entrenched practices. To address the possible risk
of transmission of disease through dried-up traps to floor drains in the soil and waste drainage systems, we worked with the City University of Hong Kong to develop a common W-trap system for our projects to ensure that the floor traps were always charged with water. A number of plumbing suppliers have expressed interest in manufacturing this design for use in HA projects and the arrangements will be used on all new developments where practicable, the first ones being Eastern Harbour Crossing Phases 3 and 4.

5.4 Safety Management Schemes
A number of measures to improve site safety standards have been progressively developed and have increased safety awareness and promoted best practices beyond basic regulatory requirements. These included the Silver Card advanced safety training scheme, Housing Authority Safety Auditing System, Pay for safety, environment and hygiene scheme. These systems has been instrumental in improving safety management and the awareness of the managerial staff engaged in projects, by setting objective safety standards and implement them on sites. The HA has a good record for site safety with 11.5 accidents per 1000 workers compared to 64.3 accidents per 1000 workers in the industry as a whole, in 2006 (Figure 1).

Figure 1:

Accident Rate for New Works per 1,000 workers, Compared to Local Construction Industry Average
5.5 Social Cohesion through Community Participation and Communication

The Estate Management Advisory Committee Scheme was introduced in 1995 to increase tenant’s participation in estate management. Each Committee consists of the Estate Housing Manager, a District Councillor of the constituent, and representatives from Mutual Aid Committees and residents associations. Regular meetings are held to discuss matters of concern to tenants and funds are provided for the Committees to carry out improvement works and organize local functions. Tenants also participate directly in appraising the performance of various service contractors. This Scheme has made a significant contribution to building a partnership between the management of estates and the tenants.

5.6 Customer Satisfaction

We have been conducting customer satisfaction surveys with our residents for many years, to gather their feedback on newly completed estates and compile statistical data. This data will be used in reviews of the types of flat that we build, the space standards that we use and specific requirements for estate facilities and communal areas. Latest survey results in 2004/05 indicated that over 60% of households were either very or quite satisfied with our services and less than 1% was dissatisfied with the estate, the block and flat facilities, and the overall workmanship in the estate. These surveys are invaluable in our drive for improvements and we apply the findings to refine our design standards, management services and administration of future projects.

5.7 Developing Community Participation in Design and Planning Processes.

Engaging the community is an important step in enhancing social sustainability during the planning and design stages. We have piloted several models to explore user-oriented neighbourhood design, on Estates at Yau Tong Estate Phase 4, Ma Hang Headland, Upper Ngau Tak Kok Estate Phases 2&3 and Lam Tin Estate Phases 7&8. A variety of interest groups have been engaged; academics, residents, schools and non-government organizations in a series of facilitated workshops,
where they were briefed on the constraints and opportunities of the project, and to help them to understand the concerns and aspirations in their neighbourhood. We ran drawing and mural painting competitions to strengthen public awareness and appreciation of local heritage, and instill a greater sense of belonging in the community. We succeeded in drawing up a design brief to meet common objectives and will continue to try to integrate community aspirations in our future designs. The experience gained will be consolidated into a guide for application in future projects.

*Photo 7: Workshop at Yau Tong Estate*

5.8 Developing Community Participation to Meet Users Needs

We have applied community participation techniques as a pilot project, after the occupation of Lei Muk Shue Estate, one of our more recent redevelopment estates, to explore how best to respond to feedback and engage the residents in refining the estate design, to meet specific users and estate management needs, that have arisen after intake. We worked with the Hong Kong Institute of Architects to develop a model for this purpose, and conducted a community workshop in May 2006. The workshop was an open forum for people to voice their concerns and develop estate improvements in an organized and rational manner. Various options were explored and evaluated and some improvement works were finally proposed. The workshop established a sense of trust and was very well received by residents. It also
demonstrated that we are sensitive to the well-being of residents and respond to their concerns. We are working on applying this model to other newly completed estates in the future, to try to build trust and a sense of ownership as the community develops.

5.9 Initiatives to Secure and Monitor Wages Payment to Workers

With the multi-layered subcontracting system in use in Hong Kong, construction workers are vulnerable to wage arrears. Commercial disputes between contractors and sub-contractors may lead to late payments or non-payment at lower levels of subcontracting and as a public sector client the HA may be singled out for public criticism when incidents of workers’ wages in arrears occur, even when we have paid the contractors for the work done or service provided. Labour disputes between contractors and sub-contractors and their workers eventually affect the quality of service or cause delays.

In response to some serious incidents on building contracts in late 2005 to early 2006, and after building on the experience gained in some Government pilot projects, we consulted the industry, including sub-contractors and workers, and have developed improvement measures to secure and monitor the payment of wages to workers which have been adopted in building contracts and nominated sub-contracts from May 2006. The measures include employing Labour Relations Officers to conduct on-site checks of labour and verify records of workers in employment, and records of their attendance; the payment of wages and acknowledgement of receipts; thoroughly monitoring the situation and identify any anomalies. The Labour Relations Officers will also receive, acknowledge and record complaints and inquiries from workers.
6. ENGAGING STAKEHOLDERS: IN PURSUIT OF ECONOMIC SUSTAINABILITY

The economic performance of an organisation provides the key to its success and hence its sustainability. Cost effectiveness is critical to the HA because decisions on any aspect of the housing programme from design, through construction, to operations and maintenance will have such an impact on the public purse. Cost-efficiency is being achieved through a number of measures, including the listing of some of our assets and implementing management measures to sustain the useful life of our existing buildings. Management measures to get the best returns out of the HA resources are constantly reviewed. Enforcing better tenancy controls to reduce the abuses of public housing, more efficient maintenance services and hence upgraded assets via the Total Maintenance Scheme and reducing vacancies in flats are very important areas.

6.1 Life Cycle Costing and Life Cycle Assessment

In view of the large stock of buildings and its large customer base, the HA has a culture of using simple designs and materials that are long-lasting, easy to care for and environmentally friendly. Life cycle cost and life cycle assessment are important components of a building’s performance, both in the design of new buildings and their future management. In 2002 to 2005, the HA commissioned consultants to carry out a study of life cycle costing and assessment on its typical domestic buildings. The study confirmed that the materials that are used, achieve an optimum environmental performance and life cycle cost effectiveness (Photo 6). Designers are now using this life cycle costing and life cycle assessment software to help them make decisions on the choice of new materials in future designs and thereby help to reduce HA’s maintenance burden in future.
6.2 Regenerating the Public Housing Stock

In 1988, the Comprehensive Redevelopment Programme was launched to improve the quality of life for residents in older estates and ensure that HA housing stock is upgraded. Since its inception, 535 blocks have been redeveloped providing improved housing for 182,010 households. The remaining 31 blocks in three estates, involving a further 10,110 households, will be redeveloped in 2008/09. A set of technical criteria was created in consultation with local and international specialists, to assess the condition of older estates and provide options for their protection, restoration and if necessary, their structural strengthening.

We subsequently launched comprehensive structural investigations at nine estates, with investigations completed so far at So Uk Estate in Sham Shui Po and Sai Wan Estate in Kennedy Town. As a result of these investigations, we announced in March 2006 that So Uk Estate would be demolished. While the 16 blocks of this estate built in the 1960’s are all structurally sound, the extensive repairs required would, apart from the nuisance and disturbance to tenants, not be cost-effective. As a result, the 5,316 flats will be cleared in two phases in 2008 and 2011. The life of Sai Wan Estate however, will be prolonged for a further 15 years, with the repairs and improvements to estate facilities carried out as part of the routine maintenance programme.
6.3 The Total Maintenance Scheme

In February 2006, a new Total Maintenance Scheme was implemented, which was a major new initiative in the maintenance of our public rental housing estates, and takes an innovative approach to proactively identifying resident’s maintenance needs and responds promptly to emergencies and requests for repairs, while also strengthening publicity and education on maintenance issues.

The Total Maintenance Scheme makes use of “In-flat Inspection Ambassadors” who will visit all households, inspect flats thoroughly to identify maintenance needs and immediately rectify any problems. The scheme aims to complete the inspection of 30 estates in a year and of all rental flats in a five-year cycle. The scheme also includes the setting up of a maintenance database on a individual flats, the strengthening of research and development in diagnostic methodology and maintenance, and the establishment of a maintenance hotline as well as the mapping out of a comprehensive promotional and educational plan.

6.4 Piloting Modified Guaranteed Maximum Price Contracting Model

In the mid 2006 we embarked on a Modified Guaranteed Maximum Price Contracting model in a pilot project at the Eastern Harbour Crossing site Phase 4. This contract arrangement requires the contractor to commit to a price ceiling (maximum price) based on his design proposals at the contract award stage. It allows for sharing of cost savings between the employer and the contractor arising from alternative design proposals after contract award, hence providing cost saving incentives and integrating the contractor’s expertise and innovation and enhancing design and buildability.

7. THE FUTURE

Public housing in Hong Kong has made an enormous contribution towards the well-being of the community. We have to define our sustainability priorities very clearly, develop and maintain a sound strategy for the future which will not only
achieve our goals but also respond to the changes that may arise from time to time. The sustainability of our programme is inextricably linked to economic, social and environmental performance. We must demonstrate through our day to day actions that our vision and mission are credible; our provision of services is cost-effective. We need to continue to engage with all stakeholders to gain their support as we articulate our strategies and lay out a road map in driving sustainability initiatives.

8. REFERENCES
THE STUDY OF PROPERTY MANAGEMENT IMPLEMENTATION FOR DESIGN AND PLAN STAGE OF THE CONSTRUCTION

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ABSTRACT: The life cycle of the buildings can be decades. As the local development expends with the growth of the economy, the environment will also change, causing influence on the living safety and quality and the early planning and designing stage for constructions has close influences on public safety and property value. Therefore, having a complete property management system is very important. The study focuses on the property management implementation in the construction life cycle. The property management implementation of the early plan and design stage of the construction life cycle focuses on problem solving between the owners’ administration committees and property management firms in the early stage before the commencement of their property management service contract. The main idea is not only consider the early stage construction costs, but also consider the design planning, subcontracting, constructing, operating and renovating repair cost. It makes an entire plan to seek the beneficial result for the budgets and to minimize the life cycle costs.

The idea is to make a detailed plan in the early plan and design stage. Instead of making the construction plan at a passive condition, the plan should be made according to the users’ living needs and maintenance management demands. The study of property management implementation for the early stage of construction life cycle is believed to help extend the life cycle of the construction; to further the functions and efficiency; to assure the safety of the users; to prevent disputes cause by the transfer of property right and even helps increase the future construction quality.

1. INTRODUCTION

Speaking of the construction management system; the construction administrative system had been well developed, but the management and maintenance strategy have yet to have an integrated and suited implementation. This often caused the difficulty of finding the right timing for the implementation of property management for construction and even caused the problem of unable to develop the real effectiveness. For the domestic case, the implementation of property management is usually after the establishment of the owners’ administrative committees (figure 1). Therefore, often cause the illegal situation of remodeling and build-after-Occupancy-Permit cases. This paper aims at proposing the implementation of property management at the planning stage of construction (figure 2) to make new change for the owners to be at a passive condition during construction planning and designing. It completes the integrity of the management mechanism in addition.

All the construction and its auxiliary facility have its life time; in another word the construction has its life cycle. The integrity for construction life cycle management (LCM) is to imply the concept of property management. Therefore, by applying property management in the long life cycle of the construction, the property management plays an integration role in the life cycle of the construction. Since property management aims at the planning, management and operation for all types of construction and its auxiliary facility, it is actually to integrate and plan the life cycle of the construction. This makes property management a sustainable management for construction.

The study focus on property management applied to life cycle management of the construction. It Expectations are thus to establish the implementation opportunity and
framework for property management into the life cycle of the construction and other related measures for the plan and design stage of the construction.

Figure 1: The implementation of property management for construction projects in Taiwan.

Figure 2: The implementation opportunity for property management in construction project.

2. LIFE CYCLE MANAGEMENT AND PROPERTY MANAGEMENT

2.1 Life cycle management

Basically, each construction project; from planning, designing, bidding, contracting, construction, operation, maintenance and demolition, forms a life cycle and the improvement in any stage of the life cycle management is an important issue in improving construction project quality. The comprehensive concept of life cycle management begins from suitable diagnosis and evaluation for use of the land; suitable construction and development; efficient operation and management of the
facility; reasonable maintenance and secure the benefit. With the help life cycle management for construction project can not only help recover or even improve the image and competitiveness of the construction industry, but also extend the construction life time; ensure the value of the construction asset; satisfy the safety and comfort for the owner.

The construction life cycle; requirement, planning, design, construction, maintenance, is closely related with property management. The study implements the integrity concept of property management for the planning and designing stage in construction life cycle. Furthermore, it also considers other stages and the impact to the management system; hoping through the construction life cycle management (figure 3) to help forward inter-industry integration and to make the best benefit.

Figure 3 : The construction life cycle management

2.2 Property management

The definition for property management according to the development guide and action plan for the property management service industry approved in 2004, by the council for economic planning and development defines as follows:
The broad definition: property management aims at providing the management for the construction facility, service and maintenance; both hardware and software, to make a best living environment for the owner. [1]

The narrow definition: property management is the real estate management and supporting services for business and living or all the related management activities for the construction.

The service of property management approved by the council for economic planning and development can be separated into these three groups:

1. The environmental and construction use management and maintenance: It provides the construction and environmental management, maintenance, clean, security, public safety inspection, auxiliary facility maintenance and other services.

2. The supporting services for living and business: It provides the property consultation agency, affair management, property living service (community network, care service, babysitter and logistic home delivery), needs and other business supporting services.

3. The asset management: It provides real estate management consultant; development; lease and other investment management services.

The property management is real estate management with living and business supporting service. According to the analysis report from the property management service industry of ministry of interior, the property management focuses on the construction hardware facility and living environment service. Property management is the management activities for all the use of the construction. [2]
3. CONSTRUCTION LIFE CYCLE

3.1 Construction life cycle cost analysis

The life cycle cost for the construction and its auxiliary facility includes the capital, manpower and time invested in the plan, design, subcontract and construction. Even more, it includes the cost spent in the long time operation and maintenance after construction. The cost spent in this stage, maintenance and operation, accounts for 51.1% of the total construction life cycle cost (figure 4) which is three to four times of the design and plan cost. In addition, the scholar Wen-Chun Chang also point out: Japan has the complete result of cost analysis for the construction life cycle since they had been doing long period of research and analysis. The result indicates that the normal Japanese construction maintenance cost accounts for 51.1% of the total life cycle cost. It is the three to four times of the design (0.4%) and construction (15.8%) cost. The result concludes that the operation and maintenance stage is important to the construction life cycle. By implementing property management in construction design, plan and maintenance stage; it not only provide better use and comfortable environment, but also make superior managerial efficiency and cost control.

![Figure 4: the distribution percentage of life cycle cost [3]](image)
3.2 Construction life cycle point of view

The construction life time can be defined as the physical life time, functional life time, society life time and tax law life time of the construction. The construction life cycle is the cycle of (1) think idea; (2) design and plan; (3) bid and contract; (4) construction; (5) operation and maintenance (figure 5). And the real estate life cycle is plan, design, market position, pre-sale, construction, sale, maintenance, lease or sale agency, operation management. With the help of coordinate the life cycle point of view for construction project, property management and human, the development can be made to find the relationship in each point of the property management point of view (figure 6).

![Figure 5: Construction life cycle [4]](image)

![Figure 6: The comparison for life cycle point of view](image)

Theme B: Creating a livable, healthy and environmentally viable cities
3.3 Importance of construction plan and design stage

No matter what type or scale of the construction, it has its life limit. When its life cycle proceeds, the construction is in function for a long period of time until it becomes no more economic value. In the research by R. Ries and A. Mahdavi, it divides the construction life cycle into three stages: construction, operation and decommission [5]. It also develops a computer evaluation system to support the life cycle assessment during the design stage of the construction in order to understand the environmental impact caused by construction. In the “Handbook of Building Maintenance Management”, it has illustrate the cost and time spend in each stage of the construction project: the average construction project requires 3 years for the planning; 1~2 years for the designing; 4~5 years for the construction depending on the scale of the project and the operating and maintaining lasts 40~50 years which is 9~10 times of the time spent for all the other stages [6]. This proves the importance for operation and maintenance within the construction life cycle. However, all the stage within the construction life cycle is closely connected, if the plan and design does not meet the need for the users, it will cause the problem of reconstruction or other future operation and maintenance problems. Therefore, with good management of the beginning stage, plan and maintenance, for the construction management; it prevents the unnecessary cost.

4. THE DEFECTS CAUSING THE DIFFICULTY IN THE IMPLEMENTATION OF PROPERTY MANAGEMENT

4.1 The implementation defects during construction plan and design stage

The study focus on the implementation defects during construction plan and design stage. The study draws the conclusion of the following three defects:
1. The disputes of the construction plan and design stage: From many cases and experiences, the disputes caused by the change to the auxiliary facilities of the construction is one the most often seen disputes in property management. People often are attracted by the hardware or auxiliary facility when buying pre-sale houses, but later they find it is inconsistent with the actual situation. For example: the statutory motorcycle parking lot was changed privately into car parking lot and resell situations. These all cause problems to the property right with the owners or buyers. This is illegal to the building certificate and only can be resolved through legal action.

2. Public profit taken illegally: There are many cases that the owners make profit by building illegal roof structure and set advertisement on the façade of the structure without approval from the administrative committees and the profit did not share with other residential owners. The situation can only be resolved through legal action or with the help with property management companies to recover within the asked deadline.

3. The price policy for property management: The price policy for property management depends on the cognition of the importance for property management. When the service is not equal to the price for the property management company, it caused damage to the trust for the company and the anxiety for paying the property management. This is the problem with the implementation of property management.

4. The implementation difficulty during construction plan and design stage

Since there is many problems with property management, for example: property management is still not popular on the market; administrative committee authority was not taken seriously; property management service was poor. Therefore the study
focus on the plan and design stage of the construction and propose the following
difficulties in implementing property management:

1. Consanguinity relation Influence on marketization: Because of the consanguinity
relation between property management company and developer, when the owner finds
problem with their house, the property management company becomes the cover for
the developer. They shift the responsibility between each other and revels the
immaturity of property management during plan and design stage. This makes
difficulty in implementing property management.

2. The contradictions caused by remain problems from the developer: The remains
problems are the defects of auxiliary facility and quality issues which cause the
distrust of the buyers. Further more, most early developed building did not establish
repair funds; making difficulty for the property management company to do repairs.
This caused the owners refuse to pay for the management fee. The study gives two
case studies, government and personnel construction, focusing on the imperfection of
quality and other problem with construction auxiliary facilities: (1) The Chu-Wei
market constructed by Chiayi government in 1995, the tiles continuously peeled off
from the building external wall (figure 7) which fall on the cars below causing
damages. The situation becomes serious whenever typhoon rages (figure 8). The Feria
typhoon, 2005, even caused serious damage to the tiles. The administrative
committee questioned the government for the construction quality and react with legal
action. (2) In 2006, just after the completion and acceptance; the roof of the privet
enterprise construction at Taichung began leaking because of the poor waterproof
quality. Moreover, there were many other problems for example: the airtight windows
could not be closed (figure 9), low quality bathroom drainage facility (figure 10) and
air exhausting facility, illegal situation of building walls at the fire prevention channel.
The construction administrative committee represented the residents to take legal action for quality problems with the developers.

3. Low participation for owners: Since not all of the administrative committee members have a certain level of legal literacy, therefore they could not fulfill the demands of all the residents on choosing the right property management company. The choosing of the suitable property management company should have a deep understanding between owners, management committee and property management company. The lack of professionals caused them have to decide by the price instead of making evaluation for finding reasonable price according to the actual situation.

4. The property management company unwillingness to do autonomous service: In the property management market, there was still a small part of the company which was unwilling and passive to do property management works. For example: they cut down the workers from three to two people that made the workers need to work over
hours. There were still a lot of this small property management companies and did not have any entrepreneurship.

5. THE STRATEGY FOR IMPLEMENTATION OF PROPERTY MANAGEMENT IN THE CONSTRUCTION DESIGN AND PLAN STAGE

5.1 The integrity of property management

Since our government construction management system is a limited construction management norm; which can only maintain the construction safety through public authority for banning the use of irregularity buildings. Therefore by implementing and combining the concept of construction management and property management should solve the problems that caused by improper planning, low price competition, construction dispute and responsibility [7].

From the actual case of the chloride building, radioactive steel house and the 921 earthquake reveal that there is still improvement to make for the construction management system of our country. It is important to re-conceive how to improve safety issue for the construction and develop a complete management and maintenance system at making plan and design to ensure the safety of the residents.

Most advanced countries like America and Japan rely on government construction management organization to make special laws. However, the problems of illegal construction still can not be solved. It is even worst for the situation in Taiwan. In order to solve the problem, the study proposed that: isolate the executive and professional; rely on professional license and community self governing. Moreover, the property management can prevent the safety issues, potential disaster and risk in
the construction management of our country. Therefore it is more effective to maintain the construction quality and also fulfill the need on safety management.

5.2 Sustainable property management

Property management plays an important role in communicating between the government and community. Property management must seek to be sustainable management. The study focused on sustainable property management and proposed the following principles:

Rationalization: Rationalization is a loop of continuous improvement. It is a life cycle of PDCA: plan; do; check and action (figure 11).

![Figure 11: PDCA Life Cycle](image)

Besides focusing on the regular management scope, property management should also emphasis on those special key points. By finding the main cause of the problem and resolve the obstacles can prevent the happening and improve the competitiveness.

Property management is standardized through the ISO9000 certification. Most of the property management companies have passed the certification. The study gives the following management principle:

No faking: theoretical is different from practical implementation.

Continuous improvement: Follow the standards and make continuous improvement.
Not to deliberately take action: Not to deliberately make a pile of information just for the assessment.

2. Performance management: performance management is to improve performance. According to research, without management, the work performance can only perform 40% of the normal level. Having the system of rewards and penalties; managing by a responsible manager are the means to reach the normal level of performance.

3. Self-management: John Naisbitt said “21th century is a self-management epoch”. Psychologist, A.H.Maslow; in his proposal of a hierarchy of human needs. There are five layers of the needs. When the living and knowledge standards improves, personnel needs self-actualization. Personnel are the most precious resource and with effective encouragement, management and self-management can improve the capabilities.

5.3 Implementation of property management at the plan and design stage of the construction

The problems of the construction, occur during the operation stage, are caused by the abnormal use and maintenance; low quality construction; inadequate planning for the demands, maintenance management, maintenance cost for the owner. Therefore, the study suggests implementing property management at the plan and designing stage of the construction (figure 12). The construction companies should be responsible for the property management considering the living needs, maintenance management to prevent the problems of reconstruction.
From the construction life cycle, plan, design, subcontract, construct, operation, maintenance, rebuild; the maintenance period is the longest. Maintenance, repairing and fixing, is a big part in the life cycle cost. With good plan and design can not only provide a comfortable and convenience environment but also can effective control life cycle cost and prevent problems. It ensures the construction quality.

5.4 Subcontract strategy for maintenance management organization

Under the complexity and specialization of modern construction, the subcontract strategy for maintenance management organization at the plan and design stage, should refer to or combine with the features from China and Hong Kong. For those facilities require difficult technology and specialization to maintain, for example: elevator, central control air conditioner, fire prevention system, it is better to subcontract to a specialized company for maintaining. For those facilities require no difficult technology, can be maintained by the property management company. Moreover, the sanitation and greening can also be subcontracted. This can effectively safe the management cost and increase the efficiency and service quality.

5.5 The business model of property management

The study focus on propose effective ways to solve problems and make improvements for the construction. The following are two actual cases of business models:

**Figure 12**: Diagram of the implementation of property management at the plan and design stage of the construction
1. No administration fee

After 8 years of promotion by the Chung Hua property management association, the Jung Kuang community and many companies (ex. Takkubin, Taipei agricultural products marketing cooperatives and etc.) made strategic alliance. The main purpose is to provide convenience living and commercial needs. Hopefully, with the huge purchasing power and needs for the living service, it can be a cooperative force to fascinate the companies to give preferential cost. Thus community property management can make living convenient with the least expenses. The administrative fee have been cut down 30–40%; from NT1000/month to NT600~700/month (figure 13). Which comes from the discount and compensation provide by the cooperative companies. The amount of the discount and compensation will gradually increase to achieve the objective of have no administration fee.

![Figure 13](image)

*Figure 13 : The diagram of the decrease for the administration fee every year*

2. Quality advertising revenue

The study suggest to take legal actions for those illegal advertisements which are self-constructed at the roof or the external wall of the building without having permit from the building administrative committees. On the contrary, a complete revenue plan of the construction and its auxiliary facilities approved by the administrative committees can help make extra income to reduce the administration fee or even make other investment.
For example: the spring autumn building located at the intersection of Sec.4, Jhongsiao E.Rd. and keeling Rd. The building is 25 years old compound building and it has 14 floors and 120 units (figure 14). Since the location has a high rate of traffic flow and the external of the building is the best place to attract the drivers’ attention, it is the best location for advertising. The two external wall (figure 15) of the building is rented at the price of 5 millions and around 2 millions of dollars. The revenue from the rental reduced the administration fee, from NT50~70/Pin to NT25/Pin or even NT20/Pin without anybody living (figure 16), and provide the repairs and maintenances cost for the building. The renewal of the building external wall and other maintenance was paid from the advertising revenue. It made a better living environment and increased the value of the building.

*Figure 14:* The location of the spring autumn building  
*Figure 15:* The external wall of the building

*Figure 16:* Comparison of the administration fee
6. CONCLUSIONS AND RECOMMENDATIONS

The study proposed the following conclusions and recommendations for the implementation of property management during the plan and design stage.

6.1 Conclusions

Early implementation of property management: Construction is like a person, which has a complete life cycle. The maintenance stage takes more than 90% of the time in the life cycle. Therefore, property management should consider details of the maintenances at the plan and design stage to prevent problems of the construction and even reconstruction caused by the inconsideration. It is important to make early implementation of property management and early participation for the design and plan of the construction.

The norm for the construction auxiliary facilities: The purpose of the norm is that public construction and public auxiliary facilities can only be changed unless approved by the administrative committee of the building. Therefore without approval, anyone can not make changes to the property.

To prevent encroachment of the public revenue: Some owners make business using public area and public facility. This kind of revenue they make belong to all the residents and the building administrative committee. It is mostly used as a repair fund and the decision should be made only through the administrative committee.

Make penalty for the illegal encroachment: In order to prevent making revenue with public property, it is important to make penalty for the illegal encroachment.

6.2 Recommendations

According to the research, in many areas of China; for example: Beijing, Shanghai and others, they had found the most suitable facility and efficient control for the
investment and management cost through focusing on the characteristic, resource saving and cost reduction at the plan and design stage of the construction. From the actual case, the effective plan and design can reduce the management cost and makes it convenient for the management. Beijing had asked that before receiving the pre-sale permit, the property developer should pass the examination of the contract; before sign the contract, the buyer should make agreement with the developer. There are still problems that the developer does not want to show the contract to the buyer [8]. The study hope that the future planning of the property management contract should consider the actual case of Beijing and the contract should also be fair and disclosure to avoid mismanagement.

7. REFERENCES

[1] 行政院經建會, 物業管理發展綱領, 台北, 2004。


[7] 內政部建築研究所研究報告，建築物設施管理維護關鍵績效指標之研究，2006。

[8] 馮曉芳（2003），我國物業管理覆蓋面占物業總量的 38%，京華時報第 A8 版，大陸。
THE STUDY OF PROPERTY MANAGEMENT OPERATION MODEL FOR ADVANCED COUNTRIES

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ABSTRACT: The study focus on a series of property management researches for those developed countries (America, Japan, Singapore, China, Hong Kong and Taiwan). The research methodologies were through differential analysis and study the development of those developed countries in their association, management system, system structure and general situation. The study not only set up an information exchanging communication between different management systems in various countries, but also with site investigation and interview to give management advices to solve management problems for construction and its auxiliary facilities. It helps extend the life of the building; maintain the safety and value of the building; fulfill the needs of the owner; increase the building management execution efficiency and sustainable development. The study will help totally increases the competitiveness and the advantage of the property management.

Keywords: Property Management, Differential Analysis, Management System.

1. INTRODUCTION

As a result of the growing economy and the expanding of the real estate market in the 21st century, the developments have been made for the economy; housing commercializing in recent years. The construction is evolving to become more refined and professional. The old management of the building made from the lease agreement only emphasize on the Building cleaning, landscaping, mechanical and electrical maintenance, security management and other routine managements. This non-professional management not only is worrisome in its management performance...
and service quality, but also cannot fulfill the needs and changes for the building owners and user. On the contrary, property management in England, America, Japan and Hong Kong have become the integration of building maintenance, renew and asset management. Therefore, the most important issue is that the value of the construction, its function and assets, can be maintained with profession and in order for the reform of this new management and maintenance model, property management has become the need for the real estate management; building maintenance and operation. To meet the need of the huge market for property management, how to develop a professional model to make better efficiency for the maintenance; management and operation of the building has been the most important task. The study focus on the development of property management for developed countries and bring management system of different countries for the overall planning for the property management.

2. PROPERTY MANAGEMENT ASSOCIATION IN VARIOUS COUNTRIES

2.1 Institute of Real Estate Management

The Institute of Real Estate Management, established since 1933, is the subordinate organization of National Association of Realtors. It is the leading organization in the global property management and assets management and it has over 16,000 members of property management specialists. The main contribution was to set up the international standards for property management; to train professionals and make professional qualification: it has the certification for the Certified Property Manager and Accredited Residential Manager. The number of certified professionals and organizations are shown in Table1. and 2. IREM believe that property management is
to manage, operate, market and maintain the property according to fulfill the demand of the owners. The main purpose of the IREM is to improve the development for the property management industry and make more value of the asset and property.

**Table 1**: Statistic data of professional qualification

<table>
<thead>
<tr>
<th>Professional Qualification</th>
<th>Number of Person</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certified Property Manager</td>
<td>9,000</td>
<td>Managing the investment for all types of properties</td>
</tr>
<tr>
<td>Accredited Residential Manager</td>
<td>3,500</td>
<td>Residential management</td>
</tr>
</tbody>
</table>

**Table 2**: Qualified management organization by the IREM

<table>
<thead>
<tr>
<th>Professional Qualification</th>
<th>Number of Property Management Company</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accredited Management Organization</td>
<td>1,000</td>
<td>It requires professional standards; financial stability and at least one CPM</td>
</tr>
</tbody>
</table>

Since the globalization and expanding development of property management from 1990, the property management training and qualification develop in IREM and all the other global cooperative organizations (Table 3).

**Table 3**: Some of the IREM global cooperative organizations

<table>
<thead>
<tr>
<th>Country</th>
<th>Property Management Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>JREM-Japan Real Estate Management and Human Resources Association</td>
</tr>
<tr>
<td>Korea</td>
<td>KREBA-Korea Real Estate Brokers Association</td>
</tr>
<tr>
<td>China</td>
<td>Beijing Property Investment and Management Company</td>
</tr>
<tr>
<td>Europe</td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>CAF-Consejo General de Colegias de Administradores de Fincas</td>
</tr>
<tr>
<td>Portugal</td>
<td>ALP-Assiociacao Lisbonense de Proprietarios</td>
</tr>
<tr>
<td>Poland</td>
<td>IREM Poland Chapter No. 108</td>
</tr>
<tr>
<td>Russia</td>
<td>RGR-Russian Guild of Realtors</td>
</tr>
<tr>
<td>South America</td>
<td></td>
</tr>
</tbody>
</table>
2.2 Japan Property Management Association

The Japan Property Management Association (JPM) formed alliance with IREM in 2000. It is authorized to give lesson and examination for becoming a qualified property management professional.

2.3 The Hong Kong Association of Property Management

The Hong Kong Association of Property Management Companies (HKAPM), established in January 1990, is composed of many property management companies(Figure 1~6), organizations and since Hong Kong was once a British colony; so the management system was influenced by them.

![Figure 1: Liang-Ching property management company](image1)

![Figure 2: Hong Yip service company](image2)

![Figure 3: Alico management limited](image3)

![Figure 4: Liu, Chong-Hing property management company](image4)
The main function of HKAPM is to help business give services and to give advises to the Hong Kong government for revising the building management ordinance. The following are some of the functions:

1. Establish the property management and building management professional standards.

2. Provide the government and organization with professional advisory and consultant in property management.

3. Set up the standards and maintain the rights for the members.

4. To advance the cooperation and service level for the property management companies.

5. Provide property management professional trainings.

**2.4 China Property Management Institute**

The China Property Management Institute (CPMI), establish in October, 2002 at Beijing, has over 1,200 members. The China local property management associations are shown in Table 4.

**Table 4**: The China local property management associations.

<table>
<thead>
<tr>
<th>Administrative</th>
<th>Associations</th>
</tr>
</thead>
</table>

333
<table>
<thead>
<tr>
<th>Divisions</th>
<th>Associations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipalities</td>
<td>Tianjin property management association; Chouqing property management association; Shanghai property management association.</td>
</tr>
<tr>
<td>Hebei Sheng</td>
<td>Hebei property management association; Shijiazhuang property management association.</td>
</tr>
<tr>
<td>Shanxi Sheng</td>
<td>Datong property management association.</td>
</tr>
<tr>
<td>Inner Mongolia</td>
<td>Hohhot property management association; Baotou property management association.</td>
</tr>
<tr>
<td>Liaoning Sheng</td>
<td>Shenyang property management association; Dalian property management association; Dandong property management association.</td>
</tr>
<tr>
<td>Jilin Sheng</td>
<td>Jilin real estate association; Jilin property management association.</td>
</tr>
<tr>
<td>Heilongjiang Sheng</td>
<td>Harbin real estate and property management organization.</td>
</tr>
<tr>
<td>Jiangsu Sheng</td>
<td>Nanjing property management association; Changzhou property management association; Nantong property management association; Shzhou property management association.</td>
</tr>
<tr>
<td>Zhejiang Sheng</td>
<td>Wenzhou property management association; Hangzhou property management association.</td>
</tr>
<tr>
<td>Anhui Sheng</td>
<td>Anhui property management association; Hefei property management association.</td>
</tr>
<tr>
<td>Fujian Sheng</td>
<td>Fujian property management association; Amoy property management association; Zhangzhou property management association.</td>
</tr>
<tr>
<td>Shandong Sheng</td>
<td>Tengzhou property management association; Qingdao property management association.</td>
</tr>
<tr>
<td>Province</td>
<td>Property Management Associations</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Henna Sheng</td>
<td>Henna property management association; Zhengzhou property management association; Xinyang property management association</td>
</tr>
<tr>
<td>Hubei Sheng</td>
<td>Wuhan property management association; Yichang property management association.</td>
</tr>
<tr>
<td>Hunan Sheng</td>
<td>Changsha property management association.</td>
</tr>
<tr>
<td>Guangdong Sheng</td>
<td>Guangdong property management association; Guangzhou property management association; Shenzhen property management association; Zhuhai property management association.</td>
</tr>
<tr>
<td>Guangxi Zhuang autonomous region</td>
<td>Nanning property management association; Beihai property management association.</td>
</tr>
<tr>
<td>Hainan Sheng</td>
<td>Hainan property management association.</td>
</tr>
<tr>
<td>Sichun Sheng</td>
<td>Mianyang property management association; Chengdu property management association.</td>
</tr>
<tr>
<td>Guizhou Sheng</td>
<td>Guiyang property management association.</td>
</tr>
<tr>
<td>Yunnan Sheng</td>
<td>Kunming property management association; Yunnan property management association.</td>
</tr>
<tr>
<td>Gansu Sheng</td>
<td>Lanzhou property management association.</td>
</tr>
</tbody>
</table>
| Xinjiang Uyghur autonomous region | Urumqi property management association; Xinjiang property management association. | After the implementation of the property management ordinance in September, 2003; the CPMI plays an important role and some of its main functions are as follows:

1. Help the government with implementation of property management law; make policy; help with industry development and training.

2. Help the government with transferring and promoting of the new technologies; products; research achievements.
3. Represent the business to coordinate and communicate with the government.

4. Help with the organization development: professional training.

The CPMI place great importance on personnel training and set up a training facility to train those personnel with their training process (Figure 7).

![Figure 7: Property management personnel training process.](image)

### 2.5 Chung Hua Property Management Association

Chung Hua Property Management Association (CHPMA), established on November 11th, 2003, is to promote property management law and policy; also help with property management works. These are some of the main functions:

1. Help the government with implementation of property management law; make policy; help with industry development, research and training.

2. Help solving the disputes that occurs during giving property management service.

3. Conduct property management professional training and implementation work.

4. Conduct entrusted property management work from the government, non-government organization and business.

5. Make property management becomes specialization, institutionalization and certification through the skill certification test.
CHPMA is also very conductive with the development of the Taiwan property management. The following are some of the situation for property management in Taiwan:

1. Set up offices in all areas in Taiwan and help with implementation work of property management.

2. CHPMA helps to set up a local property management association in places like Taipei, Taoyuan, Kaohsiung and etc.

3. CHPMA was formed by the former Taipei building service community association and Taiwan building quality management association and Figure 8 is the evolvement of the CHPMA.

![Figure 8: The evolvement of the CHPMA](image)

3. PROPERTY MANAGEMENT SYSTEM IN VARIOUS COUNTRIES

3.1 America Property Management System

1. The implementation of property management system in America

In the community and building management system of the America, the state regulation of building ownership includes the regulation of interior management
organization; stipulation agreement; rental and repair. The Unit Owners Association has the right to hire fire or manage any members.

Most of the states have their standards to manage the rent, operation, management and etc. And for the contract between the management committee and the property management company, the property management company should provide services such as rent, clean and other services. The America property management has become not just simple property management, but transforms into business investment.

2. The certification of America property management professionals

The certification of America property management professionals is awarded by the IREM according to the basis of professional training, work experience and professional morality.

3.2 Japan property management system

1. The general situation of property management in Japan

The current Japan building management ordinance was established on December 12th ,2000. As the highly development of land and environmental change, the main purpose of the ordinance is that the property management can only be handled by certified property management professionals to ensure the living environment and quality. Table 5 shows the building management works according to the ordinance.

<table>
<thead>
<tr>
<th>Work Item</th>
<th>Work Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative</td>
<td>Cashier, accounting, management and operation.</td>
</tr>
<tr>
<td>MANAGEMENT</td>
<td></td>
</tr>
<tr>
<td>Works of Manager</td>
<td>Acceptance, exam, meeting, report, communicate and assist management.</td>
</tr>
<tr>
<td>Cleaning work</td>
<td>The cleaning of the public areas.</td>
</tr>
<tr>
<td>Facility management work</td>
<td>The maintenance of the construction, auxiliary facility, elevator, water supply and drainage system, sanitary facility and fire prevention facility.</td>
</tr>
</tbody>
</table>
2. The certification of Japan property management professionals

The certification launched two types of professional licenses according to the Japan property management ordinance: the building management officer and building management managers (Table 6).

**Table 6**: The certification of Japan property management professionals

<table>
<thead>
<tr>
<th>Title</th>
<th>Building Management officer</th>
<th>Building Management manager</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authority</td>
<td>Ministry of Land, Infrastructure and Transport</td>
<td>Ministry of Land, Infrastructure and Transport</td>
</tr>
<tr>
<td>Execution</td>
<td>Building Management Foundation</td>
<td>Building Management Foundation</td>
</tr>
<tr>
<td>Ordinance</td>
<td>The 5 and 6 ordinance in the Japan building management ordinance</td>
<td>The 56 and 57 ordinance in the Japan building management ordinance</td>
</tr>
<tr>
<td>Examination</td>
<td>1. Building management ordinance.</td>
<td>1. Related works in management and entrusted contract.</td>
</tr>
<tr>
<td></td>
<td>2. Successful operation for management.</td>
<td>2. The accounting and cashier of the management organization.</td>
</tr>
<tr>
<td></td>
<td>3. Construction and auxiliary facility structure.</td>
<td>3. The maintenance plan for building and its auxiliary facilities.</td>
</tr>
<tr>
<td>Admission Rate in 2003</td>
<td>43912 people applied for the test; 37752 people took the test and 3021 people passed the test. Admission rate is 8%.</td>
<td>31558 people applied for the test; 27017 people took the test and 5651 people passed the test. Admission rate is 20.9%.</td>
</tr>
</tbody>
</table>

3.3 **China Property Management System**

1. The general situation of property management in China

The property management ordinance of China announced on June 8th, 2003, made standards for property management activities; ensure the rights between the owners and property management companies and to give a better living environment. The definition of property management in China is that the owner makes a service contract
with the chosen property management company to provide the maintenance and management of the property.

2. The certification of China property management professionals

According to the property management ordinance, the certification of the China property management professionals is only approved by the government and the professional certificate can only be awarded after passing the national exam (Table 7).

Table 7: The national exam for property management

<table>
<thead>
<tr>
<th>Title</th>
<th>Property management officer</th>
<th>Property manager</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level</td>
<td>Level 4</td>
<td>Level 2</td>
</tr>
<tr>
<td>Property</td>
<td>Chief of the management department; property manager and professional.</td>
<td>Professionals who deal with technical complexity, common-involving national property and the interests of consumers.</td>
</tr>
<tr>
<td>Requirement</td>
<td>1. Bachelor degree in related fields or qualified from the property management training. 2. At least one year work experience in the field.</td>
<td>1. Passed the property management officer exam and passed the further training of the required hours. 2. Bachelor degree or above in related fields; at least three year experience and passed the further training of the required hours.</td>
</tr>
<tr>
<td>Issued Department</td>
<td>National Labor and Social Security Department</td>
<td>National Labor and Social Security Department</td>
</tr>
</tbody>
</table>

3.4 Taiwan Property Management System

1. The general situation of building management in Taiwan

The building management ordinance is for the building community. The administrative committee makes contract to hire property management companies for the management and maintenance service.

In the stereotype contract for hiring the building management and maintenance company; the service provide by the building management and maintenance company...
should include: (1) General affairs; (2) Maintenance and repair of the construction; (3) Inspection and repair for the construction auxiliary facilities; (4) Clean and maintain the environmental sanitation; (5) Safety and disaster prevention management for the surrounding environment. Except the general affairs should be handled by the service person send by the building management and maintenance company, all the services should be first approved by the owner and then designated to the third person to be appointed executive.

2. The certification of Taiwan building management professionals

The Taiwan building management professionals are the people who qualified from the professional training and examination (Table 8). There are two types of certification for the building management: the affairs manager and the service technician. The service technician is then separated into the service technician for the fire prevention and evacuation facilities; also the technician for facility safety.

**Table 8** : Training course for the building management professionals

<table>
<thead>
<tr>
<th>Training subject</th>
<th>Contents</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulation of building management for service employee</td>
<td>Illustrate the Regulation of building management for service employee</td>
<td>2</td>
</tr>
<tr>
<td>Building management ordinance and management manual</td>
<td>Explanation of the ordinance</td>
<td>3</td>
</tr>
<tr>
<td>Management and technique for construction business plan.</td>
<td>Dements of the construction owners; construction business management; construction maintenance management</td>
<td>2</td>
</tr>
<tr>
<td>Condominiums maintenance manual</td>
<td>Building maintenance</td>
<td>2</td>
</tr>
<tr>
<td>Building management standard</td>
<td>Relationship between the maintenance management and management standard</td>
<td>2</td>
</tr>
<tr>
<td>Reporting principle for building management organization</td>
<td>Reporting procedure of the building management organization</td>
<td>2</td>
</tr>
<tr>
<td>Dispute resolution for building and community maintenance management</td>
<td>Question and answers for building</td>
<td>2</td>
</tr>
<tr>
<td>Administrative affairs</td>
<td>Documentary works; mailing management and</td>
<td>2</td>
</tr>
</tbody>
</table>
According to the research data, the non-technical safety and environment management property management employees in Taiwan, are often managed by those middle-aged people who are mostly over 45 years old (Figure 9 and 10). This is often because the work does not require special skills and the salary is low. However, it is concerned that whether those aged employees can bear the heavy work mentally and physically.

Figure 9,10 : Middle aged building manager in Taiwan

4. MANAGEMENT SYSTEM STRUCTURE IN VARIOUS COUNTRIES

4.1 America Property Management Structure

The America property is divided into the following four groups:

1. Residential property
(1) Single family house: This type of house does not require property management.

(2) Multi family house: It increased in the building cost and reduced in the open space.

(3) Pension apartment: Since the high construction cost and requires disabled facility, it needs professional person for the management.

(4) Rent apartment: Normally, the apartment is managed by the owner or property manager. For the big apartment it often requires professional property manager.

2. Commercial property

It includes all the profitable properties for example: office building; shopping mall; car park (Figure 11 and 12) and etc.

**Figure 11,12 : Outdoor car park**

(1) Office property: It requires property management from property manager and also there are some managed by the internal staff.
(2) Science park: It is specialized in technology industry. For example: 3C products; biotech company and etc.

3. Industrial property

(1) Heavy industry area: It provides the advantages of convenient communication; close to material supply and labor resource. Due to the area is designed to suit the demand of the users; the professional manager is required for example: the cities of the Great Lakes Region.

(2) Light industry area: It includes the parts assembling and merchandise storage in small factory building. It often provides multiple functions.

(3) Industrial building: It is a multi-storey building with low rental. It is a compound building for manufacturing, office, residence and warehouse.

(4) Warehouse delivery center: It is often set inside the industry area and rent to the factory. The warehouse needs the least management.

4. Distinctive property

The construction is designed for special purpose and special property use. For example: hotel; movie theater; harbor; airport; hospital; station; mass transit and etc. For this type of property, the property management can be handled by the business itself or outsourcing.

4.2 Japan Property Management Structure

1. The Japan property is divided into the following four groups:

(1) Simplex residence: It provides the best comfort within the limited space.
（2）Compound residential building: The house price is cheap and is financed by the government funds for those low-income households. It is managed by the property manager or business.

（3）Governmental public building: It is managed by the property management department formed by the professional employees. For example: ministry office building, factory, hospital and other government organization (Figure 13 and 14).

Figure 13: Japan’s nursing home

Figure 14: COREDO office building

（4）Commercial leasing building: It is managed by the property manager considering the demand and attribute of the tenant.
2. Office management

   (1) Contract management: The amount of cash deposit with monthly pay rental and administrative fee should be clearly written in the contract.

   (2) Construction property management: The safety management and facility maintenance.

   (3) Emergency treatment: Solve the problem of facility malfunction.

3. Real estate investment management

Real estate investment is mainly managed by the investment professionals in the insurance companies. It divides real estate into several stock shares for real estate investment.

5. THE DEVELOPMENT OF PROPERTY MANAGEMENT IN VARIOUS COUNTRIES

5.1 The Property Management Trend in Hong Kong

The study proposed the following features of property management in Hong Kong:

1. Professional service: Because the diversification of the construction type, it makes difficult for the property management in Hong Kong.

2. Independent accounting cost: The owner pays the administrative fee. According to different services of the construction, the administrative fee is also different. The property management company makes the budgets and puts into implementation after the owner agreed.
3. Protect optional rights: The property management company is normally selected through bargaining, public bidding or commissioning. In order to prevent that the developer appoint its subsidiary company for property management, the government stipulates that after 2~5 years managing with its subsidiary company; when the contract expired, the developer has to choose other property management companies.

4. Public contract: The Hong Kong government asks to make public contract when one building has two owners. After registration the contract becomes a legal document and is always effective even the owner or property management company is replaced.

5. Comply to the relevant standards: Although the property management manual does not have legal effectiveness, the property management still has to comply with the ordinance.

5.2 China Property Management Trend

1. China property management model

According to the research, there are two main management models in China:

（1）Professional property management model: It provides householder with non-gratuitous integrated service. It mainly focuses on high benefit properties; for example: office building, villa and etc.

（2）Specialize and administrative management model: The management is for small area of residence providing quiet, comfortable and safety living environment.

2. The current development implementation principle in China
The study did research on the current development in China and the following are the implementation principle for the issue of renewing old communities:

1. Property management for old community

The huge population in China causing many has to live in old communities. However, the limited economic capability makes the reconstruction work very different. Therefore, it can only focus on the planning of construction management for improving living quality and maintenance management.

2. Property management for new community

Property management for new community focus on integrated service for people: such as security, cleaning, maintenance and other works.

5.3 The Situation of Property Management Development in Singapore

Current property management promotion strategy in Singapore:

1. Healthy property management organizational system: The responsibility is given to the Singapore construction development organization. There are 36 division offices under the organization and each division is in charge of 2 to 3 smaller divisions. The division is responsible for 4000~6000 householders.

2. Strengthen the management by law: It has made many laws and ordinance for property management. For example these are some of the regulations for interior decoration:

   (1) Do not change the construction main frame and its appearance. For example: the wall, column and beam.
(2) The grindstone floor and ceramic tiles on the wall of the kitchen and bathroom cannot be replaced for 3 years.

(3) Do not change the indoor pipeline and power switch.

3. Provide high quality maintenance and service:

(1) The government focuses on the construction maintenance. It is asked to do the repair of the construction external wall and internal public area.

(2) For the elevator maintenance, it demands high performance. When the elevators break down, it is asked to arrive within 5 minutes for the repair.

(3) For the maintenance of indoor water, electricity and sanitary facilities, it provides a 24 hours hotline service.

6. CONCLUSION

The study proposed the following conclusions in the implementation of property management system:

1. Develop the educational system for property management: Speaking of the educational system for property management in America, it has already developed a fine management system. From their long-term experience, they have developed an educational system and expanded worldwide. Therefore, it is important to learn and use the advantages and professions in the America property management educational system for the future development in property management.
2. The importance of asset management concept: Many advanced countries have seek to make the most profit with management and make property into stock shares to make the best investment for the owners. Therefore, an effective property management is to focus on the development and property implementation plan to increase the value of the property; to make the investment in minimum time with right information according to market analysis; asset valuation and budget control.

3. The integrate operation of non-government professionalized organization: The government should focus on assist making a healthy market mechanism and use non-government power to provide relevant assistance. The cooperation between non-government industry and between the industry and schools is the main power to improve professional knowledge to help the total development of the industry.

REFERENCES


A FEASIBILITY STUDY ON THE LIFE CYCLE COSTING OF GREEN RENOVATING FOR EXISTING BUILDINGS OF TAIWAN

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2 Professor, Department of Architecture, National Cheng-Kung University, Taiwan.
3 Associate professor, Department of Architecture, National Cheng-Kung University, Taiwan.

ABSTRACT: Green development is a vital component for the Earth sustainability. Relatively, healthy issues always take a critical role in Human life cycle. Green Renovating in existing buildings, therefore, becomes one of efficient approaches to achieve the contributions to the Earth sustainability and human Health. This is because Green Renovating in Taiwan includes the improvement of both outdoor and indoor environment to scientifically explore the relationship between Healthy Quality, Sustainable Loading and Efficiency. This study investigates the renovating cases of existing buildings in Taiwan from the aspect of Eco-efficiency corresponding to Life Cycle Costing, LCC. Consequently, this study concludes some empirical and experimental points of view earned by the cases of Green Renovating adopted the concept of life cycle cost analysis (LCCA) to fundamentally deduce the better renovating efficiency of existing buildings in Taiwan.

Keywords: Sustainability, Green Renovating, Existing Building, Eco-efficiency, Life Cycle Cost (LCC)

1. INTRODUCTION

Over the past decade, green building has become one of the most efficient measures to pursue a sustainable built environment. Various evaluation methods, assessment tools, and certification systems were developed worldwide. Taiwan, as some developed countries, confronted with both global and local challenges of climate change and environmental impact. Therefore, a series of green building promotion programs has been proposed and implemented that cover a wide range of topics of sustainability in ecological environment and efficiency in energy and resources. This implementation on new buildings, existing buildings, building materials, education, training, as well as international cooperation and interchange, were effectively carried out.
In addition, international organization OECD (Organization for Economic Co-operation and Development) investigated the current situations of the buildings in member countries. The statistical data indicated that the ratios of new buildings in many advanced countries were almost below 2% (show in Table 1). The ratio of new building license from 1990 to 2006 in Taiwan has reduced by 3% and ratio of the existing buildings was up to 97% (show in Figure 1). With the increase of building duration, there will be many problems generated. The metropolis is the population and economy center in the world and with the major pollutants of energy consumption and Greenhouse air emission. Therefore, the functions and environmental quality of old buildings were deteriorating and these buildings also caused environmental pollution and landscape damage. If we can propose correctly sustainable improvement strategies and accelerate reactive usage of the buildings, human environment will also be improved.

<table>
<thead>
<tr>
<th>OECD Country</th>
<th>Housing starts/stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>1.7%</td>
</tr>
<tr>
<td>Canada</td>
<td>1.3%</td>
</tr>
<tr>
<td>France</td>
<td>1.0%</td>
</tr>
<tr>
<td>Germany</td>
<td>2.1%</td>
</tr>
<tr>
<td>Japan</td>
<td>2.8%</td>
</tr>
<tr>
<td>UK</td>
<td>0.8%</td>
</tr>
<tr>
<td>US</td>
<td>1.4%</td>
</tr>
<tr>
<td>NL</td>
<td>1.3%</td>
</tr>
</tbody>
</table>

Consequently, this study focused on the implementation of green renovating in existing buildings of Taiwan for private sector since 2004 adopted the concept of Eco-efficiency to essentially emphasize on the topics of sustainability and efficiency. The buildings include apartments with Condominium Management Ordinance, office buildings and private college and schools that focused on the issues of ecological environment design for building sites, building energy saving, resources recycling, building pollution prevention, and indoor environmental quality. The green renovations in private sector have been improved in the
following aspects, such as energy saving, water saving and retention, greening, the energy and resource consumption, waste reduction, indoor quality and ecological environment protection. By the end of 2006, 33 projects were completed and made significant contributions to the ecological environment. The achievements include improving the energy saving efficiency of building envelop, increasing the permeability of building site, reusing rainwater and grey water for water resource conservation, adopting recycling materials for construction waste reduction, enhancing the effect of fixing CO2, as well as providing the human habitats for indoor air quality improvement.

<table>
<thead>
<tr>
<th>Year</th>
<th>Construction Licenses</th>
<th>Total Floor Area (one thousand m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case</td>
<td>Housing</td>
</tr>
<tr>
<td>1990</td>
<td>49,122</td>
<td>12,059</td>
</tr>
<tr>
<td>1991</td>
<td>65,100</td>
<td>12,289</td>
</tr>
<tr>
<td>1992</td>
<td>86,539</td>
<td>15,657</td>
</tr>
<tr>
<td>1993</td>
<td>76,578</td>
<td>21,769</td>
</tr>
<tr>
<td>1994</td>
<td>67,431</td>
<td>28,584</td>
</tr>
<tr>
<td>1995</td>
<td>54,295</td>
<td>26,459</td>
</tr>
<tr>
<td>1996</td>
<td>42,669</td>
<td>20,631</td>
</tr>
<tr>
<td>1997</td>
<td>42,207</td>
<td>14,593</td>
</tr>
<tr>
<td>1998</td>
<td>37,221</td>
<td>13,916</td>
</tr>
<tr>
<td>1999</td>
<td>28,067</td>
<td>13,561</td>
</tr>
<tr>
<td>2000</td>
<td>29,493</td>
<td>8,429</td>
</tr>
<tr>
<td>2001</td>
<td>22,175</td>
<td>4,854</td>
</tr>
<tr>
<td>2002</td>
<td>25,282</td>
<td>7,066</td>
</tr>
<tr>
<td>2003</td>
<td>34,468</td>
<td>11,961</td>
</tr>
<tr>
<td>2004</td>
<td>45,934</td>
<td>18,891</td>
</tr>
<tr>
<td>2005</td>
<td>43,805</td>
<td>17,673</td>
</tr>
<tr>
<td>2006/01-09</td>
<td>26,068</td>
<td>15,042</td>
</tr>
<tr>
<td>New/Exist</td>
<td>3.36%</td>
<td>3.82%</td>
</tr>
</tbody>
</table>

Figure 1: 1990-2006 Construction Licenses statistics of Taiwan
2. GREEN BUILDING EVALUATION SYSTEM IN TAIWAN

The definition of Green building is a healthy and comfortable building that is capable of efficiently reducing the consumption and natural resources, and the pollution caused by wastes during the life cycle of the building. In order to examine the integrated performance of the building, an appropriate evaluation system that is accommodating with the subtropical/tropical climate in Taiwan should be developed. Therefore, the Architecture and Building Research Institute (ABRI), Ministry of the Interior, established an evaluation system for Green Buildings that was first announced in 1998 and comprised of seven evaluation categories. Over the past few years, the ABRI modified the evaluation system by adding two new indicators in addition to the original ones, Biodiversity and Indoor Environment Quality. An evaluation system, integrated with nine categories, was thus established in 2003. These indicators can be divided into four categories, Ecology, Energy Conservation, Waste Reduction, and Health (known as EEWH system). The evaluation indicators are listed in Table 2.

These nine indicators can be evaluated independently in order to reply to the various impacts upon the earth environment. Each category has quantitative calculation methods, equations, and criteria for the evaluation judgment. The system has proved to be simplified, quantified, and localized for the subtropical climate of Taiwan and regarded as a standard evaluation method for green building.

<table>
<thead>
<tr>
<th>Table 2: Indicators for Green Building Evaluation in Taiwan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Climate</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>* * * * * * *</td>
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<tr>
<td>* * * * * *</td>
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<td>* * * * * *</td>
</tr>
</tbody>
</table>

by the Ministry of the Interior of Taiwan. The evaluation system, additionally, the ABRI also developed a Green Building Labeling system for green building certification. The Green Building Labeling System consists of two parts: Green Building Label for completed buildings, and Green Building Candidate Certificate for building projects. The minimum requirement for Green Building certification is to pass two prerequisites (energy conservation and water conservation), and two optional indicators from among the other seven indicators. To date cited from the ABRI source in 2006, 209 buildings have been certified as Green Buildings, and 1,255 projects have received Candidate Certificates. Total building floor areas reached 16.60 million m², electricity saving 432 million KWH that equals to 28.5 million CO2-kg, and water saving 18.32 million ton per year.

3. GREEN RENOVATING PROJECTS FOR THE EXISTING BUILDINGS

“Nine indicators for Taiwan’s green buildings” primarily applies to newly constructed buildings, whereas, the existing buildings take very high percentage (97%) in all buildings. Construction and Planning Agency, Ministry of the Interior, has undertaken green renovating projects for the existing buildings since 2004. By the end of 2006, there are 33 cases have been provided with financial assistance to make improvements divided into three categories for the evaluations containing items for each one (shown as the table 5), as construction sites, shells of buildings and indoor environment, building facilities. The cases listed below are the representative examples of the apartment, office building and private college evaluated by the three categories to demonstrate for the outcome of the existing building improvements.

3.1 Apartment building

There are improved measures including lower contractual capacity, improve power factor, the pump and illuminated equipment. These measures respectively applied
for the different items of the three categories to renovate this case. The effective findings are as the following,

a. Contractual capacity from 190kw down to 130kw.

b. Improved power factor from 68% up to 99%.

c. Illumination system used the T5 tube and economized bulbs for the reduction of the electric consumption.

The table 3 shows the differences of energy efficiency after the improvement.

<table>
<thead>
<tr>
<th>Table 3: The contrast to Electric consumption and Electric fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>December</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>2004</td>
</tr>
<tr>
<td>Electric consumption (KWH)</td>
</tr>
<tr>
<td>Electric fee (dollars)</td>
</tr>
<tr>
<td>Power factor (%)</td>
</tr>
<tr>
<td>Contractual capacity (KW)</td>
</tr>
</tbody>
</table>

3.2 The office building

The improved measures are energy saving on air conditioning. These measures respectively applied for the different items of the three categories to renovate this case. (table 4) The effective findings are as the following,

a. Reducing the opening areas of the building by 62.5%. The outer wall loss to 2.12(W/m² · K.)

b. ENVLOAD from 147 loss to 91.3 [kWh/(m²-fl-a · yr)] EEV=0.794 <

<table>
<thead>
<tr>
<th>Table 4: The Improved Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Items</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
</tbody>
</table>
c. Making an improved rate up to 38%.

d. The air conditioning for energy saving 7.2RT, that is equal to 5.76kw of electricity.

e. Leading fresh air to the building for the improvement of IAQ.

f. Average LUX from 475 LUX up to 560 LUX.

g. Energy consumption from 14240W up to 9324 W.

h. Formaldehyde, TVOC, CO2 < Standard Value

The Figure 2 shows the differences of indoor environment after the improvement.

![Figure 2: Concentration of HCHO, CO2, after the improvement.](image)

However, in associate with the Green Building Labelling system for green building certification based on the nine indicators (known as EEWH system), it seems better to accommodate the system for the evaluation of the existing building renovations becoming Green Buildings. The table 5 shows the correlations between the nine indicators of Green Building and the three categories of improving the existing buildings.

Viewing from the comprehensive statistics data in three years, the distributions of individual evaluation indicator are 2% for bio-diversification, 13% for greenish volume, 7% for site water preservation, 21% for daily energy saving, 8% for
indoor environment improvement, 9% for water resources, 18% for polluted water and trash improvement, and 12% for others. The percentages are shown in Figure 3.

Furthermore, comprehensive adapting the items (shown as Table 2) of ecology, energy, waste and healthy in the nine indicators to the items of the three categories in the period of three years, a total of 25 cases in ecology, 25 cases in energy and 52 cases in health were improved. Hence, it can be seen that in Taiwan, with all concerned items in the overall life quality, “health” is still the most concerned one. Its distribution is shown in Figure 4.

Green renovating projects for the existing buildings seem to be quantified as the evaluations of the nine indicators to certificate Green Building Label under the comparison of the statistic data for the adaptability. Nevertheless, the life cycle of the existing buildings is varied from one to another that involves the variation in initial capital cost, maintenance costs, life span, demolition cost and lifetime cost etc.. The concept of life cycle costing (LCC), therefore, could also be adapted to fundamentally deduce a new vision for the future green renovation of existing buildings in Taiwan, that is, an Eco-efficiency Model. This is because the LCC is an approach with mathematical method that takes explicit account of the life cycle costs of assets including initial and future costs, is essential to effective decision-making to justify and identify the value of green renovating for the existing buildings.
4. EVALUATION AND ANALYSIS OF FEASIBLE ECO-EFFICIENCY MODEL

According to the “Sustainable Building Evaluation System” which is widely used internationally, the “Comprehensive Environmental Efficiency Indicators” were created based on WBCSD’s “Environment Efficiency” concept, the standards of international standard organization ISO 21930, ISO 15686 series, and the method of “Economic Benefit Evaluation”. The indicators are mainly divided into two parts including Environment Quality and Environment Loading. These two parts are further divided into factors including the utilization features and quality of building environment based on different “Evaluation Structure”. Finally, Environment Quality and Environment Loading are evaluated individually through the method of “Building Life Cycle Cost” joining with “Economic Benefit Evaluation”, in order to calculate the “Environment efficiency”. Figure 4 shows the concept of Eco-efficiency Model.

$$\text{Eco-efficiency} = \frac{\text{Quality of Life}}{\text{Environmental Load}}$$

Figure 4: the concept of Eco-efficiency Model

4.1 Evaluation and Analysis of Environmental Loading Cost Model

4.2 Evaluation and Analysis of Environmental Quality Benefit Model

The “Health Base Value” of indoor environment quality indicator (IEI) is used as the “Baseline of Environment Quality Health Features”, plus “Economic Benefit”, the total environment quality benefit cost is formed. “Baseline of Environment

| Table 5: the correlations between the nine indicators and the three categories |
|-----------------------------------|------------------|------------------|
| The nine indicators | The three categories with items |
| Ecological             | site              | building         |
| 1. Biodiversity       | water storing and diosmosing facilities | sun shading and light effecting facilities |
| 2. Green             | eco-pond          | wall-way balcony greening |
| 3. Soil water content | water diosmosing pavement | well heat-proof exterior wall |
|                      | multi-aperture habitat for creatures | well heat-proof roof top |
|                      | rainwater storing facility on artificial surface | well heat-proof materials for open parts |
|                      | artificial surface greening(roof top) | high effect on equipment |
| Site                | grass trench      | reasonable method to window |
|                    | base greening     | reasonable routes for indoor ventilation |
| Building            | using of base-environment eco-building material | indoor sunshading technique |
|                    | multi-aperture habitat for creatures | high effective illumination machine |
| Energy              | site              | building         |
| 4. Energy conservation | high effect on equipment | high effect on air condition equipment |
| 5. CO₂ Emission Reduction | energy control system | high effect on elevator system |
| 6. Construction waste reduction | alternative energy | renew and maintenance of facilities and ducts |
| Waste               | site              | building         |
| 7. Indoor Environment Quality | artificial swamp / sewage disposal system | using of recycling materials on building shell |
| 8. Water conservation | sewage reusing technique | grey water reusing technique |
| 9. Sewage and garbage | plants reusing technique | rainwater reusing technique |
|                      | using of eco-building material on base environment | using of eco-building material on interior decoration |
|                      | using of recycling materials on building shell | using of eco-building material on interior decoration |
| Health              | site              | building         |
|                      | basement humidity proof technique | using healthy building materials on interior decoration |
|                      | using healthy building materials on building shell | using high-performance building materials on interior decoration |
|                      | using high-performance building materials on building shell | indoor vibration control technique |
|                      | indoor acoustics control technique | indoor disability glare proof technique |
|                      | indoor noise control technique | indoor ventilation control technique |
|                      | noiseless vibration facilities | drinking water quality technique |
|                      | colding water quality technique | |

Quality Health Features” includes air, sound, light, warmthness, and mental comfort.
Figure 3: shows statistics data in three years.

Figure 4: shows statistics data of the adaptability
4.3 Evaluation of Comprehensive Environment Efficiency

The “Comprehensive Environment Efficiency Evaluation Model” is derived from the factors of “Environment Quality” and “Environment Loading”.

5. CONCLUSION AND RECOMMENDATIONS

The results of this study have paved a foundation for the innovative “Life Cycle Environment Efficiency” to apply for the green renovations of the existing buildings as a new evaluation model. In the future, conducting the further researches on the diagnosis of existing buildings is needed to find (1) the impact factors for the quantitative evaluations of the Environmental Load as well as the analysis of building duration, (2) the Life Cycle Costing with Eco-efficiency model for the evaluations of the existing building improvement in different phases, (3) that can be implemented including “Planning”, “Design”, “Construction”, “Use”, “Renovation” and “Advancing Features” of “Building Performance”, in order to effectively complete the “Cost Evaluation of Building Overall Features”. Additionally, it is also need to launch a study on a real renovating project to testify the model’s practicality and to increase the level of influence started from “points to points” to form “lines to lines”, then expanded into “surfaces to surfaces” regional management.

6. REFERENCES


[17] Shuzo Murakami, Kazuo Iwamura, Masaaki Sato, Toshiharu Ikaga, and Junko Endo, Comprehensive Assessment System for Building Environmental Efficiency (CASBEE)


REDEVELOPMENT OF PUBLIC RENTAL HOUSING ESTATES IN HONG KONG

CONNIE LAI

Hong Kong Housing Department

ABSTRACT: In response to the growth of economy and increased housing demand, the Hong Kong Government prepared the ‘Long Term Housing Strategy’ (LTHS) to review the housing policies in 1987. One of the key policies under the LTHS was to establish a Comprehensive Redevelopment Programme (CRP). The target of CRP was to redevelop 57 public housing estates built before 1973. After 20 years of redevelopment, the CRP has achieved its objectives of improving the living environment of the residents. However, it also exerted a heavy drain on land, manpower and financial resources. As such, the Government recognized that in future, redevelopment should be undertaken only when necessary to replace housing blocks which were no longer safe or economic to maintain. This principle was reinforced by the Hong Kong Housing Authority (HA) in 2005. Safety and cost-effectiveness are the major considerations in determining the sustainability of existing public rental housing estates. To ascertain the condition of the estates, the HA will conduct comprehensive structural appraisals for estates which are over 40 years old where there are often soaring maintenance and repair costs. For estates which remain structurally sound but require functional improvements, appropriate works will be arranged so that no further major structural strengthening will be necessary for at least 15 years. This paper will examine the impact of CRP on the public housing development since 1988 and the future plans and contribution towards sustainability in Hong Kong.

1. INTRODUCTION

Comprehensive redevelopment of old public rental housing estates contributes significantly to urban renewal in Hong Kong. It marks the era of success in providing self-contained public rental flats, as well as improving the living environment of millions of residents.

Figure1: Shek Kip Mei Fire in 1953
Public housing initially emerged in the form of transit housing, i.e. the resettlement estates following the disastrous fire at Shek Kip Mei in the Christmas Eve of 1953 when over 53,000 people were left homeless overnight. The old resettlement estates are the 7-storey Mark I & II blocks with communal toilet facilities between two linear blocks.

*Figure 2: Typical Floor Plan of Mark I Block*

*Figure 3: Mark I blocks in Shek Kip Mei Estate*

With the influx of immigrants from Mainland China, the demand for public housing increased throughout the 1950’s and 1960’s and these transit housing gradually turned into a form of permanent housing. A total of 240 Mark I & II blocks in 12 estates were built during the period. By 1970’s public housing blocks have evolved from Mark I & II to Mark VI. In 1972, the Government announced the Ten-year Housing Programme with a view to providing permanent self-contained flats in a reasonable environment by building new public housing estates and redeveloped the non self-contained Mark I & II blocks.
In April 1973, the new Hong Kong Housing Authority (HA) was established by the Government to develop and implement the public housing policies and programme. The HA is responsible for all aspect of public housing developments including the public rental estates, Home Ownership Scheme (HOS) flats for sale, flatted factories and ancillary commercial and other non-domestic facilities etc. To implement the public housing development, Housing Department (HD) was also formed to act as the executive arm of the HA.

In 1980, about 45% of Hong Kong’s population lived in public housing estates. The HA initiated a review of the structural condition of its housing stock, which indicated growing maintenance problems with the old estates. The first survey in March 1984 showed that approximately half of the buildings inspected at that time were likely to require significant repair work. As a further follow-up action, a more intensive structural coring survey was conducted which recommended the HA to demolish 26 structurally unfit blocks. To enable such large-scale demolition to proceed, an Extended Redevelopment Programme (ERP) was developed, giving priority to rehousing the affected residents in the same district wherever possible within 3-year period. This required the urgent acquisition of supplementary public housing sites in addition to offering residents priority status to purchase their own flats through the Home Ownership Scheme (HOS), where available without affecting the programme of redeveloping the Mark I & II blocks.
2. COMPREHENSIVE REDEVELOPMENT PROGRAMME (CRP)

In 1988, the CRP was drawn up after the announcement of the Long Term Housing Strategy (LTHS) in April 1987. It recommended that redevelopment should be extended to clear all older public housing stocks including all Mark I to VI Estates and Former Government Low Cost Housing Estates.

2.1 Objectives of CRP

The objectives of redeveloping the old public rental housing stocks include:

To improve the living conditions and liveability of the public housing estates.

To optimise the development potential of the individual housing sites.

To implement comprehensive social and environmental improvements.

To stimulate revitalisation of the larger community.

Priorities for redevelopment are determined largely by the availability of reception estates, structural conditions, age and build-back potential of the old estate.

Reprovisioning of social welfare, school, transport and commercial facilities are all carefully planned to avoid creating serious disruption to the local community.

Figure 5: Tsui Ping Estate (Before)
In view of the massive scale of the CRP involving clearance of over 500 domestic blocks 240,000 households and 630,000 persons, it has to be executed by phases from 1988 to 2008/2009. The redevelopment programme is being reviewed periodically to suit the changing circumstances. A 5-year Rolling Programme is announced at the beginning of each financial year to keep the public informed of the planned redevelopment operations over the period. The following table shows the progress of the CRP since 1988. The whole Programme will be completed by 2008/09 with only 16 blocks or 10,800 flats remain to be cleared as at September 2007.

### Progress of Comprehensive Redevelopment Programme (CRP) (as at 31.3.2007)

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Blocks Cleared</th>
<th>No. of Flats Cleared</th>
<th>No. of Persons Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988 - 97</td>
<td>326</td>
<td>138,340</td>
<td>391,710</td>
</tr>
<tr>
<td>1997/98</td>
<td>33</td>
<td>14,810</td>
<td>37,200</td>
</tr>
<tr>
<td>1998/99</td>
<td>35</td>
<td>15,490</td>
<td>35,620</td>
</tr>
<tr>
<td>1999/00</td>
<td>17</td>
<td>5,870</td>
<td>14,680</td>
</tr>
<tr>
<td>2000/01</td>
<td>49</td>
<td>13,590</td>
<td>36,180</td>
</tr>
<tr>
<td>2001/02</td>
<td>55</td>
<td>32,360</td>
<td>66,880</td>
</tr>
<tr>
<td>2002/03</td>
<td>9</td>
<td>4,510</td>
<td>11,760</td>
</tr>
<tr>
<td>2003/04</td>
<td>7</td>
<td>5,170</td>
<td>9,930</td>
</tr>
<tr>
<td>2004/05</td>
<td>4</td>
<td>490</td>
<td>1,000</td>
</tr>
<tr>
<td>2006/07</td>
<td>15</td>
<td>2,170</td>
<td>3,750</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Sub-total for completed CRP</th>
<th>550</th>
<th>232,800</th>
<th>608,710</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-going/planned CRP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007/08</td>
<td>(9)</td>
<td>(5,480)</td>
<td>(13,970)</td>
</tr>
<tr>
<td>2008/09</td>
<td>(7)</td>
<td>(5,410)</td>
<td>(8,840)</td>
</tr>
<tr>
<td>Sub-total for on going/planned CRP</td>
<td>16</td>
<td>10,890</td>
<td>22,810</td>
</tr>
<tr>
<td>Total for CRP</td>
<td>566</td>
<td>243,690</td>
<td>631,520</td>
</tr>
</tbody>
</table>

Note 1: Based on Completion Report of CRP, HD.
Note 2: Figures excluding residents already moved out before the target evacuation date.
Note 3: (No.) of blocks, flats and persons not yet cleared.

2.2 Process of Redevelopment

Redevelopment of a large estate works in cycles. A pump-priming site must be identified, wherever possible, in the nearby area or within the estate due for redevelopment for building reception flats for rehousing tenants affected by the first phase of the redevelopment scheme. Once the affected tenants are rehoused to the new blocks, the old buildings will be demolished and the vacant site will be used for building reception flats for the subsequent phase. This process continues until completion of the whole redevelopment scheme. Some large estates take more than twenty years to complete the whole redevelopment process.

The redeveloped estates are planned to be self-contained with basic necessities such as retail and social welfare facilities, local open space, primary schools, car parks and Public Transport Interchanges etc. During the redevelopment process, views and expectations of the local residents and District Councils are seriously considered and taken into account, wherever appropriate, by the HA. As such, tenants moving in the new redeveloped estates can enjoy a healthier living environment and better quality of living.

The ensuing paragraphs highlight the HA’s established policies to assist the removal of domestic and commercial tenants.

2.3 Arrangement for Domestic Tenants

In order to minimize disturbances, the HA gives sufficient notification to the affected tenants through annual announcement of the 5-Year Rolling Programme.
and formal notification of about 18-24 months prior to the target evacuation date. Tenants are offered designated rehousing within the same district as far as practicable. Their preferences for other districts will also be considered as far as resources are available. Face-to-face interviews with tenants to identify individual problems are conducted after formal notification. CRP tenants are given priority to purchase Home Ownership Scheme (HOS) flats. Financial assistance in the form of Domestic Removal Allowance is payable to assist tenants to meet part of the removal cost as well as decoration expenses.

**Figure 7: Briefing of redevelopment arrangement to tenants**

### 2.4 Arrangement for Commercial Tenants

Commercial tenants will have their existing rent levels frozen upon formal notification which is about 18-24 months prior to the target evacuation date. They are granted an ex-gratia allowance as compensation for disruption of their established business. In addition, they are allowed to participate in restricted tender exercises so as to acquire alternative non-domestic premises in other public housing estates to continue their business. A three-month rent-free period in the newly acquired premise is also granted. For those who relinquish their opportunities to take part in the restricted tender exercises, a lump sum payment in lieu is paid.
2.5 Community Support and Involvement

Service teams led by professional social workers are set up to provide the community services required by the affected tenants. The HA will line up representatives from other government departments, Non Government Organizations and volunteers to form an ‘Elderly Removal Working Group’ to assist the needy elderly in their removal. Special cases will be referred to the Social Welfare Department for provision of counselling service or other assistances required by the affected tenants.

Liaison meetings with District Council members, Mutual Aid Committees, local leaders and concern groups are regularly held from time to time with a view to inform them of the redevelopment arrangement for domestic and non-domestic tenants for each CRP operations.

2.6 Achievements of the CRP

After 20 years of redevelopment, the CRP has achieved its objectives of clearing all the oldest public rental housing estates. It also enables large families to split into smaller units and rehoused within the same locality. Family ties and relationship with neighbours can be maintained.

The quality of public housing has also improved significantly through redevelopment. The newly redeveloped estates are all self-contained with adequate local open space, car parking spaces, commercial, social welfare and community facilities. Tenants can enjoy better quality of living environment.
2.7 Problems of CRP

In 1998, the ‘White Paper on Long Term Housing Strategy in Hong Kong’ (‘the 1998 Strategy’), recognized that the large-scale CRP has exerted a heavy drain on land, manpower and financial resources. As shown in the table below, about 30% of the new public rental flats were allocated to the CRP affected tenants during the first decade of the Programme. This arrangement had greatly reduced the allocation opportunities to other needy categories like waiting list applicants.

<table>
<thead>
<tr>
<th>Year</th>
<th>Waiting List</th>
<th>Clearance</th>
<th>CRP</th>
<th>Others Categories</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987/88</td>
<td>38%</td>
<td>26%</td>
<td>23%</td>
<td>13%</td>
<td>100%</td>
</tr>
<tr>
<td>1988/89</td>
<td>38%</td>
<td>15%</td>
<td>26%</td>
<td>21%</td>
<td>100%</td>
</tr>
<tr>
<td>1989/90</td>
<td>43%</td>
<td>16%</td>
<td>32%</td>
<td>9%</td>
<td>100%</td>
</tr>
<tr>
<td>1990/91</td>
<td>35%</td>
<td>25%</td>
<td>30%</td>
<td>10%</td>
<td>100%</td>
</tr>
<tr>
<td>1991/92</td>
<td>38%</td>
<td>21%</td>
<td>33%</td>
<td>8%</td>
<td>100%</td>
</tr>
<tr>
<td>1992/93</td>
<td>44%</td>
<td>15%</td>
<td>28%</td>
<td>13%</td>
<td>100%</td>
</tr>
<tr>
<td>1993/94</td>
<td>43%</td>
<td>14%</td>
<td>33%</td>
<td>10%</td>
<td>100%</td>
</tr>
<tr>
<td>1994/95</td>
<td>38%</td>
<td>25%</td>
<td>20%</td>
<td>17%</td>
<td>100%</td>
</tr>
<tr>
<td>1995/96</td>
<td>39%</td>
<td>13%</td>
<td>29%</td>
<td>19%</td>
<td>100%</td>
</tr>
<tr>
<td>1996/97</td>
<td>31%</td>
<td>20%</td>
<td>31%</td>
<td>18%</td>
<td>100%</td>
</tr>
<tr>
<td>1997/98</td>
<td>38%</td>
<td>15%</td>
<td>29%</td>
<td>18%</td>
<td>100%</td>
</tr>
<tr>
<td>1998/99</td>
<td>58%</td>
<td>6%</td>
<td>14%</td>
<td>22%</td>
<td>100%</td>
</tr>
<tr>
<td>1999/00</td>
<td>49%</td>
<td>4%</td>
<td>32%</td>
<td>15%</td>
<td>100%</td>
</tr>
<tr>
<td>2000/01</td>
<td>50%</td>
<td>1%</td>
<td>38%</td>
<td>11%</td>
<td>100%</td>
</tr>
<tr>
<td>2001/02</td>
<td>65%</td>
<td>2%</td>
<td>15%</td>
<td>18%</td>
<td>100%</td>
</tr>
<tr>
<td>Year</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>Total</td>
</tr>
<tr>
<td>---------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>-------</td>
</tr>
<tr>
<td>2002/03</td>
<td>66</td>
<td>0</td>
<td>11</td>
<td>23</td>
<td>100</td>
</tr>
<tr>
<td>2003/04</td>
<td>71</td>
<td>0</td>
<td>1</td>
<td>28</td>
<td>100</td>
</tr>
<tr>
<td>2004/05</td>
<td>67</td>
<td>1</td>
<td>3</td>
<td>29</td>
<td>100</td>
</tr>
<tr>
<td>2005/06</td>
<td>65</td>
<td>1</td>
<td>5</td>
<td>29</td>
<td>100</td>
</tr>
<tr>
<td>Overall</td>
<td>48</td>
<td>12</td>
<td>23</td>
<td>17</td>
<td>100</td>
</tr>
</tbody>
</table>

Notes:
1. Figures exclude applicants joining the Rent Allowance for Elderly Scheme and Buy or Rent Option Scheme.
2. Clearance includes clearance from Squatter Areas / Temporary Housing Areas / Cottage Areas, Interim Housing / Temporary Housing Areas trawling and Urban Renewal Authority.
3. Other Categories include ‘emergency’, ‘compassionate’, ‘junior civil servants and pensioners’, and ‘transfer and relief of overcrowding’.

Source: Housing in Figures, HA

Financial costs involved in redevelopment are high. It is estimated that about HK$48 billion was spent on the construction of reception estates for the CRP between 1987 and 2006. The additional costs in granting ex-gratia allowances, management and maintenances are not included.

The actual housing stocks after redevelopment has reduced by about 30% due to the larger flat size, provision of sufficient local open space, free standing schools, commercial and car park buildings within the estates.

3. SUSTAINABLE FUTURE OF PUBLIC HOUSING STOCKS

After extensive consultation, the 1998 Strategy has set out the strategy for redeveloping aged public rental housing estates after completion of the CRP. It states that in future, redevelopment will be carried out as required having regard to the actual conditions of individual estates rather than by types of estates or blocks. Clearance will be undertaken only when the estate is structurally unsafe or has become uneconomic to maintain. Following the completion of the CRP, the need for another large-scale clearance of a certain class of old estates is no longer necessary. The need for clearance should hence be considered on an estate or block basis only.
To ensure a safe, comfortable and sustainable living environment for public housing residents and in light of the principles set out in the 1998 Strategy, the HA adopted a new strategy in 2005 for sustaining the existing public rental housing estates. It will be driven primarily by safety and cost-effectiveness considerations, alongside the existing maintenance regime.

4. THE NEW STRATEGY

Under the HA’s regular maintenance programmes, the public rental housing stock is kept in good repair through regular inspection and prompt maintenance. Whilst all blocks are structurally safe, the building conditions are deteriorating at varying degrees as a result of ageing and other factors. This has given rise to persistent and multi-faceted problems concerning the upkeep of public rental housing estates. At present, there are a total of eight public rental housing estates aged 40 or above, comprising 64 blocks and some 22,100 units. The number will grow to 17 estates, in the next decade. To face the challenge arising from ageing of the public housing stock, it becomes imperative for the HA to devise a holistic and systematic approach to ensure the structural safety of old housing blocks on the one hand, and the strategy for sustaining or clearing aged estates on the other.

To ascertain the building conditions of individual estates, the HA has commenced a comprehensive structural survey on ageing estates. The ensuing paragraphs set out the approach of this strategy.

4.1 Comprehensive Structural Appraisal for Aged Estates

In general, comprehensive structural appraisal will be carried out for public rental housing estates around aged 40 or above which are often associated with soaring maintenance and repair costs. Flexibility will be exercised to extend the investigation scheme to other estates taking into account the actual building conditions.
The detailed survey aims to determine the material strength and rate of deterioration of the structural elements of a building, focusing on major aspects such as concrete strength, extent of spalling and cracks and corrosion of steel reinforcement bars etc. The findings will facilitate the consideration and planning of the necessary follow-up actions such as monitoring, repair, or clearance. If certain blocks or estates were found to be structurally unsafe, demolition would be recommended. For other blocks or estates which remain structurally safe but require improvement works to enhance the structural capacity, appropriate works such as structural strengthening, recasting or normal concrete repair will be arranged so that no major structural strengthening work will be necessary for at least 15 years. Another detailed structural appraisal will be carried out near the end of the 15-year period with a view to mapping out the way forward for a particular estate.

4.2 Financial Appraisal
The expenses on maintenance and improvement works for old buildings will increase with age. While it may be technically feasible to extend the serviceable lifespan of the rental blocks through various upgrading works, the associated costs may at certain point outweigh the benefits, thus making it uneconomic to retain the buildings. Hence, in considering whether to undertake repair works for aged estates, a financial appraisal will be carried out to determine the financial viability of the proposal. Demolition may be considered if the cost-benefit analysis suggests that the aged buildings or estates are beyond economic repair.

4.3 Investigation Programme
Eight public housing estates, with age ranging from 40 to 53, have been or will be subjected to comprehensive structural investigation starting from September 2005, with completion targeted for 2008/09. Nonetheless, the actual progress will be subject to the complexities of building conditions of each estate, residents’ co-operation, availability of resources and logistical considerations such as availability of vacant flats for on-site testing.
5. CONCLUSION

CRP has greatly improved the living conditions of many public housing tenants in the past 20 years. It has also allowed those better-off affected tenants to have priority in purchasing HOS flats which in turn free up the rental flats to those in need. However it is a huge commitment from Government in terms of land, finance and manpower resources. As the oldest blocks have all been redeveloped, it is time to consider whether this commitment should be continued indefinitely.

In view of the 1998 Strategy, Government has decided that redevelopment should only take place when the housing blocks are no longer safe or economic to maintain. Comprehensive structural and financial appraisals for old estates will become the key elements of sustainable public rental housing development in future.

REFERENCES


[7] Redevelopment of Public Housing in Hong Kong, Housing Authority (Presentation to the Selangor Housing and Land Board, Malaysia on 4 October 2004)

[8] Fifty Years of Public Housing in Hong Kong, Housing Authority, 2003
SUSTAINABILITY THROUGH PREFABRICATED CONSTRUCTION IN HONG KONG PUBLIC HOUSING PROJECTS

JOSEPH YW MAK

Hong Kong Housing Department, HKSAR Government, HKSAR

ABSTRACT: Prefabrication offers cleaner, more efficient and safer construction and makes a significant contribution to sustainability in housing development. The key benefits from these methods are the conservation of construction materials, savings in overall resources and energy, minimizing construction waste, providing a clean and healthy working environment and shortening the overall construction time. Upon completion, there are also life cycle cost benefits when compared with the hitherto more traditional approaches to design and construction.

The Hong Kong Housing Authority (HA) has been a pioneer in developing prefabrication in the territory. In the early 1980’s, the HA initiated a programme to encourage prefabrication and mechanized construction technology through well known international contractors. In the late 80’s, leading local contractors were encouraged to develop their own pre-casting systems to suit the Hong Kong context. The follow-up contractual, procurement and quality assurance measures were then developed and implemented in building contracts. In parallel, new technological initiatives have been introduced one by one and a very comprehensive prefabrication system for high rise residential buildings has evolved.

This paper will share the experience in the evolution and development of prefabrication initiatives in the public housing programme, for the benefits to be appreciated by the industry as a whole and for the advancement of the sustainability in the construction industry.

1. INTRODUCTION

In the mid 1960’s, due to the influx of immigrants from Mainland China to Hong Kong, the majority of these immigrants lived in squatters or very old buildings. A
large number of flats had to be built speedily to meet the massive demand for housing. At the same time, rapid industrial development meant people had begun to receive stable incomes, and hence higher expectations in the supply of better housing.

On the other hand, the construction industry in Hong Kong in those years was still relatively primitive, low skills and labour intensive. The public housing blocks then developed could only serve the functional requirements, but not on durability and sustainability.

2. SUSTAINABILITY OF EARLIER HOUSING STOCK

Starting in the early 1970’s, because of the growing population in HK, medium rise reinforced concrete buildings were the normal mode of accommodation for the citizens at large, in particular those living in public housing. Concrete material was adopted basically due to the abundance of granite rock from the excavation of local quarries and from Mainland China, instead of importing structural steel from abroad which was more expensive. Concrete was deemed to be more durable under the subtropical humid climate in Hong Kong.
However, at the technological level in the 1970’s to 1980’s, there were some critical shortcomings in the quality of construction workmanship at that time:-

a) The method of construction was by traditional in-situ construction, using timber formwork. The finished profile and in particular the concrete cover protecting the reinforcement from corrosion were very much subject to the carpentry skills of the workers.

b) The other aspects of workmanship such as steel fixing, compaction of concrete, finishing of concreting works, all operated in a very labour intensive and congested working site and generally with unskilled labour. This had worsened the corrosion protection to the concrete elements.

c) The secondary infringement by water seepage at joints (e.g. at windows), water ponding in slabs (e.g. roof, cantilever corridor), water leakage at pipe connections (e.g. exterior of kitchen and bathroom), also led to the deterioration of the building structural frame and fabric.
In Hong Kong, there were over 250 nos. of public housing blocks constructed in this way during the period of 1970’s to 1980’s, ranging from 7 stories to 20 stories buildings. These blocks have been under an extensive maintenance programme over the years in tackling concrete spalling, recasting of concrete elements and even substantial strengthening works. The annual expenditure for concrete repair is in the order of HK$2M to $3M per year. The table below shows the repair cost trend.

**Table 1: Cost Trend of Concrete Repair**

<table>
<thead>
<tr>
<th>Age of Blocks (years)</th>
<th>Handover Year</th>
<th>No. of Blocks Completed</th>
<th>Cost of Repair per flat per year (HK$)</th>
<th>Total Cost of Concrete Repair per year (HK$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 -- 35</td>
<td>1972 ~ 1976</td>
<td>60</td>
<td>301</td>
<td>1.9M</td>
</tr>
<tr>
<td>26 -- 30</td>
<td>1977 ~ 1981</td>
<td>194</td>
<td>158</td>
<td>3.1M</td>
</tr>
<tr>
<td>20 -- 25</td>
<td>1982 ~ 1987</td>
<td>219</td>
<td>15</td>
<td>0.4M</td>
</tr>
</tbody>
</table>

The life cycle of the earlier domestic blocks have been typically in the range of 40 to 50 years when the maintenance cost is continually increasing. Because of the need to go for more high rise redevelopment due to the scarcity of land and the upgrading of living standard through enlarged flat sizes, the majority of these earlier blocks have been progressively demolished under the Housing Authority’s Comprehensive Redevelopment Programme. From the sustainability point of view, compared with other structures like bridges which have the life of over 100 years, this is a significant cost tag to the society and should be improved.
In Table 1 above, it is clear that maintenance expenditure on the older buildings is greater. It can also be seen that the repair cost drops significantly in the 1980’s which was the time when mechanization and prefabrication was introduced.

3. ENHANCEMENT OF QUALITY AND WORKMANKSHIP OF STRUCTURAL WORKS

With a strong strive to enhance the quality and workmanship of structural works, the Housing Department responsible for the construction of the public housing had mandatorily introduced the use of large panel steel formwork and associated mechanized construction in the mid 80’s.

![Figure 3: Mechanized and Prefabricated Construction](image)

This is not only a pioneer environmental initiative to reduce the use of timber, but also gives assurance to the accuracy in lines and profiles of the structural elements. The surface finish of off-form concrete is also much enhanced with no more uneven surfaces and/or left-in peeling off timber pieces in concrete.

In the early 1990’s, another great step forward in the public housing construction was the mandatory use of precast facades. The main purpose of the move was to prefabricate the complicated concrete profile of the facades in a factory instead of
casting them at the working floors and to cast-in the windows in the facades to avoid water leakage at the window/façade interfaces.

From a sustainability point of view, the immediate benefits of precast concrete construction are:

a) Great reduction in use of timber for formwork.

b) Assurance of concrete cover to reinforcement as a front line defence to corrosion.

c) More robust and reusable steel formwork/steel mould which facilitate better compaction of concrete.

d) Better surface finishes to greatly minimize the touching up with repair materials which might detach in the longer term.

4. PROCUREMENT OF MECHANIZATION AND PREFABRICATION

During that period, the HA has also initiated a programme to encourage prefabrication and mechanized construction technology by inviting well known international
contractors to participate. The outcome was promising. Stakeholders in the industry began to be exposed to these new technologies both in design offices and on site. However, in the later years, not many of these international contractors could sustain their business because of the higher overhead costs and their difficulty in managing local subcontractors. In the early 1990’s, leading local contractors were encouraged to develop their own precasting systems to suit the Hong Kong context, drawing experience from the international contractors and from experience in Singapore which has a similar form of construction of medium rise buildings.

5. MORE PREFABRICATION IN DESIGN

Following the design of precast facades, more prefabrication had been developed. These precast components are reckoned to be “for a purpose” within their different locations and contexts, which are elaborated as follows:-

a) Semi-precast slabs, tie beams and staircases

To prefabricate these components in factory instead of constructing it at working floors. The latter would require relatively substantial formwork/falsework on site, which might be vulnerable to poor workmanship and have severe safety concerns.

Figure 5: Semi-precast Slab
b) Volumetric precast bathroom/kitchen

To precast a box-type structure to be installed to each flat unit. With this volumetric set up, it could embody numerous pipeducts, fittings, tiles, waterproofing membranes, etc. It could also incorporate cast-in pipe sleeves instead of box-outs which are vulnerable to leakage. A lot of wet trade could be transferred to the factory which is a better controlled working environment. From past experience, bathrooms and kitchen areas are locations which call for frequent maintenance throughout their life spans.
c) Precast structural walls

A pilot project in Kwai Chung Flatted Factory has been launched successfully to extensively try out the use of precast structural walls. This innovative approach has opened up a new era for high rise precast construction which could further reduce the operations on site. Their applications are currently being reviewed for their effectiveness and opportunity cost.

d) Prefabrication along the building perimeter

Prefabrication not only enhances construction workmanship but also enhances safety construction at height. In normal mechanized construction, it is prudent for the contractor to make provisions for safe working platforms at open edges along the building perimeter. Metallic working platform with robust railings are required.
Nonetheless, there is still a risk of workers falling out of the railings. By adopting precast facades and semi-precast walls (also called ‘lostforms’), the perimeter could basically be surrounded by precast ‘walls’ and workers are not required to step outside into the working platforms. Hence, all activities are confined within the building enclosure. This approach is becoming popular in the private sector in Hong Kong and has also been tried out in our Kwai Chung Flatted Factory pilot project.

Figure 10: Semi-precast Wall (Lostform)

6. BUILDABILITY CONSIDERATIONS

Prefabrication and modular construction have been widely used in European countries like France, UK, Sweden and many others. They are usually adopted, however, in low rise houses or medium rise blocks up to around twenty stories. These countries do not have the need to construct high rise residential blocks like those in Hong Kong. The precast technology in Hong Kong is therefore somewhat unique though reference have been made to similar usage in Singapore. In Singapore, not until recent years, their building heights has been up to 30 stories with column beam structures as their main stream. In Hong Kong our residential blocks are 40 stories or above, where the structural forms are essentially shear wall structures.
The characteristics for this form of prefabrication in high rise construction demands special considerations for buildability: -

a) **Symmetry of Block Layout**

Blocks are designed with symmetry to allow for more repetitiveness in the components and to facilitate the rotary construction by tower cranes.

b) **Modular Flat Unit**

The flat units are designed to be in modular types, including one bedroom, two bedroom, three bedroom, etc. These have a lot of benefits in terms of unifying the flat unit components, including the building and structural components, and allow the repetitiveness in prefabricated production.

c) **Weight of Precast Components**

Weight of components is critical. Heavier items may require greater carnage of the tower crane, hence jacking up the construction cost. Similarly, volumetric precast components have to be carefully located in the layout to ensure that the tower crane has sufficient capacity to lift them during construction.

d) **Monolithic Connections**

Connections of precast elements with the insitu structure should be through monolithic construction. Post-fixing with brackets and grout/mortar infill are not desirable for tall buildings, mainly because of to the high cyclic wind load which may render the connections unstable and/or lead to cracking of infill grout, hence water leakage.
e) Dimensional Tolerance

In high rise construction in which precast components are interlocking with insitu structural components like shear walls or columns, dimensional accuracies are very important. Only very tight tolerances could be allowed for the components to be fitted into, otherwise the construction cycle would be disrupted.

7. QUALITY ASSURANCE OF PREFABRICATION

Prefabrication off-site was an activity rather new in our contract procurement. It has also triggered the establishment of another sector of suppliers to invest in setting up factories in region of South China next to the Hong Kong. This is because Hong Kong has a scarcity of land for accommodating large factories and the cost of labour is also high. With the introduction of extensive prefabrication, many of our main contractors have the incentive to set up factories and inject management staff to undertake the factory production.

One of our major concerns is the quality assurance in these remote factories. The HA has now established a series of QA measures as elaborated below:-

a) Independent consultants have been appointed to supervise the production of these factories, with full time staff stationed at the factories.

b) Each factory has to carry out internal audits at regular intervals. The independent consultant is required to conduct monthly external audits and the HA would also carry out regular audits to the performance of the consultants.
c) A Performance Assessment Scoring System (we called the PASS) is also imposed to these factories, with particular focus on the workmanship of the production. Scores obtained from the PASS would be related to the performance of the main contractor employing the precast supplier and affect the tendering eligibility of the main contractor.

d) At the initial set up of the factory, it has to be accredited to ISO standards. In addition, the supplier has to carry out a pilot production run to demonstrate its competence before it is approved for production.

8. CONCLUSION

Prefabrication offers cleaner, more efficient and safer construction and makes a significant contribution to sustainability in housing development. The key benefits from these methods are the conservation of construction materials, savings in overall resources, including energy, minimizing construction waste, providing a clean and healthy working environment and shortening the overall construction time. Upon completion, the result is an aesthetically pleasing, versatile and highly durable development. There are also life cycle cost benefits when compared with the hitherto more traditional approaches to design and construction.

The prefabrication experience gained by the HA is indeed very rewarding. Private sector in Hong Kong are following suit and are developing further in breadth and in depth because of their affordability to use more luxurious components. Compared with the earlier housing blocks in Hong Kong, this approach has brought about longer life buildings for our next generation to continue to live in.
MULTI-OBJECTIVE OPTIMIZATION FOR DESIGN OF VENTILATION SYSTEM IN APARTMENT BUILDINGS

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ABSTRACT: This paper addresses multi-objective optimization for design of residential ventilation system in an apartment floor plan in Korea. In the paper, optimal design means optimal sizing and location of diffusers/registers. Performance criteria for decision-making include initial and maintenance costs, indoor air quality, energy use and comfort. The multi-criteria optimal design problem introduces multi-objective optimization with Pareto optimality. In the study, the genetic algorithm was chosen for solving this constrained discrete optimization problem. The CONTAMW 2.4 developed by NIST (National Institute of Science and Technology) was used to simulate ventilation phenomena. The paper shows an example of an optimal design problem for a chosen apartment plan.

Keywords: ventilation, optimal design, apartment building, Pareto, Genetic Algorithm, multi-criteria

1. INTRODUCTION

With the recent increased expectation of better indoor environment, many research efforts have focused on the Indoor Air Quality (IAQ). The IAQ is determined by thermal control, removal of indoor contaminants, proper ventilation, occupant’s behaviour, etc. Among these, determination of adequate ventilation method (natural, hybrid or mechanical), size and location of diffusers and grilles, the amount of outdoor airflow rate is crucial. Hence, a new ventilation code [1] was enacted in Korea in 2006 to ensure a healthy environment for occupants. The code specifies a minimum 0.7 Air Changes per Hour (ACH, h⁻¹) in multi-family apartment buildings.

This study aims to achieve optimal design of residential ventilation system in multi-family apartment buildings from the architectural perspective. Here, a distinction should be made between mechanical and architectural perspective. Optimal design in light of mechanical perspective focuses on the efficiency of heat
recovery, fan configuration, filter type and location, motor efficiency, etc. The optimal design in light of architectural perspective is based on the ventilation method, size and location of diffusers and grilles, the amount of outdoor airflow rate, heat recovery method, etc. In the paper, optimal design from architectural perspective is of main interest.

In general, the optimal design process has two elements [2]:

Decision: The designer must make a decision as to which pay-off between the criteria results in the most desirable design solution;

Search: a procedure to search for one or more solutions that reflect the desired pay-off between the criteria.

The relationship between decision and search has three forms [2].

A priori preference articulation (decide→search): The most general method where the decision maker (DM) predetermines the weight factors according to different evaluation criteria. For example the initial investment cost is twice as important as the operation cost.

Progressive preference articulation (decide↔search): The DM repeatedly performs decide and search actions by varying the weight factors until a satisfactory design alternative is found.

A posteriori articulation (search→decide): A set of feasible design alternatives is first created, and the DM selects an optimal design among them.

In this study, (1) initial investment cost, (2) operation cost, (3) percentage dissatisfied (PD) and (4) CO2 concentration are selected as the objective function elements. Architectural parameters such as ventilation method, size and location of diffusers and grilles, the amount of outdoor airflow rate, and heat recovery method are chosen as design variables. However, the objective function is discontinuous
and nonlinear; leading to difficulty to find an optimal solution that minimizes the objective function elements with a classical optimization method (gradient-based search method). Accordingly, the genetic algorithm (GA) was employed since it is adequate for our optimization problems. For the multi-criteria decision making, the ‘A posteriori articulation (search→decide) approach’ was employed using Pareto optimality.

2. OPTIMIZATION ALGORITHM

2.1 Genetic Algorithm
The genetic algorithm (GA) solves optimization problems through the evolutionary process. The concept of biological evolution was introduced in [3] and the computational algorithm was performed in [4]. It was Schaffer [5] who suggested that the GA can be effectively used in solving discontinuous and nonlinear optimization problems.

While the GA is effective in finding the global minima, it is more computationally extensive than the gradient-based method (Table 1). The GA was employed in this study since it can efficiently solve for nonlinear and nondifferentiable optimization problems.

Table 1: Comparison of gradient method and GA

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Gradient Optimization</th>
<th>Genetic Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonlinear problem</td>
<td>not possible</td>
<td>possible</td>
</tr>
<tr>
<td>Nondifferentiable Problem</td>
<td>not possible</td>
<td>possible</td>
</tr>
<tr>
<td>finding global minima</td>
<td>difficult</td>
<td>easy</td>
</tr>
<tr>
<td>computing time(slow)</td>
<td>fast</td>
<td>slow</td>
</tr>
</tbody>
</table>

2.2 Pareto Optimality
The GA optimization is a process of finding global minima from a randomly selected initial population. The range of feasible solutions is shown in Fig 1 (f1 and f2 are objective function elements). The main objective of optimization is not
finding local minima in the feasible region but identifying global minima on the boundary of the feasible region.

![Figure 1: Multi-criteria optimization [6]](image)

In order to find global minima, the approach for multi-criteria problems must be first determined. As explained earlier, the a priori preference articulation (decide→search) method involves the DM first determining the weights and then finding an optimal solution. Methods for determining weights include WSM (Weighted Sum Model) [7], WPM (Weight Product Model) [8], AHP (Analytic Hierarchy Process) [9], ELECTRE (Elimination and Choice Translating Reality) [10] and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) [11]. These methods find a design alternative for minimizing the objective function ($F(X)$) by applying the weights to Eq. (1).

\[
MINF(X) = w_1 f_1 + w_2 f_2 + \cdots + w_n f_n
\]

where, $w_i$ = weights, $f_i$ = objective function elements.

However, the weights are usually determined based on the DM's subjective and qualitative decision, which is not an absolute solution for multiple non-comparable objectives. For example, weights of apples, bananas, oranges and watermelons will vary according to personal taste.

The progressive preference articulation (decide↔search) method is laborious and time-consuming since it requires changing the weights until a satisfactory solution
is found. In this study, ‘a posteriori articulation (search→decide) approach’ was used. The approach generates a Pareto optimal set (non-dominated solutions) allowing the DM to choose his/her preferred design alternative among the set.

The concept of Pareto optimality is explained in Fig 2. A superior solution is referred to as a non-dominated Pareto and a non-superior solution as a dominated Pareto. In other words, a non-dominated Pareto is always superior to any dominated Pareto. In Fig 2, A, B and C are always superior to A1, B1 and C1 and superiority among A, B and C cannot be determined. A, B and C are not dominated by any other solution, and a set of such non-dominated Pareto solutions are referred to as a "Pareto optimal set" or "efficient frontier".

![Figure 2: Pareto Optimality.](image)

### 2.3 Integration of Genetic Algorithm with Pareto Optimality

Fig 3 shows the procedure for generating a Pareto optimal set by integrating the genetic algorithm with Pareto optimality. The generation process is repeated through initial population, fitness sharing, selection, recombination/crossover and mutation.
Figure 3: Integration of Genetic Algorithm with Pareto Optimality

**Initial Population**

In the genetic algorithm, each design variable is randomly selected within boundary condition, represented as an integer. The integer is then converted into a binary vector consisting of either 0 or 1. The vector constitutes a population consisting of multiple subpopulations. A subpopulation consists of multiple individuals, resulting in an initial population.

**Fitness Sharing**

Fitness sharing was introduced in [12]-[13]. It increases the diversity of feasible solutions in the Pareto initial population. Fitness sharing is one of niching methods to maintain diversity of a set of individuals. In the paper, the NSGA-II (a fast elitist Non-dominated Sorting Genetic Algorithm) proposed in [14] is used for fitness sharing.

**Selection**
Selection methods include roulette wheel selection, stochastic universal sampling selection, truncation selection, tournament selection and local selection. The stochastic universal sampling selection method was used in this study because of its high fitness accuracy.

- Recombination/Crossover

Each selected individuals evolve to new individuals (offsprings) through recombination/crossover. The combination is based on the combined variables from the parents.

- Mutation

Mutation creates new variables by forcing changes in variables with low probabilities of modification. For example, for an individual consisting of binary numbers, 0 is randomly changed to 1 and vice versa. This allows more diverse variable sets to have optimal solutions.

3. APPLICATION

3.1 selected building and ventilation simulation

An apartment building located in Jeju island, Korea was selected for this study. The floor plan is shown in Fig 4(a). Through site visits and questionnaires, it was found that the average of occupants are two per household and occupants spend most of time in the living room and the bedroom.

To simulate airflow rate entering the building, CONTAMW 2.4 developed by the National Institute of Standards and Technology [15] was selected. The reason for CONTAMW is as follows: if a computationally intensive approach (e.g., Computational Fluid Dynamics, CFD) is selected for a large number of simulation runs required for the GA optimization, this will become a hindrance. CONTAMW 2.4 is not the most detailed approach compared to the CFD, but accurate enough and suited for assessing ventilation phenomena in a building. CONTAMW, based
on nodal flow network modeling, predicts time histories of the airflows between nodes and concentration of indoor pollutants. Fig 4(b) shows the COMTAMW 2.4 model. The simulation inputs were obtained from site visits and construction documents.

The simulation was performed in winter days (exclusive of summer and spring/fall) since most residents fully utilize natural ventilation by opening doors and windows during intermediate and summer seasons. In simulation runs, it was assumed that windows and doors are closed (except doors to the living room and bedroom) while the ventilation system operates.

Figure 4: Floor plan and CONTAMW Model

3.2 Design Variables and objective functions

The ventilation method, size and location of diffusers, the amount of outdoor airflow rate, heat recovery method are selected as design variables. The initial investment cost, operation cost (fan energy, heating, and maintenance (filter exchange and cleaning), Percentage Dissatisfied (PD) and CO₂ concentration are chosen as objective function elements. Table 2 and Eq. (2) outline the design variables and objective function elements.
### Table 2: Used encoding

<table>
<thead>
<tr>
<th>Used encoding</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_1$</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>$X_2$</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>$X_3$</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>$X_4$</td>
<td>0/100</td>
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<td>/250/350</td>
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<td>0/100</td>
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<td>/150/200</td>
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<tr>
<td></td>
<td>/250/350</td>
</tr>
<tr>
<td>$X_6$</td>
<td>0/100</td>
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<td>/150/200</td>
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<tr>
<td></td>
<td>/250/350</td>
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<td>/250/350</td>
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<tr>
<td>$X_9$</td>
<td>0/100</td>
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<td></td>
<td>/150/200</td>
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<td>/250/350</td>
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<tr>
<td>$X_{10}$</td>
<td>0/60</td>
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<tr>
<td></td>
<td>/120/180</td>
</tr>
<tr>
<td></td>
<td>/240/300</td>
</tr>
</tbody>
</table>

\[ MINF(X) = F(f_1, f_2, f_3, f_4) \]  

Where,  
$ f_1 =$ Initial Investment Cost (KRW)  
$ f_2 =$ Operation Cost (KRW / Yr)  
$ f_3 =$ Percentage Dissatisfied (%)  
$ f_4 =$ CO₂ Concentration (PPM)  

### 3.3 Optimization process

The optimization process consists of the following five steps.

Step 1: used encoding and population size
Step 1 involves defining the used encoding for the design variables as shown in Table 2. $X_1$-$X_3$ is 1 if hybrid supply is installed and 0 otherwise. $X_4$-$X_6$ and $X_7$-$X_9$ are the airflow rates of total and sensible heat exchangers (CMH: cubic meter per hour), and 0 indicates that such heat exchanger is not installed. $X_{10}$ is the rate of the hybrid exhaust (CMH). $X_1$-$X_{10}$ are randomly selected within range of boundary condition, and then converted into a 2000:1 vector. In other words, each of $X_1$-$X_{10}$ consists of 2000 individuals. For this study, the size of subpopulation was set at 40 and the individuals of the subpopulation at 50 to generate the initial population, resulting in 2000.

It is important to establish a proper population size for an optimization problem [16]. The size in this study was obtained through seven ‘trials and errors’.

Step 2: CONTAMW 2.4 and GA

Step 2 involves integration of CONTAMW 2.4 with GA which runs on the MATLAB platform. The process is as follows: (1) The CONTAMW simulation input files are read in MATLAB, (2) a new individual generated from GA is overwritten in the CONTAMW 4 simulation input file by a matlab m-codes, (3) CONTAMW 2.4 is executed from MATLAB. (4) Once a CONTAMW 2.4 simulation result file is created, the file is converted to a text file to be read in MATLAB. It should be noted that the CONTAMW 2.4 simulation result file is a binary file, SimRead3.exe is automatically executed in MATLAB to convert it to a text file. In Step 2, CONTAMW 2.4 input files are created from MATLAB, CONTAMW 2.4 simulation runs are carried out, the results are read until the iterative process finds a global minima.

Step 3: objective function calculation

In Step 3, the four objective function elements (initial investment cost, operation cost, PD, and CO$_2$ concentration) are calculated. The initial investment cost data was provided by a ventilation company (www.ventopia.com), a participant in this study. The operation cost includes fan energy, heating energy and maintenance.
Fan and maintenance cost data were provided by the participating company. The heating energy calculation is based on the hourly weather data (winter months, Oct.-Feb.) and calculation method was based on [17]. The PD was calculated based on [18]. For a measure of IAQ, CO₂ concentration is selected since it is a typical contaminant generated primarily by occupants and, in addition, measurement of CO₂ in occupied spaces has been used widely to evaluate the sufficiency of outdoor air supplied to indoor spaces [19]. For CO₂ calculation, an adult is assumed to generate 0.31 liter per minute [20]. As a threshold of CO₂ concentration, 1,000ppm, a non-mandatory but recommended value of the code [1] is chosen. The number of occupants in each room (Fig. 4) was obtained through on-site interview and questionnaires. The CO₂ concentration was calculated every hour for 24 hours in each zone (living room, bedroom and dining room). In order to reduce the computation time required by the genetic algorithm, PD was categorized into three levels (A, B and C) [18], and CO₂ concentration was rounded up to the nearest hundred PPM.

Step 4: finding Pareto set

Step 4 involves finding the Pareto optimal solution set. The number of generations was set at 500. Theoretically, the maximum number of trial solutions can be 1,000,000 (500 multiplied by 2,000 individuals). The individuals of X₁-X₁₀ generated in Step 1 makes a single generation through Steps 2-4. When one generation is finished, new individuals are generated in Step 4 by fitness sharing, selection, recombination/crossover and mutation, after which the optimization process is repeated according to the number of generations. The NSGA-II method proposed in [14] was used so that diversity of individuals could be maintained without DM’s determining the niche size.

4. RESULTS

Table 3 shows the results of the optimization algorithm that combines the genetic algorithm and Pareto optimality. A set of Pareto optimal solutions consists of 18
solutions. To validate the results, two approaches were employed. The first is to check the dominance relationships among the 18 Pareto optimal solutions, and the second is to check superiority of the optimal solutions by varying design variables.

The first validation method is described below, details of which will not be given in this paper for want of space. The comparisons between optimal solutions are made to confirm that every optimal solution from the algorithm is a non-dominated Pareto solution.

Comparison of Optimal Design 1 with Design 2 (Table 3): Design 1 has lower operation costs, whereas Design 2 has lower PD and CO₂ concentration, indicating that both designs are non-dominated Pareto solutions whose superiority cannot be determined.

Comparison of Optimal Design 4 with Design 5 (Table 3): Design 4 has lower initial investment and operation costs, whereas Design 5 has lower PD and CO₂ concentration, indicating that both designs are mutually non-dominated.

Table 3: Optimal Designs (Non-Dominated Pareto Solution Set)

<table>
<thead>
<tr>
<th>Optimal Design</th>
<th>Hybrid (supply diffuser)</th>
<th>Design Variables</th>
<th>Objective Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LR (X₁)</td>
<td>BR (X₂)</td>
<td>DR (X₃)</td>
</tr>
<tr>
<td>1</td>
<td>0*</td>
<td>0**</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
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<td>5</td>
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</tr>
<tr>
<td>18</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

LR: Living Room, BR: Bed Room, DR: Dining Room
*diffuser not installed, **diffuser installed, ***includes fan energy, heating energy (Oct. – Feb.), maintenance
Comparison of Optimal Design 17 with Design 18 (Table 3): Design 17 has lower initial investment and operation costs, whereas Design 18 has lower PD and CO₂ concentration, indicating that both designs are non-dominated Pareto solutions to each other.

By cross-comparing all of the 18 optimal designs as explained above, it was found that all optimal solutions are non-dominated.

The second validation method is to validate propriety of the Pareto optimal solutions by varying design variables (ventilation method, size and location of diffusers and grilles, the amount of outdoor airflow rate, heat recovery method).

By changing supply diffuser location: The diffuser location of Design 1 in Table 3 (hybrid, supply diffuser located in the dining room) was varied to the living room and the bedroom for the purpose of comparison. As shown in Table 4, the solution becomes a non-dominated Pareto when the supply diffuser is located in the dining room. Installing supply diffuser in the living room or the bedroom requires higher initial investment cost because an additional diffuser should be installed. Although the actual CO₂ concentration level differs according to the supply diffuser location, the CO₂ levels are identical for all three cases in Table 4. As described earlier, this is due to the fact that the CO₂ values were rounded up to the nearest hundred PPM for the sake of GA computation time. The calculation resolution can be adjusted by changing the degree of rounding. But, for the purpose of this study, accuracy level of CO₂ concentration in order of less than 100 PPM is considered acceptable in ventilation simulation.

Table 4: by changing supply diffuser location

<table>
<thead>
<tr>
<th>Design</th>
<th>Supply diffuser location</th>
<th>Initial Investment cost (KRW)</th>
<th>Operation cost (KRW/Yr)</th>
<th>PD</th>
<th>CO₂ (PPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-dominated Solution (Design 1)</td>
<td>Dining Room</td>
<td>710,000</td>
<td>151,230</td>
<td>B</td>
<td>1100</td>
</tr>
</tbody>
</table>
By changing airflow rate: The capacity of the total heat exchanger of Design 4 (Table 3) was varied from 150 to 200, 250 and 350 (CMH) for comparison. As indicated in Table 5, the solutions become non-dominated Pareto for airflow rates of 100, 150 and 200 (CMH). On the other hand, solutions for 250 and 350 (CMH) become Pareto dominated by Design 8.

Table 5: by changing airflow rate

<table>
<thead>
<tr>
<th>Design</th>
<th>Air flow rate</th>
<th>Initial Investment cost (KRW)</th>
<th>Operation cost (KRW/Yr)</th>
<th>PD</th>
<th>CO2 (PPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-dominated Solution</td>
<td>100</td>
<td>1,000,000</td>
<td>182,400</td>
<td>B</td>
<td>900</td>
</tr>
<tr>
<td>(Design 4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-dominated Solution</td>
<td>150</td>
<td>1,252,900</td>
<td>223,590</td>
<td>A</td>
<td>800</td>
</tr>
<tr>
<td>(Design 7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-dominated Solution</td>
<td>200</td>
<td>1,569,700</td>
<td>264,780</td>
<td>A</td>
<td>700</td>
</tr>
<tr>
<td>(Design 8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominated Solution</td>
<td>250</td>
<td>1,966,600</td>
<td>305,970</td>
<td>A</td>
<td>700</td>
</tr>
<tr>
<td>Dominated Solution</td>
<td>350</td>
<td>2,463,900</td>
<td>388,350</td>
<td>A</td>
<td>700</td>
</tr>
</tbody>
</table>

By changing heat exchanger type: The heat exchanger type of Design 8 (Table 3) was varied. As indicated in Table 6, the total heat exchanger is non-dominated.
Table 6: by changing heat exchanger type

<table>
<thead>
<tr>
<th>Design</th>
<th>heat exchanger type</th>
<th>Initial Investment cost (KRW)</th>
<th>Operation cost (KRW/Yr)</th>
<th>PD</th>
<th>CO₂ (PPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-dominated</td>
<td>Total Heat Exchanger</td>
<td>1,569,700</td>
<td>264,780</td>
<td>A</td>
<td>700</td>
</tr>
<tr>
<td>Solution (Design 8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominated</td>
<td>Sensible Heat Exchanger</td>
<td>1,619,700</td>
<td>826,450</td>
<td>A</td>
<td>700</td>
</tr>
</tbody>
</table>

The sensible heat exchanger was not selected as shown in Table 3 for the following reasons: since a sensible heat exchanger uses a heat exchange component made with metal, it is more expensive and has lower heat transfer efficiency than a total heat exchanger which uses a component made with paper. An advantage of the sensible heat exchanger is that it reduces problems associated with a total heat exchanger such as mold growth and dust clogging in the filters, etc because it uses metal as a heat exchange element. However, these problems in the total heat exchanger can be solved by replacing filters regularly. Be noted that the cost of filter exchange is included in this study. With a given airflow rate, the sensible and total heat exchanger provide identical PD and CO₂ concentration. But, the sensible heat exchanger requires higher initial investment cost and provides lower heat recovery. Thus, the sensible heat exchanger becomes dominated by the total heat exchanger. Accordingly, the sensible heat exchanger is not selected in this study.

4.2 Application in design scenarios

In the previous section, it was shown that all 18 designs were non-dominated Pareto optimal solutions. The advantage of Pareto optimality is that it offers not ‘one’ but ‘multiple’ non-dominated solutions, enabling the DM to select his/her preferred design choice. In other words, there is no need to determine the weights among the objective function elements. As mentioned earlier, the weights can vary according to the DM’s preference. Since Pareto optimality is not associated with the issue of weights, the DM is able to select an optimal design of his/her choice from Table 3.
In this context, anyone such as ventilation system engineer, architect, building owner, occupant can be the DM. A DM looking for a system with the lowest initial investment cost can select from Designs 1 and 2. Design 1 is a hybrid ventilation with air supply diffuser installed in the dining room (60 CMH, constant airflow rate fan), and Design 2 is with a 120(CMH) constant fan. Be noted that although Designs 1 and 2 have different airflow rates, they have same initial investment costs because their exteriors are identical, and only the internal motor and circuit board are different, which do not affect the initial costs. A DM looking for a system with the lowest operation costs can select Design 1. A DM interested in the lowest PD may select Design 18, which is a combination of the hybrid and total heat exchanger (a hybrid supply diffuser installed in the living room and the dining room, 60(CMH) ventilation fan in the dining room, and 200 and 250(CMH) total heat exchangers in the living room and the bedroom, respectively). If the initial or operation costs of Design 18 are deemed excessive, the DM can select from other alternatives in Table 3. It should be noted that all designs in Table 3 are non-dominated Pareto optimal solutions. This means that no matter which solution is selected, there is no other solution that dominates it. The case for selecting a system with the lowest CO₂ concentration is not presented here because it is identical to that of selecting the lowest PD.

5. CONCLUSIONS AND FUTURE WORK

In this study, it is shown that optimal design of residential ventilation system in apartment buildings can be found using the genetic algorithm and Pareto optimality. The NSGA-II method proposed in [14] was used to improve the diversity of optimal solutions. The objective function includes four elements (initial investment cost, operation cost, PD, and CO₂ concentration). As a result, the DM can choose a optimal solution among the Pareto set according to his/her preference. The future work includes:
Optimal design for different floor plans: Applying the proposed optimization algorithm to various floor plans such as two bedroom, three bedroom, and four bedroom floor plans.

Optimal design for different climates: This study was conducted for an apartment building in Jeju island. Since the operation cost can vary in different climates, different optimal solutions can be found according to climate regions.

Optimal design for different user-scenarios: One of the most difficult problems in building simulation is to predict the occupant’s behavior. For further study, optimal system will be determined based on multiple user scenarios.

Optimal control: real-time optimization of ventilation system performance will be a future avenue. This control strategy will use current weather information, indoor environmental conditions integrated with heating and cooling system. The control will be linked to the Internet so that the user can access from PDA, wall pad, or any standard web browser.

6. ACKNOWLEDGEMENT

This research is part of a research project (Grant No. 05 CTRM D06 : High-tech Urban Development Program ) sponsored by KICTTEP (Korea Institute of Construction & Transportation Technology Evaluation and Planning). The financial support is gratefully acknowledged.

7. REFERENCES


ENERGY AND ECOLOGY EFFICIENCY OF URBAN MORPHOLOGIES: A COMPARATIVE ANALYSIS OF ASIAN, AMERICAN AND EUROPEAN CITIES

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ABSTRACT: The growth in energy consumption in cities obeys laws derived from physics, thermodynamics and ecosystems theory. The fundamental energy pattern of a city consists of various buildings and spaces. This urban morphology interacts with people behaviour and with the local climate. A sustainable city is an integrated entity: structurally, functionally and environmentally. The following comprehensive analysis uses macro level indicators such as ecological footprints and metabolism inputs and outputs and micro level parameters in order to compare the transforming energy patterns of European, American and Asian cities. At the micro level of city texture, we will use the passive zone concept and a set of indicators, such as density, roughness, porosity, sinuosity, occlusivity, contiguity, solar admittance and mineralization. With this environmentally oriented model of urban fabric, we will describe an analysis method that we will use to connect architectonics, urban morphology, energy flows and climate in a comparison of Asian and European cities. What we will draw is a better understanding of how the city morphology governs the patterns of energy flows at the global scale level and at the scale of the urban texture and what are the most energy and ecology efficient urban morphologies.

Keywords: Energy, urban morphology, urban metabolism, cities ecological footprints, climate change

1. INTRODUCTION

Home of interaction between people and buildings, the city is where human civilization changes patterns of living and of energy consumption. UK data show that the energy requirements for buildings in the domestic and non-domestic sector exceed those for transport and industrial processes. In urbanized countries like UK buildings represent half of energy consumption; and with transportation, cities represent more than three quarters or energy consumption.

The complex relationships among climate, ecosystem health, and socioeconomic development call for an integrated theoretical framework within which to study the world’s cities. Advances in the fields of industrial ecology, urban metabolism and urban ecology shed light on these relationships.
2. MACROLEVEL FLUX ANALYSIS: METABOLISM COMPARISON BETWEEN ASIAN AND EUROPEAN CITIES

2.1 Cities Metabolism
An urban metabolism analysis [1] is a means of quantifying the overall fluxes of energy, water, material, and wastes into and out of an urban region. Analysis of urban metabolism can provide important information about energy efficiency, material cycling, waste management, and infrastructure in urban systems. The material metabolism of the modern city is based on the redeployment of the processes of nature. This redeployment provides energy for processes in which complex social and physical hybrids (heating, lighting, transportation, communication, water-supply systems and climate-controlled micro-environments) are built from simpler structures.

2.2 Linear Metabolism versus Circular Metabolism
Following the economic growth euphoria of the post-war years, increasingly profligate use of resources became the norm in the second half of the 20th century. Cities acquired an essentially linear metabolism, with little concern about the origin of resources flowing into them and the destiny of waste emanating from them. This has become a major systemic problem regarding their environmental sustainability. To become sustainable, cities must be more closed-loop ecological systems. Cities should thus be apprehended in their entirety as ecological systems. They should be as autonomous as possible by optimising resources reuse, with input and output levels (resources and wastes) that respect the carrying capacity of the earth.

2.3 The Planetary Metabolism of Global Cities
Modern cities depend heavily on materials and energy from outside their boundaries. London total ecological footprint is 300 times London surface area. London’s per capita ecological footprint, at 6.6 ha, is lower than that of New York or Los Angeles, at more than 10ha, but in a world of cities, where American, Australian and European lifestyles are copied all over the world, significant improvements in resource productivity are called for.
Pressures exerted on the environment by human settlements can be evaluated by the sustainable index of the “ecological footprint” [2], which translates the amount of resources swallowed up by cities and the amount of wastes they produce into areas of productive land. This measurable index thus represents the total amount of different areas scattered all over the world on which each city depends and which largely exceed its physical boundaries.

Nowadays, as a result of present harmful patterns of production and consumption, the ecological footprints of existing cities already cover almost the total area of the earth, and are tending to increase day by day, while arable soils, forests and natural areas continuously decrease. In addition to this land use issue, the ecological impacts of current cities exceed by 30% the carrying capacity of the earth as regards renewal of resources and assimilation of wastes.

An important point concerning cities is the fact that the ecological footprint (corresponding to the ecological territory necessary to sustain the city) exceeds by a factor between 100 and 1000 their physical territories. That means that through the local control of the physical structure of the city, urban planners control only less than 1% of the ecological territory of the city, which is scattered around the whole planet and is mostly unregulated.

This fact can be seen in the percentages of direct and indirect energies of some Asian cities (Fig.1) and is particularly critical in the case of Hong Kong as will be explained below.
2.4 The Density/Energy Curve and the Transformation of Asian Cities
A survey carried out in the 80s on 32 cities across the world by P. Newman and J. Kenworthy [4] on the effects of density on energy consumption linked to transport, revealed a strong relationship between the transportation energy and the population density. In 1980, around twice as much fuel was consumed for transport in American cities than in Australian cities, four times more than in European cities and six times more than in the considered Asian cities (Fig 2).

This relationship between energy consumption and the population density of cities was confirmed by subsequent studies: P.Naess (1996) concerning Scandinavian cities, V. Fouchier (1997) for the Ile-de-France, ECOTEC (1993) for Great Britain, etc.

At the end of the 1970s, the work carried out by Y. Zahavi [5], a World Bank researcher, provided a statistical explanation of the relationship between city,
mobility and density. Using Zahavi’s temporal conjecture, the reduction in population density is due to increased travel speed.

He hypothesised that the daily time-budget average is constant and equal to approximately one hour in all cities and that this time factor will remain unchanged over time. The impact of this time-budget constant on the relationship between economic growth and mobility is particularly important as it indicates that, should it continue, the more economic development provides rapid modes of transport, the more these will be used within the limit of just over one hour a day. According to this logic, it is the access to higher speeds that has permitted the expansion of urban sprawl. The time-budget constant means that the more we can travel at high speed, the more distance we consume. Speed is therefore a “pivotal variable” linking the number of kilometres covered and the transport time-budget and defines the population density of agglomerations.

The other constant proposed by Zahavi is that of monetary budgets. The monetary budget of households also represents a limit to the city’s expansion. The temporal and economic limits of the city make it necessary to consider the cost of speed to define the mobility behaviour patterns of city inhabitants. The movement distances accessible within a one hour per day time limit and within a budget proportional to income define the urban land take. However, they provide little information concerning the structure of the city. Inherited from the past, the various fabrics forming the city structure result from successive modes of mobility and their specific speeds, as well as the density of interactions permitted by the urban fabric.

Three types of city successively developed to match the dominant mode of transport, which changed from walking to public transport and then to the automobile. Cities with a long history present hybrid forms. The history of European cities implies that they are not totally dependent on the automobile. Other modes of transport continue more or less to operate. In the 1970s, Schaeffer & Sclar [6] established an analysis framework to understand changes in urban
forms and modes of transport by defining three types of cities: the walking city, the public transport city or transit city and the automobile city (Fig. 3).

In 25 years, the situation in this respect has dramatically changed in Asia with the creation of mega-urban regions some like Jakarta and Manila with more than 100 km radius and an increased dependence on automobile.

Newman & Kenworthy [7] defined four criteria representing the automobile dependence of cities: the intensity of the use of space, the move towards non-automobile modes of transport, the constraint represented by traffic levels, and the centrality and performance of public transport systems. The relationship discovered by Newman & Kenworthy has remained steady and even increased over the last two decades. This relationship is the most critical in Asia as the urban form is only emerging and as avoiding a super-Los Angeles type future for Asian mega-urban regions is the most critical path to ensure their sustainability.

2.4 Case Study: Hong Kong Metabolism Evolution

In 1980, the inhabitants of highly dense Hong Kong were consuming 50 times less energy than Australians for comparable standards of living [8].

However the situation has dramatically changed with the integration of Hong Kong in the Pearl River Delta mega urban region. From a hyper dense compact city, Hong Kong has transformed itself into a component functionally and economically
integrated into a huge mega scale urban region. As could have been forecasted by a look at the metabolism of giant American cities this change of global scale has completely transformed the metabolism of Hong Kong. Kimberley Warren-Rhodes and Albert Koenig [9] updated the Newcombe et al. pioneering study of Hong Kong's urban metabolism in 1971, highlighting trends in resource consumption and waste generation. Per capita food, water and materials consumption have surged since the early 1970s by 20%, 40%, and 149%, respectively.

Tremendous pollution has accompanied this growing affluence and materialism, and total air emissions, CO₂ outputs, municipal solid wastes, and sewage discharges have risen by 30%, 250%, 245%, and 153%. As a result, systemic overload of land, atmospheric and water systems has occurred. While some strategies to tackle deteriorating environmental quality have succeeded, greater and more far-reaching changes in consumer behaviour and government policy are needed if Hong Kong is to achieve its stated goal of becoming “a truly sustainable city” in the 21st century.

3. MACROLEVEL ECOLOGICAL FOOTPRINT COMPARISON

3.1 The Asia Carrying Capacity Overshoot
A massive social, economic, cultural and political transformation takes place as Asian countries develop vast mega-urban regions. The future of this populated region is an urban one, and the majority of its people will inhabit cities by 2020.

Asia as a continent has overshoot its ecological carrying capacity as early as 1970, that is to say 15 years before mankind as a whole has overshoot the carrying capacity of planet Earth in 1985. The ecological footprint of Asia is already 1.75 times its carrying capacity (Fig. 4).

If the creation of mega urban regions in China and in South East Asia, some of them 100 km radius, leads to a Los Angeles type urbanization of Asia, the
continent would need 10 to 12 times its carrying capacity. By following globally a Los Angeles urban pattern of development, Asia would need by itself the biosphere of several planets, with at least one planet for China alone with levels of efficiency similar to those of Canada and 3 planets with current Chinese levels of efficiency.

![Figure 4: Asia-pacific ecological footprint, 1961-2000](image)

3.2 **Case Study: Tokyo, Shanghai, Beijing, London, Paris, and American Cities**

**Ecological Footprint Comparison**

Shanghai ecological footprint per inhabitant is already higher than Paris and London ecological footprint: 6 ha per inhabitant according to Ove Arup calculations in Shanghai against 5.58 in Paris (Fig. 5).

![Figure 5: Comparison of ecological footprints of several world cities according to Ove Arup](image)
In figure 5, we see that Beijing ecological footprint per inhabitant is getting close that of Tokyo and that Shanghai ecological footprint is already in between the situation of European and American cities.

Energy consumption per inhabitant is almost double in Shanghai than in Paris (2.16 kilotons equivalent oil/year in Shanghai against 1.28 in Paris). This is partly due to the structure of economic activity (primary industry in Shanghai and services economy in Paris and London) but also to the huge differences in urban morphologies (urban sprawl in Shanghai compared to a density 6 times higher in the centre of Paris than in Shanghai).

As the GDP per inhabitant is 8 times lower in Shanghai than in Paris, the result is an ecological efficiency 8 times lower in Shanghai than in Paris and energy efficiency 16 times lower in Shanghai than in Paris. In other terms, it requires 8 times more biological resources and 16 times more energy to produce a unit of GDP in Shanghai than in Paris. In this huge efficiency difference, urban morphology at various scales accounts for a big part.

3.3 Is Shanghai a sustainable Model for China?
If the 500 Chinese urban dwellers of today had the same consumption patterns and the same ecological footprints as the Shanghai citizens, China would have today a 2.6 billion global ha footprint deficit, and would need 3 times the biological resources of its territory to sustain its urban population. With the rural population, China would need 4 Chinas and about half the planet resources.

In 2050, if 1.1 billion Chinese were urbanised according to the current Shanghai model with an American type footprint due to the urban sprawl and the increase in living standards and with an extremely optimistic 10 fold improvement of its systems efficiency, China would have a 11 billion global ha footprint and would need the resources of more than one planet Earth (8.7 billion global ha). Such a scenario is clearly unsustainable.
As noted by Herbert Girardet [10], “to create an environmentally sustainable London means reducing its resource use – as measured by its ecological footprint – by a factor of around 4. But often this may require a Factor 10 improvement in the performance of London’s engineering systems”.

As we have seen, due to its overall low density in spite of its many high rise buildings, Shanghai is moving towards a super-Los Angeles type urban structure, thus its ecological footprint will even be higher than that of Los Angeles due to its huge size, industrial structure and overall lack of resources efficiency.

To achieve Shanghai sustainability a factor 4 would be required now and a factor 10 will certainly be required in 2030 if Shanghai was as efficient in its resources use as London or North America. But Shanghai is 8 times less efficient than Paris.

If we follow Herbert Girardet assumption about London and cross it with the fact that Shanghai needs now 8 times more biosphere resources to produce one unit of value, a factor 80 may already be required in the performance of Shanghai engineering systems to achieve sustainability. As this is an impossible goal to reach in the short term, the action on engineering systems must be complemented by an action of control and optimisation of urban form, avoiding sprawl and promoting compactness.

3. THE TARGET FOR A FAIR EARTHSHARE AND FOR CLIMATE CHANGE: FACTOR 20

4.1 The Limits of the Carrying Capacity, Urbanisation and Climate Change

The carrying capacity of the Earth, that is to say the quantity of biosphere available to support human life is only an average of 1.7 ha per human being [2]. The struggle against Global Warming and a fair Earth share (an equitable share of the biosphere) imply a radical transformation of urbanism.

The planet Earth as a whole and the Asian continent in particular have not a carrying capacity sufficient to sustain a Los Angeles type urbanisation of Asia.
Rural people in developing countries use less than 0.8 ha of biosphere per inhabitant. Urban dwellers use between 12 ha (USA) and 6 ha (Europe, Japan).

The massive transition from rural to urban (which is a key feature of South east Asian societies) is the main reason of the ecological footprint overshoot, i.e. the fact that mankind uses 1.4 planets Earth now and will need at least 3 planets Earth by 2020. This urban transition is the most important driver of Climate Change.

4.2 The Target to Reach for a Fair Earth share
If we want to achieve a fair Earth share while using one planet only and limiting climate change, the goal to reach before the end of this century must be dividing by 15 the ecological footprint of American cities and by 7 the ecological footprint of European cities.

The average carrying capacity of planet Earth is 1.7 global ha per human being if we leave 15% of the biological resources of the Earth for sustaining the 50 million other living species. Anyway from 6 billion today mankind population will reach between 10 and 11 billion before stabilizing at the end of the century. At the same time as the mankind impact on the biosphere increases, the absolute carrying capacity of the planet diminishes due to soil erosion, desertification, deforestation, and death of algae due to ocean warming. Before the end of this century the average carrying capacity for each human being may be as low as 0.8 ha per inhabitants, that is to say the levels of Bangladesh today.

Thus there are two main scenarios: an increase of the inequalities between rich urban societies and poor rural and urban societies (1 billion urban dwellers live in slums) or improving living conditions for all with a much lower pressure on the planet. Mankind now uses 1.4 the resources of the planet but 2 billion human beings live with less than 2 dollars a day, and have no access to electricity or drinkable water. Sustainability means also overcoming poverty and achieving a fair Earth share of the planet resources. Thus we must move towards a reduction of cities footprints towards a goal of less than 1 global ha per inhabitant. At the
moment this may seem impossible and the most innovative realizations or projects like Bed Zed in Great Britain and Dongtan in China are in the range of 2.6 global ha per person which is sufficient for today but will not cope with the population increase; in Europe, the political target is to divide by 4 the emissions of CO₂ by 2050, which is a strong move in the right direction as half of the ecological footprint is linked to CO₂ absorption.

4.3 Dividing by 20 the Energy Footprint of Cities

This paper proposes an ambitious goal of dividing by 20 the energy footprint of cities by a combined action on their morphology, their architecture, their systems, and their inhabitants' behavior. An energy efficient urbanism associated with bioclimatic architecture, new systems and fundamental changes in people behavior and patterns of consumption can lead to a division of energy consumption and associated Greenhouse Gas Emissions by a factor 20 (Fig. 6)

![Figure 6: Factors that affect the energy performance of cities [11].](image)

The sustainable construction movement concentrates mainly on the improvement of building systems (factor 2) and not enough on people behavior (factor 2) and on urban and architectural bioclimatic and energy efficient forms (factor 5). Working on all the factors, and on urban design, and not only on systems, we can reach a factor 20.

In a planet where 1 billion people are urbanized every 10 years, which represents a factor 100 in the intensity of urbanization, the urban planners and architects must take the leadership in the fight against Global Warming.

4.4 Dongtan: A Sustainable Model for China

The eco city of Dongtan on Chongming Island near Shanghai is an ambitious project targeting an ecological footprint of 2.6 ha per inhabitant compared to a conventional approach of 5.8 ha per person (Fig. 7).
Compared to a conventional city, water consumption is divided by 2 and water discharge by 10. Energy demand is divided by 3 and CO2 emissions are divided by 10. By extrapolating this model to its whole urban population China would still need one third of the resources of the planet by 2050.

4. MICROLEVEL URBAN TEXTURES COMPARISON

51. A Method of Analysis of the factor 2 of Urban Texture

The following section of the paper focuses on urban texture; a key factor which determines both energy demands linked to the local microclimate and to artificial lighting but also determines energy demand for people and material flows of transportation.

Cities are simultaneously human systems and complex porous physical surfaces that exist on several scales at the same time. They associate a high level of variability and a more or less organised subjacent structure.

At present, cities are thermodynamics machines, which transform solar radiation into heat. They transform low entropy solar energy into high entropy heat. They must become positive energy cities and transform solar radiation into energy.

Studies on the relations between density and energy remain too general to be able to define operational action criteria for existing cities. Global studies do not
analyse the various morphological components of the cities, the impact of the grid, the fragmentation of the distribution of activities on the generation of mobility, or the impact of size, hierarchy, accessibility and connectivity of movement networks. The city is seen as a homogenous entity and the complex linking of factors resulting in the global relationship between energy and density is not analysed.

Cities are both built volumes (solids) and empty spaces. The analysis of the discrete spaces forming the solids (being the buildings) has undergone considerable developments in terms of their bioclimatic and energetic aspects. However, far less work has been devoted to the overall texture of the city (grain size, porosity, grid density, connections between empty spaces, major and minor breaks).

To attain operational results, it has become necessary to refine and quantify the morphological description of the various types of density in terms of their impact on mobility and the microclimate. The urban texture offers various degrees of insulation from the natural climate. While the urban microclimate affects external spaces it also needs to have an effect on the internal climate of buildings to create passive bioclimatic architectures able to reduce energy intensity and the carbon footprint. For example, the possibilities of using natural ventilation depend on the morphological properties of the buildings as well as the climatic conditions next to the buildings, such as air movement and atmospheric and noise pollution. These conditions depend on the urban morphology.

It has now become necessary to study the link between modes of travel, urban density and energy consumption through the interaction between transport systems, activity morphologies and grids, and to specify the role of speed as a pivotal variable in urban organisation.

5.2 The Scale and Level of Complexity Transformation of Urban Texture
Traditional European urban texture was complex and fragmented at different scales. Lead by Le Corbusier, the Modern movement of the 1920’s, still widely applied in Asian cities has favoured simple, repetitive mega scale patterns (Fig. 8).

Figure 8: The traditional urban texture of Paris versus the modern city, as seen by Le Corbusier in his 1920 theory of modern urban planning. One century later, all studies show that Le Corbusier theories lead to unsustainable cities.

This transformation of city pattern is obvious in Ho Chi Minh City, which juxtaposes a classical European pattern, an American pattern and a recent Asian pattern close to le Corbusier theories (Fig.9)

Figure 9: At the same scale, left traditional city Saigon centre, right modernist Saigon South

5.3 Cases analysed
The comparative analysis of Shanghai and Paris that we are carrying out and that we will further extend to mega urban regions of South east Asia will reveal how population and activity density gradients and profiles can be used as variables for urban interactions and the way that these now affect the possibilities of modal transfers towards other modes of transport with reduced energy intensity and a
lower carbon footprint. In order to form a database that can help identify the underlying interaction mechanism between the urban morphology and the energy patterns, a number of cases were constructed by studying the GIS of different cities one square kilometre morphology (Fig. 10 and 11).

Figure 10: Paris (lower left) and Shanghai morphologies at the same scale

Figure 11: Beijing, Shanghai, Paris and Berlin urban textures at the same scale

5.4 Methodology
The analysis will include the following stages:

1. The construction of a typology of urban forms

The construction of this typology will result in the calculation of quantitative parameters. The parameters will describe morphological types:

On the one hand, through their physical characteristics: form of constituent units, grids, sizes, degree of regularity, modes of assembly, degrees of connectivity,

On the other hand, their economic and social characteristics: levels of mixed uses, intensity of activities, density of occupation and uses, size of the use grid, distribution of activities, density (number of inhabitants per hectare).
This morphological and typological analysis will be carried out on several scales, from the agglomeration to the district and the plot.

2. Evaluation of energy consumption and greenhouse gas emissions of the various urban fabric typologies in Paris and Shanghai.

We use a simplified spatial modelling of urban morphology complexity resulting in defining a set of environmental indicators. The DEM (Digital Elevation Model) is a compact way of storing urban 3D information using a 2D matrix of elevation values; each pixel represents building height and can be displayed in shades of grey as a digital image. The analysis of DEMs with image processing techniques has already proven to be an affective way of storing and handling urban 3D information, and being very conducive to a number of urban analyses.

5.5 Urban morphology Parameters

Computer-based analysis techniques and methodologies will be applied to various datasets, including digitized buildings, land use/land cover, and other essential datasets for Shanghai and Paris. This effort will use a database of urban morphology parameters [12]:

- Mean and standard deviation of building height
- Mean and standard deviation of vegetation height
- Building height histograms
- Area-weighted mean building height
- Area-weighted mean vegetation height
- Surface area of walls
- Plan area fraction as a function of height above the ground surface
- Frontal area index as a function of height above the ground surface
• Height-to width ratio

• Sky view factor

• Roughness length

• Displacement height

• Surface fraction of vegetation, roads, and rooftops

• Mean orientation of streets

### 5.6 An Example: Modelling the passive zone concept

According to C. Ratti et al. [12], the surface-to-volume ratio is an interesting descriptor of urban texture. It defines the amount of exposed building envelope per unit volume, and can be used in a number of different applications. Its relevance to the energy consumption of buildings, however, must be considered carefully. Minimizing heat losses during the winter requires minimization of the surface-to-volume ratio; but this implies a reduction of the building envelope exposed to the outside environment, thus reducing the availability of daylight and sunlight and increasing energy consumption for artificial lighting and natural ventilation.

In fact, the main energy distinction to be drawn within buildings is a function of the exposure to the outside environment. This concept is made explicit with the definition of passive and non-passive zones, which quantify the potential of each part of a building to use daylight, sunlight and natural ventilation. By a simple rule of thumb, based on empirical observations, all perimeter parts of buildings lying within 6 m of the facade, or twice the ceiling height, are classified passive, while all the other zones are considered non-passive (Fig. 12).
Figure 12: Parts of a building, which can be naturally lit and ventilated, are called ‘passive zones’.
By a simple rule of thumb given by the LT method, they extend approximately for 6 m (or twice the ceiling height) from the facade. Image adapted from Baker and Steemers [11].

According to C. Ratti et al. [12], the surface-to-volume ratio, while being an interesting morphological parameter, does not describe the total energy consumption in urban areas.

A better indicator seems to be the ratio of passive to non-passive zones, although accurate energy consumption values can only be derived from an integrated simulation such as LT (where LT stands for lighting and thermal). The proportion of passive to non-passive areas in buildings provides an estimate of the potential to implement passive and low energy techniques.

Main results of this type of methodology are shown in the comparative study of Berlin, London and Toulouse undertaken by C. Ratti et al. [12] (Fig. 13, 14 and 15)
Figure 13: London (left), Toulouse (upper right) and Berlin (lower right) urban morphologies at the same scale. Three examples of European urban textures (Victorian, medieval and modern). The most sustainable is the medieval one.

Figure 14: Passive zones (within 6 m from the facade) in London, Toulouse and Berlin, second floor (from C. Ratti et al. 2005).

Figure 15: Energy consumption in London, Toulouse and Berlin, non-passive zones consume approximately the double of unobstructed passive zones [12].

5.7. Coupling of the Digital elevation model analysis with the light and thermal simulation tools

The analysis of DEMs (Digital Elevation models) will be used to explore the effects of urban texture on building energy consumption in various areas of Shanghai. DEM is an effective support to derive morphological urban parameters quickly. Some of these will then be passed to a simulation tool (LT), in order to get energy consumption figures (Fig 16).
5. CONCLUSION

This cross-regional study that follows our previous work on Chinese cities [13] is an attempt to explore the general laws that govern energy flows in cities. Studying multiple cities at different periods of time, allows making a comprehensive comparison and contrast of city morphology efficiency between regional cultures in the west (Paris, Berlin, London, Toulouse) and in the east (Shanghai, Beijing, Guangzhou, Shenzhen, Hong Kong), between periods of time of the rapid growth (Shanghai and Beijing) and the steady growth (Paris, Berlin, London and Toulouse).

The proposed approach allows a quantified diagnosis of urban sustainability, useful for comparing the bioclimatic and energy efficiency of different urban morphologies, useful for design and planning, but also monitoring of the long term urban planning.

6. ACKNOWLEDGEMENT

We are indebted to Cambridge University and to the Massachusetts Institute of Technology for their extremely stimulating research papers, which have been the main source for extending their parametric methodology to Asian cities.
7. REFERENCES


LINEAR CITY, A STUDY OF URBAN DEVELOPMENT AND RAIL TRANSPORT IN HONG KONG

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ABSTRACT: Urban development and transport have a complementary and close inter-relation throughout the history of human culture. At every age this relation has held a key position in formulating and implementing policies as wide ranging as national expansion, establishing new frontiers, or increasing cultural and commercial communications between different regions. At the present time, this dual relationship again holds one of the keys to the critical issue in continuous prosperity of the cities; SUSTAINABILITY.

Keywords: Linear City Research, rail transport, urban design, sustainability

1. INTRODUCTION

The project was initiated by KCRC, The Chinese University of Hong Kong, and the University of Hong Kong. With a view to examining the current practice of developments associated with railway and searching for possibilities for improvements particularly in terms of the contribution of such development to the urban quality in Hong Kong.

It was organized in three phases –modules- which extended over three years, and concluded with recommendations in the form of design strategies, which are the subject of the present paper. The research involved various disciplines such as architecture, geographic sciences, economics, transport planning, environmental studies, as well as professionals such as planners, property managers, KCRC directors, and government bureau officials.

Module 1 comprised background research into relevant case studies, KCRC network and stations, public views and priorities, and government policies in several key areas specifically related to the research including the following:
KCRC development policies

Government policies: Planning, Lands Bureau, Transport Rail Board

Demographic patterns,

Land Economics

Development and Environmental imperatives

Module 2 comprised synthesis of the results from module 1, consultations with community groups and professionals and preliminary application of the results to possible new directions in the design of railway stations and their associated developments.

Module 3 comprised the development of final policy and design strategy recommendations illustrated through application to selected cases of stations such as the one which is Kam Sheung Road/Pat Heung, the subject of the present paper.

2. URBAN DEVELOPMENT AND RAIL TRANSPORT IN HONG KONG.

Urban development and transport have a complementary and close inter-relation throughout the history of human culture. At every age this relation has held a key position in formulating and implementing policies as wide ranging as national expansion, establishing new frontiers, or increasing cultural and commercial communications between different regions. At the present time, this dual relationship again holds one of the keys to the critical issue in continuous prosperity of the cities; SUSTAINABILITY.

This is especially true in the case of extremely dense urban developments such as Hong Kong. In relatively low-density instances it’s possible to deal with transport and urban development relatively separate from one another without oversimplifying the situation at hand. But in Hong Kong the majority of the urban
development projects and of course the city as a whole are so complex and involve such large orders of magnitude that it is difficult to act with a properly coordinated view of the two without the to grasp a total model which takes into account the issues both of transportation and urban development and the complex processes of their interaction. It was the aim of the research project to explore methods for doing so, and arrives the results as a resolution, not simply an analytical report.

Our research shows that HK is operating one of the most efficient, high quality rail transport systems in the world with a strong potential for its own sustainable continuation as well as significant contribution to the well being and sustainable development of Hong Kong. This operation has been created and continues to prosper with the support of government policies and full recognition of its role. “. The new transport strategy entitled “Hong Kong Moving Ahead” promulgated in October 1999 has reaffirmed the need to rely on railways as the backbone of Hong Kong’s transport system. Railways are essential to Hong Kong’s continued economic, social and land development, and will be given priority in Government’s plans for infrastructure development...”{Policy on Railway Development. HKSAR Railway Policy, Oct. 1999}

But the pre-requisites for such sustainability are adaptability in development policies and more importantly change and adaptability in the conditions for its operational environment. These conditions lie mainly beyond the reach of KCRC and are vested in Government ordinances and policies.

The network is markedly compact with fewer stops and therefore greater efficiency compared to rail transport systems in other major cities such as Tokyo, London, Paris, and New York.
The government working paper RDS-2 seems to address this issue in the following terms:

The Study Objectives*

2.2 The RDS-2 examined the needs of the future railway network to fulfill the following objectives:

(a) To relieve bottlenecks in the existing railway systems;

(b) To provide rail service to strategic growth areas for housing and economic development;

(c) To meet cross-boundary passenger and freight demands; and

(d) To increase the share of rail in the overall transport system to reduce reliance on road-based transport

[HKSAR RDS-2 Study]

The results make a clear case in favour of what is already Government policy in Hong Kong in the interest of sustainable quality of the city and well being of Hong Kong residents. Its stated priorities are in principle consistent with considerations for sustainability.
The policy acknowledges many distinct benefits of rail over other modes of transport, specifically in terms of environmental and economic benefits.

Environmental benefits*

“The Strategic Environmental Assessment carried out as part of the RDS-2 has concluded none of the new railway schemes will present insurmountable environmental problems, though all have some potential environmental impacts. These will be addressed during the design and development process of individual railway scheme.

On completion, the Network would increase the rail share in the public transport system from 31% at present to 43% by 2016, or in terms of the distance travelled by passengers, from 34% to almost 60%. This would reduce the reliance on road-based transport and translate to environmental benefits amounting to a reduction of air pollutants by some 600 tonnes of NOx and respirable suspended particulates per year and 160,000 tonnes of CO2 per year.”

Economic Return

“The investment in the Railway Network will yield an economic internal rate of return of more than 15%.”

[re. HK 2030, SAR Rail Development policy]

Much attention has been paid rightly to “integrated transport planning” but the integration has been limited to “transport” and directed at an integrated view of different modes of transport.

One notable characteristic of these policies and their extensions is their limited vision focused on railway in itself, and transport as a nearly closed system even when it goes beyond rail transport to include alternative modes. (ref. paper by
Yan et al. Their vision of “integration” is limited to inter-modality of transport and does not extend to numerous other factors in the larger context of URBAN DEVELOPMENT amongst which transport is an important but not the only factor. The policy limits itself to addressing the many distinct benefits of rail over other modes of transport, specifically in terms of environmental and economic aspects, but does not go further to reach a comprehensive URBAN DEVELOPMENT PLATFORM FOR ACTION.

In short, the model as designed for conditions at its inception has served Hong Kong well. But the model has been slow to adjust and respond to important changes and is likely to be unsustainable without recognizing the reason for its past success and adjusting its course of operation to the new conditions. This observation is consistent with the conclusion of other researchers such as the following independent study of the transport system in Hong Kong.

“By most definitions of sustainable transport, Hong Kong [1] is currently at the sustainable end of the spectrum because of its low levels of car ownership and use and concomitantly high levels of use of public transport. This paper argues, however, that there are two major threats to this position. The first is the increasing extent of the integration with the Chinese Mainland and the subsequent diminution of the strength of the borders between Hong Kong and the Mainland. The second is the aspirations and intentions of young Hong Kong residents to become car owners in the future”*

*CULLINANE, Sharon, Transport sustainability in Hong Kong: Safeguarding its future.

What are the factors that can lead to the decline of what has so far been a successful and sustainable operation?

One point is clear. It would be unwise to disregard the potential for such a decline. Sustainability of this operation has to be guarded and nurtured as a major consideration in other government initiatives regarding transportation and
development. Continuous increase in roads, recent plans for road connections to the mainland, ... all have general environmental impact as well as specific impact on the economic viability of the rail service.

The challenges to sustainability of the operation are essentially different forms of inadaptability and uncritical acceptance of limitations embedded in current policies and practices. Even where this clear and open to debate in for example planning policies such as HK2030, it seems to go unchallenged in the execution of the changes into architectural designs and development.

Here, practice seems to be rigidly limited to a standard vocabulary of building types and urban design.

The limitations of this approach, we suggest also limit the scope of debate and discussion even below what the policies in their own limitations would allow. Furthermore, they fail to contribute to widening the scope of a discourse by presenting rigid choices for negotiations between different priorities.
Here we present one example of architectural resolution as a conclusion to our research where the resolution is really a basis for discussion leading to variations which accommodate different priorities. Thus the point of discussion does not become to accept or to abandon all or large parts of a “design” but to use discussion as a last stage of the process in arriving at a design.

3. RAIL ACTION AREA

Although the immediate project concerns the land under KCRC control the strategic design is developed with a broader vision taking into consideration the community of Pat Heung and the adjacent rural and natural areas to the extent that they can affect and be affected by the presence of the railway station:

A “RAIL ACTION AREA” would be an area lending itself to coordinated action, where different interests and ordinances act within a collective vision of urban quality. The notable effect of this concept is to integrate into the process of design coordination of otherwise isolated actions regarding different parts and functions such as open space, communal facilities, shopping, entertainment, leisure, and health facilities.

In reality of daily experience these functions are interrelated even if they are designed and executed in isolation from one another. But such isolation of functions two negative phenomena with costly and wasteful effects. 1. Optimization on the basis of singular functions. 2. Negation of the synergic potential amongst the various functions.
4. ACCESSIBILITY OF PUBLIC DOMAIN

continuity between the existing community and the new one.

We ensure that despite necessary changes of density and types of building in terms of urban movement and access the new and the old are part of one entity. Ease of access from the existing into the new

Do not design the new such that it is “inaccessible” to the existing population, or that it forms a barrier to amenities that exist prior to the building of the new project.
5. VISUAL CONTINUITY AND VARIETY.
Variety, differentiation, and openness are visual signs of incremental growth which provide the image of manageable change rather than imposition of whole new and intrusive change into a community. Uniform, disconnected, imposing in its uniformity and assertive isolation.

6. STRATEGY FOR INCREMENTAL GROWTH AND CHANGE
Strategy which lends itself, even as a part of the process of design, to incremental change, and variation, provides a platform for public participation in the process of design. Furthermore, it allows different detailed design of different parts of a development under the influence of other factors such as changing priorities and changes of environmental conditions while the fundamental considerations remain intact.

Figure 4.: Pat Heung Density study
7. CONCLUSION

The design meets all current regulations and achieves the same density and economic profile as the more typical HK approaches. (see fig. ). It illustrates that while there is much room for improvement in housing and related development policies, a major factor in improving the urban quality of Hong Kong lies in improvements in the process and the product of DESIGN. Hong Kong operates a highly successful rail transport system whose operating model is based on a close interaction between rail ridership and property development.

This relationship which is a longstanding one throughout history is the basis for an operation which in contrast to almost all other railway systems in financially self-sufficient. However, the potential benefits of this relationship reach well beyond
what is so far exploited. The research project "linear city" is to explore such potential.

In the history of cities, transportation, and particularly rail transport has been a spine of urban development.

Railway transport has played a central role in the history of urban developments. It now can be a major factor in the government policies, and planned sustainable development. These policies include a host of ordinances such as Land ordinance, Rail ordinance, transport and planning policies. These all play a decisive part in the quality of the transport itself as well as urban developments that are an integral part of the railway transport model in Hong Kong.

Examination of the developments show that they have developed in isolation from one another. Railway as railway, housing as a part of housing policy and practice, civic development as stand alone institutions. But it doesn't seem to be recognized that the railway presents a special condition with special opportunities. This along with a new approach as illustrated in the present research to the design of housing developments can contribute significantly to the improvement of urban quality in Hong Kong and offer an effective platform for the increasing desire on Hong Kong residents to participate in the formation of their environment.

The approach as illustrated in the design for Pat Heung meets all current regulations and achieves the same density and economic profile as the more typical HK approaches. (see fig. 4). It illustrates that while there is much room for improvement in housing and related development policies, a major factor in improving the urban quality of Hong Kong lies in improvements in the process and the product of DESIGN.
8. REFERENCES

HK 2030 provides a good basis for achieving this condition. It recommends “special areas.”


[2]. Integrated Transport; A Case Study on the KCR East Rail In Hong Kong (15-16 November 2001, Singapore)

Anthony S.T. Yan,(General Manager, East Rail Operations KCRC)
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[4]. Transport sustainability in Hong Kong: safeguarding its future

CULLINANE Sharon

[5]. ROME MANIFESTO

Information on International precedents such as London, Paris, Tokyo and New York.

[ref. Module 1, Appendix … ]

Linearcity Research Project, as one of the research unit of The Chinese University of Hong Kong, has involved various background of researcher and resource experts.
SMART MEASURES FOR SUSTAINABLE OUTCOMES: INTEGRATED CONSIDERATIONS FOR SUSTAINABLE REFURBISHMENT OF OFFICE BUILDINGS

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ABSTRACT: The increasing stock of aging office buildings will see a significant growth in retrofitting projects in Australian capital cities. Stakeholders of refitting works will also need to take on the sustainability challenge and realize tangible outcomes through project delivery. Traditionally, decision making for aged buildings, when facing the alternatives, is typically economically driven and on ad hoc basis. This leads to the tendency to either delay refitting for as long as possible thus causing building conditions to deteriorate, or simply demolish and rebuild with unjust financial burden. The technologies involved are often limited to typical strip-clean and repartition with dry walls and office cubicles. Changing business operational patterns, the efficiency of office space, and the demand on improved workplace environment, will need more innovative and intelligent approaches to refurbishing office buildings. For example, such projects may need to respond to political, social, environmental and financial implications. There is a need for the total consideration of buildings structural assessment, modeling of operating and maintenance costs, new architectural and engineering designs that maximise the utility of the existing structure and resulting productivity improvement, specific construction management procedures including procurement methods, work flow and scheduling and occupational health and safety. Recycling potential and conformance to codes may be other major issues.

This paper introduces examples of Australian research projects which provided a more holistic approach to the decision making of refurbishing office space, using appropriate building technologies and products, assessment of residual service life, floor space optimisation and project procurement in order to bring about sustainable outcomes. The paper also discusses a specific case study on critical factors that influence key building components for these projects and issues for integrated decision support when dealing with the refurbishment, and indeed the “re-life”, of office buildings.

Keywords: office building, refurbishment, integration, decision support, raised floor systems.

1. INTRODUCTION

Commercial office buildings in Australian metropolitan cities have reached a mature age of 30-30 years on average (Khan et al 2006, Jones Lang LaSalle 2005). With recent technological advancements and changing user business operation, asset owners are facing major decisions in regards to refurbish or rebuild. Escalating costs of new build and the increasing focus on the sustainable use of
resources encourage warrants better studies on refurbishment options (CAR 2003 and Balaras 2004).

Traditionally, retrofitting of office buildings have been done on ad-hoc basis. Owners, designers and contractors alike were often troubled by the poor building documentation and lack of reference to successful examples. As a result, designers may not foresee all of the potential problems while the contractors apply huge mark-up for having to deal with the risks. As these professionals begin to get more volume of work, the characteristics of these refurbishment projects and strategies to maximise the opportunities for technological, sustainable and economic solutions become important issues.

Previous research identified the needs for the total consideration of buildings structural assessment, modelling of operating and maintenance costs (Reyers 2001), new architectural and engineering designs that maximise the utility of the existing structure and resulting productivity improvement, project risks and their mitigation (Gray, 1999 and Skorupka 2001), specific construction management procedures including procurement methods, work flow and scheduling and occupational health and safety (Cox 2004). Recycling potential and conformance to codes may be other major issues (Faniran, 1998 and Nigel et al 2001).

This paper introduces examples of Australian research projects which provided a more holistic approach to the decision making of refurbishing office space, using appropriate building technologies and products, assessment of residual service life, floor space optimisation and project procurement in order to bring about sustainable outcomes. The paper also discusses the case studies that helped identify and evaluate critical factors that influence key building components for these projects and key issues for integrated decision support when dealing with the refurbishment, and indeed the relifing, of office buildings.
2. THE NEED FOR REFURBISHING AGED BUILDINGS

The significant growth in the construction of new commercial office buildings since the early 70’s means that we now have a large stock of ageing buildings. The service components of these buildings are now obsolete after decades of operation, and may not meet today’s efficiency standards or the changing requirements of modern businesses. Over the recent years, research efforts have been made to explore the advantages of retrofitting of aged buildings (Allehaux and Tessier 2002; Anderson and Mills 2002; Jones Lang LaSalle 2005). The recent foci and commitment to sustainability encourages retrofitting options. In Europe for example, the retrofitting market has experienced considerable growth over the past 6 years (Caccavelli, 2002). Several reasons can explain this paradox:

User requirements have changed considerably during the last decade in terms of office equipment, communications, automation, quality of use and comfort;

The past property crisis, which has affected many European countries, has amplified the stock of not rented office spaces: buildings that do not offer amenities for comfort and flexibility, are difficult to sell or rent;

Costs of retrofitting a building is more or less half to one third of the cost of demolition and reconstruction;

Office buildings are classified amongst the buildings with highest energy consumption (e.g. annual energy consumption in European office buildings averages 100-1000KWh/ m² of conditioned floor space).

In Australia, refurbishment of buildings is expected to form an increasing proportion of the annual capital budget with some estimates being as high as 50% by 2020. This has important implications for sustainability. If the Koyoto targets were to be reached, it is the existing building stock and their efficiencies which must be improved. Waste minimisation and recycling can also form a significant part of the equation, accounting for an estimated 0.5% of GDP. An exemplar
project in this area is the lead of the national WasteWise construction program which has already decreased the amount of waste going to landfill by 90%. The pressure for all retrofit building projects to follow suit is mounting.

While the potential of this market sector is evident, there remain some challenges of the refurbishment option as opposed to new build such as:

Decisions on political, social, environmental and financial implications of re-life compared to new build (Balaras 2004);

Feasibility studies assessing the condition of the existing building, the residual service life, and estimating construction costs, modelling of operating & maintenance costs, and the utility and productivity expected from the refurbished building (Reyes 2002, ECI 2003)

Architectural and engineering design to maximise the utility of the existing structure (Thomas et al 1996).

Coordinated work scheduling for clients, consultants and contractors in terms of forward capacity and production planning linked with design, procurement and decanting schedules.

Additional challenges for demolition and waste handling and disposal, potential recycling, occupational health and safety, condition surveys and identification of services etc (Nigel et al 2001).

Effective decision making will also need more data and modelling of different scenarios to allow comparison of the alternatives. Largely due to the lack of as-built on old buildings, information on the modelling of operating and maintenance costs, the utility and productivity expected from the refurbished building, and the monitoring of building energy performance depending on the alternatives is particularly hard to come by.
Nevertheless, these phenomena and evidence imply that there is a new market developing which not only requires attention but also application tools that can help stakeholders making decisions such as:

Sustainability issues including indoor air quality, energy saving, waste handling, disposal, potential recycling and Occupational Health and Safety (OH&S);

Conditions of existing buildings and the residual service life;

Waste management issues and recycling potential;

Associated risks, costs, time and project delivery patterns and project management processes.

3. BUILDING PERFORMANCE AND MEASUREMENT

Considerable research efforts have been made to explored methodologies and software tools for the assessment of a building’s existing structural conditions, energy usage and estimation of costs.

TOBUS is an evaluation tool for the assessment of retrofitting needs of office buildings in European countries and for estimating the costs to meet these needs in compliance with sustainability issues such as energy performance and indoor environment (Caccavelli et al, 2002). Office Scorer is a tool developed by the Building Research Establishment (BRE) in the UK in 2002 to systematically compare and test the environmental and economic impacts of different building design concepts for offices. BRE has modelled a number of buildings over a 60 year life and evaluated the economic and environmental impacts of a range of factors including building elements degradation, ventilation and cooling system energy saving (BRE and DTI 2002). EPIQR and MEDIC are software which can provide diagnosis of degradation of existing residential buildings, energy performance and indoor air quality (Flourentzou 2000).
A Facility Energy Decision System was developed by the Pacific Northwest National Laboratory in the US to inform decisions on energy-saving retrofit projects (FEDS 2004). In Australia, the Building Division of the Queensland Department of Public Works developed the Ecologically Sustainable Office-Fitout Guideline as a strategic asset management framework. It covers key aspects of community, energy, material and water in relation to office building fitout works (Queensland Government 2004).

These methodologies and tools provide the global view and focus shift to building’s renovation and refurbishment processes. Some enable users make informed decisions in targeted specialty areas. However, most of the tools approached the building refurbishment issue in an ad hoc basis and tend to deal with specific issues within a region. The evaluation results of these tools can be very subjective depending on input and will require substantial as-built information, which is often lacking. Over reliance on computer programming development may render these tools to become inflexible, unadaptable and non-updatable. Therefore, there is an urgent need to develop a more integrated and holistic tool that operates in a scientific and procedural manner. In particular, knowledge gaps need to be covered in residual service life, waste management, floor space optimisation, project risk assessment, contractual issues and procurement patterns.

4. INTEGRATED RESEARCH ON RE-LIFING OFFICE BUILDINGS

4.1 Research overview and Dephi study
Integrated research was recently undertaken in Australia to explore holistic approaches to dealing with issues impacting on office refurbishment projects, design, engineering and procurement, and issues of decanting and sustainability. The research also developed a decision-making support mechanism for assessing the condition of the existing building structure, residual service life and floor space optimisation.
The project objectives are to investigate the characteristics of refurbishing projects that impact upon the effective management of the construction process, such as the identification and mitigation of risks, issues of decanting and existing tenants, identification of existing structure and services, work scheduling, occupational health and safety issues for construction personnel and tenants, demolition, waste and recycling, issues of quality and workmanship, cost planning and cost modelling methodologies. Based on a comprehensive literature study, it embarked on a path of Delphi study, Process Integration, Case study and Industry interviews, before extracting and presenting information through the development of decision support tools.

Following literature review and preliminary industry consultation, a Delphi study was conducted with the assistance of a panel of industry experts to determine the most relevant and important issues of consideration of refitting commercial office buildings. Through four rounds of electronically mailed questionnaire surveys, these experts evaluated, considered and reconsidered the relative importance of 49 issues presented particularly taking onboard feedback from peer reviews. A unique aspect of the Delphi Questionnaire is that the industry experts consider the issues individually, without discussion with other experts (Chan 2001). There were five categories of issues:

1. Sustainability & Building Efficiency,
2. Project Management,
3. Residual Service Life,
4. Recycling & Waste Management, and
5. Floor Space Optimisation.

The number of issues grew to 68 after Round 1 of Delphi study as 19 new issues were proposed by the panel of experts. The highest, the lowest, the mean and the
deviation of scores for each of the issues were analysed so that the new order of issues and their “relative importance” could be established for the next round of study. The highest ranked issues and their average scores were also evaluated and compared between rounds to identify swing of opinions and affirm reliability of the information.

Following the Delphi study and subsequent industry interviews, a total number of 36 critical issues with commonly agreed high rankings were revealed. The five top ranking critical issues are Purpose of refurbishment, Energy saving potential, Cost analysis for sustainability and building efficiency, Project cost risks and Building Condition assessment. As Sustainability and Building Performance was the primary goal of another research project funded by the same agency, this research concentrated on the other four categories as research strands. At the research completion stage, cross reference to the Sustainability research project was made.

4.2 Development of integrated project map

To aid decision marking, the 36 critical issues need to be amplified within their disciplines and knowledge areas. They also need to be integrated and articulated along the path of project lifecycle for holistic consideration and problem solving. An integrated project map was developed and linked the 36 issues with logic, order of execution, cross-reference, and quality control in mind, along the continuum of project development phases (i.e., conception, feasibility, design, procurement, construction and operation phases), therefore providing the integration among issues of all four strands. Figure 1 shows an example of the issues that need to be examined in the Project Conception phase.
4.3 Key findings on the four research strands

Project Management: ten issues critical to the management refurbished projects are nature and scope of work (objective & market research), type of contract, market demand by location and type, perception of tenants, pre-commitment by tenants, key project risks (cost, quality and schedule), decanting, workplace health and safety issues, modifying existing documents and management of tenants. The design team has to bear in mind of client’s/tenants’ needs. Communication and understanding between project stakeholders are important to ensure smooth implementation of the project. Guided decision support will be required for project stakeholders.

Residual service life: to evaluate remaining service life of specific components, assessment of the current degradation state or functional use and the future patterns of degradation is important. State-of-the-art methods on residual service life estimation appear to be mostly conceptual and need significant forms of data. Seven key variables identified are condition assessment, defects – structural,
defects – functional, status of structural health, life of elements and components of the building, performance monitoring and security. These variables were analysed and compared with other buildings in developing a generic approach. Residual service life methods have been established to determine the underpinning factors.

**Recycling and waste management:** there is a widespread willingness among office building professionals to operate more sustainably. However this should be met with targeted guidelines for project stakeholders. Specific building materials where recycling rates are variable across the states need to be identified and ‘state of the art’ recycling information dispersed to all contractors. Secondary markets for reuse of components such as sinks, basins and cupboard need to be encouraged by state governments, whereas asbestos material needs to be addressed in detail, so that all waste from such buildings is not automatically directed to landfill.

**Floor space optimisation:** the crux of the issue here is the maximisation rentable floor space. Options available to the client in maximising floor space include removal or addition of floors and partitions, relocating services, cutting openings and relocating lift wells etc. In these situations, innovative structural strengthening schemes could be implemented to strengthen the existing structure after an initial structural appraisal. Five critical issues identified are structural appraisal, structural safety, structural strength, change of use of floors, relocate/renew services. Typical design examples and calculations were developed for reference.

**4.4 Best practice guide**

As part of the research deliverables, the Best Practice Guide that encapsulates the relevant problem solving logic and knowledge for decision making on all 36 issues was developed. The knowledge and information required for decision making is organised according to (1) the potential causes for this issue, (2) the problems it will bring about, (3) the possible actions that can be taken, and (4) the results from such actions. The top part of the module presents graphical linkage between these elements, depicting the inherent relationships. The bottom part further elaborates “what-to-do” actions of these elements according to the related project
development phase. An application example of the Best Practice Guidelines is shown in Figure 5 as a way of dealing with Space Volume Limitation in a Case Study.

By cross-checking the guides against real life projects and by consulting with professionals in facility management, architectural design, demolition, contracting, and project management, research validation was done. The Best Practice Guide was considered highly valuable especially to project partners for guided decision-making assistance when contemplating alternatives of retrofitting projects. In particular, professionals confessed that while they have in-depth knowledge in one or more areas, they may not be able to consider and cover all of the areas. The Best Practice Guide can provide building owners, developers and contractors a systematic tool to evaluate potential projects holistically, rather than make hasty decisions on demolition and build new buildings, thus avoiding unviable technological, economical and marketing outcomes.

5. EMPIRICAL APPLICATION OF THE BEST PRACTICE GUIDE

As part of the application of research findings on real-life projects on sustainable refurbishment of office building, an empirical case study was undertaken as presented in the following sections.

5.1 Case study introduction

An office building in Melbourne CBD area was studied, with two floors of office space and one as a customer centre. The building was developed in early 1980s and then transferred to its owner occupier, an international investment company in 1992. After 15 years’ operation, the company found that the interior fitout and the facilities of the building could not satisfy three current business requirements as below:
1. Cubic offices do not support effective team communication and work routine, and cannot provide enough workstations due to the increasing number of staff;

2. Improved interior office environment has been generally expected by the staff and customers;

3. Space in the customer centre became limited due to increasingly expanded business, with more workstations and facilities;

A team of consultants were engaged by the investment company to make a rational decision on redevelopment or refurbishment of the current buildings. Extensive inspection was carried out to explore conditions of major structural components such as columns, beams, slabs, exterior walls, and windows. It was found that these components were still working well and can service the three-storey building for another 30 years without substantial risks. Extension of the current structure would also encounter the following problems:

   a) Safety of the current structural components supporting additional levels;
   b) Excessive construction waste;
   c) Substantial construction costs under today’s building economy;
   d) Interruption of the company’s business operation;

After contemplating the options of redevelopment versus refurbishment and the potential impact on the company operation, the company decided to refurbish the aged building. Open plan office was chosen for reasons of better accommodation of workstations in a given floor space and also the facilitation of team dynamics. Raised floor system (RFS) was recommended as an optimal option by the architects.

RFS typically consists of raised floor panels, pedestals, stringers, floor coverings, underfloor air distribution system, underfloor Power Video and Data distribution system and other accessories such as steps and ramps. Pedestals supporting the panels create a plenum between the sub-floor and the panels that allows the tidy
distribution of building service systems, particularly cabling and wiring systems and provides easy access to maintenance (Zhang and Yang 2006). This system improves ventilation, air quality, and thermal comfort while allowing for individual control. It also enables quick and economic relocation of workstations thus minimizing impact of churns in modern office environment. A typical environment with RFS fitout is shown in Figure 2.

![Figure 2: A typical RFS fitout environment](Source: Courtesy of Tate Access Floors, www.tateaccessfloors.com)

5.2 The concerns
While retrofitting with raised floor systems can potentially meet the aforementioned three outstanding requirements, a few concerns related to the design and construction phases are raised by the consulting engineers and the project manager employed by the investment company. Typical concerns include but not limited to:

- The space volume (floor to floor distance 3880mm) is not enough to encase the RFS;
- The irregularity of building structural restricts retrofitting with RFS;
- Transitions to lift system, existing doors, stair landings, etc. are problems;
• The existing structural beams influence the RFS application; and
• RFS may make the refurbishment uneconomical.

5.3 Exploring integrated considerations for sustainable RFS fitout
Brainstorming among the design team was carried out to ascertain all concerns. With reference to the Best Practice Guide discussed in last section, the causes of the concerns, the possible problems if the concerns are not dealt with properly, the actions that can be taken, and the results of the actions are explored. Using “Space volume limitation” as an example of a Critical Issues, the application of the Best Practice Guideline was made and discussed as follows.

![Figure 3: Section view of an office room with RFS embedded in](image)

Figure 3 shows a typical section view of an office room. The space volume depends on multiple factors, e.g. finished floor height of RFS, use of under-floor air delivery (UAD) system, and the ceiling based air return. The ceiling space also needs to house the structural beam, air ducts, cable and wire distribution, fire safety services, etc. An equation reflecting the causality between the allowable finished floor height (FFH) of the RFS system and space volume can be expressed as (1):
Where, FFH is the finished floor height of RFS; H is the height between slab and slab; X1 is the thickness of the slab; X2 is the sectional height of the structural beam; X3 is the sectional height of air ducts; X4 is the thickness of the ceiling panels; Y1 is the interstice height between the structural beam and the air ducts; Y2 is the interstice height between the air ducts and the ceiling panel; and L is the distance between the ceiling panel and the top surface of raised floor panel.

The investment company intends to refurbish the existing building without interfering with the current structure. Accordingly, the thickness of slab (X1) and the sectional height of the structural beam (X2) are constant. As per the above equation, the allowable FFH of RFS is mainly determined by the distance between slab and slab (H) and the renovation of the ceiling plenum (X3, X4, Y1, Y2).

Brainstorming points out that the use of UAD determines the appropriate FFH, which further decides whether the space volume (H) is sufficient.

If the UAD method is used, a deep floor plenum is expected. As per the engineer’s opinions, 300mm is generally perceived as the minimum FFH to allow desirable air distribution in the floor plenum. For a typical multi-level office building, X1 is around 120mm; X2 is around 500mm; X3 is around 300mm; X4 is around 30mm; Y1 is around 100mm; Y2 is around 150mm; and L is not less than 2400mm as per the Building Code of Australia. Accordingly, the distance between slab and slab needs to meet Equation (2).

\[ FFH = H - X_1 - X_2 - X_3 - X_4 - Y_1 - Y_2 - L \]  

(1)

\[ H \geq (X_1 + X_2 + X_3 + X_4 + Y_1 + Y_2 + L) + 300\text{mm} \]  

(2)

- If the clients wish to keep the ceiling air system while applying UAD for the special reasons such as using a ceiling and under-floor mixed system and keeping the ceiling air system as a backup, slab to slab height must not be less than 3900mm.
• If the old air conditioning is removed and the ceiling is kept solely for concealing the overhead service systems, e.g. fire sprinklers, ambient lighting, cable and wire distribution, etc., the ceiling space can be reduced. The space height between the ceiling panel and the structural beam is allowed 200mm. Then, the distance between slab and slab must be not less than 3550mm.

• As a way of maximising space, the whole ceiling can be removed and upper slab exposed. The height between slab and slab must be not less than 3320mm. For flat structural beams or no structural beams in the building, the height can be even shorter.

If UAD is not used, a RFS with 150mm FFH is enough to accommodate the under-floor cable/wire distribution, with the ceiling air system kept without change. As per Equation (1), the slab and slab height must be not less than 3750mm.

With a perceived structural beam of 500mm in height, the above analysis works out the minimum slab to slab height for RFS application in retrofit projects as summarized in Table 1.

<table>
<thead>
<tr>
<th>Table 1: Minimum slab to slab distance for RFS applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>With UAD</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>Reduced ceiling</td>
</tr>
<tr>
<td>Removal of ceiling</td>
</tr>
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</table>

Using this information, the consulting engineers and the project manager were able to adopt the Raise Floor fitout system, knowing that the slab to slab height in this building is 3880mm. To achieve integrated and coordinated RFS fitout design and construction process, the team adapted the Best Practice Guidelines and developed a problem solving module for space volume limitation, as shown in Figure 4. As it included all aspects of conception, design, construction and commission, the
project team was able to design and deliver the interior fitout space with all stakeholders in mind and involved them for early anticipation of and decision making on the issues encountered.

### 6. CONCLUSIONS

The Australian building industry will experience an increasing volume of refitting works as the bulk of the office buildings in capital cities continue to age. There is a need to develop consistent and holistic project approaches, while responding to the sustainability challenge. This calls for exemplar projects as well as research into integrated decision making and knowledge support for these types of projects.

The research efforts reported in the paper was a starting point to logically and systematically address the problems that will face building owners, their design consultants, the contractors, and very importantly, their tenants and clients, when dealing with the refurbishment of office building spaces. There are five areas of...
main concerns, including building structure and condition reporting, floor space optimisation, recycling and waste minimisation, and overall project management, and sustainable design and construction. Through a Delphi study process involving industry panel experts and subsequent interviews to professionals involved this refurbishment projects, a set of Best Practice Guidelines were developed to encapsulate critical issues of refurbishing office buildings into decision modules of practical decision making and problem solving. A case study on the use of raise floor systems for a Melbourne CBD office building refurbishment demonstrates the innovative construction methods and the use of the Best Practice Guides as assistance to the project team.

7. REFERENCES


CAR (2003), CRC Report to the Energy Saving Trust (EST) titled ‘Refurbish or replace’, UK.


ECI (2003), ‘Workshop on the ‘Engineering and management of retrofit projects’, UK.


ENHANCING SUSTAINABILITY DELIVERABLES FOR INFRASTRUCTURE PROJECT DELIVERY

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ABSTRACT: Despite an increasing highlight on the sustainability agenda by the construction industry, sustainable development is often treated with different philosophy, interpretation, and responsibility at various stages of project development by various stakeholders involved. The actual sustainability deliverables from the industry is not substantially tangible, especially at project levels. For infrastructure projects which typically span over long periods of time, achieving consistent sustainability outcomes during various stages of development remains as a formidable task. The absence of common understanding among stakeholders and the lack of appropriate sustainability reporting mechanism are possible causes. Many policies dealing with these issues tend to be too generic and broad-based for practical adaptation.

While there had been a plenty of research initiatives on sustainability assessment, there is often a gap between sustainability deliverables during project implementation and the grandeur of promises during project conception. This paper reviews the historical context of sustainable development and its principles, and past studies on sustainable construction, focusing on infrastructure projects. It goes on to introduce a QUT research project aimed at identifying and integrating the different perceptions and priority needs of the stakeholders, along with identifying issues that impact on the gap between sustainability foci and its actual realization at project end level, in order to generate a framework of enhancing sustainable deliverables. It is expected that the research will help promote more integrated approaches to decision-making on the implementation of sustainability strategies and foci during the construction project delivery processes.

Keywords: Sustainable development, infrastructure, construction management, project delivery, performance enhancement.

1. INTRODUCTION

Construction industry world-wide has taken on a positive response to support the agenda of sustainable development since the last decade. This is evidenced by the engaging sustainability initiatives by governments, industry as well as academic researchers across the globe. Despite an increasing level of adoption of the sustainability agenda by the construction industry, the actual sustainability deliverables from the industry is not substantial and tangible, especially at project levels (Figure 1).
Figure 1: Gap between sustainability focus and project end realisation during construction project delivery.

A recent research on construction companies' attitudes to sustainability in United Kingdom found that very few companies positively embrace sustainable ideas (Myers, 2005), or different companies have described different individual and organizational perceptions and definitions of sustainability (Shelbourne, et. al, 2006). The research further revealed that the fragmented and diverse nature of the industry is the main reason for such scenario. Worst still, it is beset with an adversarial culture (Chan, et al., 2005). At any given project, construction stakeholders have their own concerns, priorities and interests, resulting different expectations in the project delivery. Often the disciplines are unwilling or unable to consider the views represented by others because there is not a common language place (Lombardi & Brandon, 1997). In the absence of common understanding among these stakeholders, achieving sustainability outcomes remains as a formidable task.

In the meantime, decision-making for sustainable development in the built environment requires new approaches that are able to integrate and synthesise all the dimensions and different point of views in a holistic matter (Mitchell, 1999; Deakin, et al., 2001). This process requires the application of a suitable operational framework, and an evaluation method or approach that is able to guide stakeholders through the decision-making. However, at the moment, such a structure for organizing the information required in decision-making is not yet available or agreed on among the different disciplines and fields of activities. The
lack of an agreed structure that can help decision-making processes achieve greater sustainability is a major problem (Brandon and Lombardi, 2005).

2. THE EVOLVING NATURE OF SUSTAINABLE DEVELOPMENT IN CONSTRUCTION

Since the milestone publication of Bruntland Report that read development is sustainable when it "meets the needs of the present without compromising the ability of future generations to meet their own needs", the call of sustainability was resonated world-wide. This was further intensified by the crystallization of Agenda 21 that calls for a greater application of sustainable development principles in the construction industry,

Despite these principal references, it is widely acknowledged that sustainability is still a vague, uncertain and polymorphous concept (Philis and Andriantiatsaholiniaina, 2001) as different people interpret sustainability differently. Scholars and researchers have attempted to bring about universal principles for sustainability, but their efforts were far from success. Instead they are often criticized, for not representing the full vision of sustainable development (Eagan and Joeres, 1997).

Though still evolving, the most commonly accepted set of principles of sustainable development is called the Triple Bottom Line. This international set of sustainability metrics, often used to gauge the success of a particular development project (Rogers, et. al., 2006), includes three broad components; social, environmental and economic aspects of sustainability.

Premised on the Triple Bottom Line, scholars and researchers of various disciplines then engage in and formulate the sustainable principles concept for their respective area of development interests. For built environment, sustainable construction is seen as a way for the building industry to respond to achieve sustainable development (Bourdeau, 1999).
Principally, sustainable construction can be defined as a construction process which incorporates the basic themes of sustainable development (Parkin, 2000; Chaharbaghi & Willis, 1999; Sage, 1998). In other words, a construction project is sustainable when it responds to the conventional environmental challenges of resources depletion, addresses social and cultural needs and practices, as well as generates economic empowerment or alleviates poverty.

3. SUSTAINABLE DEVELOPMENT AND INFRASTRUCTURE
The fact that infrastructure constitutes large built assets on earth, and the ever-increasing demands, its necessary involvement and impact towards global sustainable development efforts is critical. To effect a global and universal sustainability achievement, therefore, driving sustainable development in infrastructure projects is a major integral part.

Drawing from the understanding that sustainable construction can be defined as a construction process which incorporates the basic themes of sustainable development (Parkin, 2000; Chaharbaghi and Willis, 1999; Sage, 1998),
sustainable infrastructure means the application of basic sustainable principles into infrastructure development. In a more concrete term, this means ensuring that our infrastructure is environmentally, socially and economically sustainable.

To achieve sustainable infrastructure development, however, it is important to firstly understand how an infrastructure project relates to the principles of sustainability. Sahely et. al. (2005) proposed a simple framework focuses on key interactions between infrastructure and environmental, economic and social systems (Figure 2).

In this context, the first crucial step in this process includes definition of overall goals, system boundaries, and sustainability criteria and indicators. The goals of the sustainability assessment must be well defined on an infrastructure system. Subsequently, the criteria and generic sub-criteria for sustainable infrastructure systems can be based on *Triple Bottom Line*, with an addition of engineering criteria that pertinent to infrastructure project undertakings, as follows:

i) Environment – including resource use and residuals production

ii) Economic – including expenditures (capital, operation and maintenance)

iii) Social – including accessibility, acceptability, and health and safety

iv) Engineering – including performance.

Engineers Australia (2005) contends that an infrastructure is sustainable if it meets the following sustainability criteria:

i) Environment sustainability – reducing greenhouse emissions, lowering pollutant levels in stormwater and effluent discharge into rivers and oceans. Resources are limited and need to be managed through conservation, reuse and renewable strategies;

ii) Social sustainability – reducing commuter times, increasing road safety, improving air quality and providing access to broadband communication to all citizens.
Economic sustainability – ensuring that taxation and regulatory systems promote new private sector investment in all infrastructure capable of generating adequate returns of investment.

A recent research of identifying Key Performance Indicators (KPI) for infrastructure in South Africa construction industry, Ugwu and Haupt (2005) have developed a comprehensive list of key sustainability items and its indicators. These constructs incorporate internationally accepted sustainability metrics, coupled with other performance-based indicators such as health and safety, resource utilization and aspects related to project management.

Though the above research initiatives provide a good basis for establishing infrastructure sustainability criteria and indicators, they do not probe into the gap between sustainability foci and actual deliverables.

4. DEVELOPING SUSTAINABLE INFRA-STRUCTURE PROJECTS

In a broader picture, infrastructure is often discussed in the context of the role and influence it has on public development, community and social issues (Bayntun, 2000). Therefore, its development is not to be taken lightly. To achieve sustainability, it requires thorough planning in its overall execution. However, this is not an easy task as there are many issues and stages involved in the infrastructure development process.

According to Dasgupta and Tam (2005), the life stages of any infrastructure project can be divided into (i) preproject planning (King et. al, 1994), which involves setting up designs, facilitating and mobilizing funds, preparing bills of materials, calculating costs and incorporating short-term and long-term plans to implement the physical modification; (ii) project implementation, which incorporates the physical work of project implementation and could, for example, include refurbishing the existing structure wherever necessary; and (iii) ongoing operation, which includes the financial management, planning, accountability of
responsible authorities, and maintenance of the structure during its design life after starting the intended operation.

Proper design, operation, and management of infrastructure must deal with every facet of its service life, ranging from conception, feasibility studies, design, construction, operation, maintenance, repair and rehabilitation, and finally decommissioning and disposal of the system after it has outlived its useful life (Mirza, 2006).

If an infrastructure project were to be sustainable, every phase of its development must be guided by the principles of sustainable development which embraces the issues of environmental concerns, social needs, and economic empowerment, along with health and safety and project management (Figure 3).

**Figure 3: The conceptual framework of sustainable infrastructure development processes**
In this respect, the infrastructure development process should go through the various stages from conception, to feasibility studies, to design, to construction, to operation, to maintenance and disposal or decommissioning. These processes will be improved by the application of sustainable principles that cover key sustainability items such as economy, environment, society, resource utilization, health and safety and project management aspects. Consideration must also be given to the differential needs of sub-criteria of each of these key sustainability items. By close monitoring of these processes and checking them against sustainable principles, we can thereby ensure and enhance sustainability in infrastructure development.

5. A RESEARCH NICHE

Thus far, much of the focus on sustainability has concentrated on buildings. Little has been done on infrastructure systems, such as sanitation, transportation, and utilities, which may extend over large geographic spaces, have much wider and more varied potential impacts, and may be harder to understand from a sustainability perspective by multiple stakeholders (Dasgupta and Tam, 2005).

At one end, sustainable development efforts mainly remain ideological as seen in macro-level policies and broad-based concepts. They have not explained how they could be translated into practical decision-making during project delivery. The same observation holds for infrastructure projects where the current focus is largely on macro-level policy planning, with little research focusing on the micro level design and construction stage ((Ugwu & Haupt, 2005). The situation exacerbates due to multiple stakeholders having different expectations and perceptions towards achieving sustainability in infrastructure projects.

On the other end, there were many research initiatives attempting to develop sustainability assessment. In between the two, there is a perception-reality gap and
mismatch, specifically on how to enhance sustainability deliverables during infrastructure project delivery (Figure 4).

To influence a holistic chain of decisions and actions towards achieving sustainability in infrastructure projects, due attention must be given to finding effective ways to enhance sustainability foci during project delivery, along with the development of the policy and assessment methods. It is precisely at the project implementation level that any sustainability objectives and goals should be premised upon. Unless this bottleneck situation is addressed, the policy on sustainable development will continue to remain ideological and the sustainability assessment methods will not fulfill their intended purposes.

Figure 4: Bridging the gap of sustainability policy and assessment.

6. THE QUT RESEARCH

As an exploration on ways of rectifying some of the problems discussed above, a research project is being undertaken at the Queensland University of Technology, Australia. It is aimed at identifying and integrating the different perceptions and priority needs of the stakeholders, along with identifying issues that impact on the gap between sustainability foci and its actual realization at project end level. Filling the niche found in previous studies, this research focuses on the practicality and real-world implementation of sustainability agenda in infrastructure projects delivery. This can be achieved based on the common understanding by various stakeholders, with individual view points shared, understood and mutual benefits supported.
The on-going research project employs a combination of face-to-face interviews with industry professionals, Delphi study among experienced practitioners and academics, and case study techniques to collect expert opinions as well as real-life project information. This is coupled with secondary data such as existing government guidelines on environment impact assessment and management, sustainable construction environment and literatures on sustainability research (Figure 5). Both the primary and secondary data will provide triangulation of results covering the perceptions of various stakeholders in infrastructure projects that shall underpin the basis for establishing decision-making process model for sustainable infrastructure projects.

**Figure 5: Research methodology**

While still at early stages of development, initial industry consultation and feedback has indicated strong interests in this research among stakeholders of infrastructure projects. The guidelines to be formulated will help promote more integrated decision-making and actions on the implementation of sustainability strategies and foci during the construction project delivery processes. With the different perceptions and views shared, discussed, debated, and with common values and mutual benefits identified, fragmentation on the responsible roles of sustainability will be avoided. Accordingly, this helps facilitate collaboration, consultation and communication among all stakeholders involved in order to
achieve consistent decision-making steps throughout infrastructure project development life span.

Work to date has identified over 200 criteria on sustainable agenda and possible actions through six stages of infrastructure project development. Interviews and Delphi study will refine these criteria to a conceptual framework which will then be tested through three major infrastructure projects by case studies. Involved stakeholders and industry professionals are also supportive of on-going consultative meetings to provide further insight to preliminary findings and guidance on the overall research approach. It is expected that the final framework will be formulated by October 2008 and the complete research results be disseminated to the industry by early 2009.

7. CONCLUSION
Infrastructure projects result in most of the largest built assets on earth. As an integral part of developing a sustainable future, these projects deserve special attention. To date most of the existing research on sustainability has been focusing on building works. A few research initiatives that dealt with infrastructure limited themselves to macro issues of sustainability policies and assessment methods. They have not covered the important aspects of enhancing the sustainability foci and deliverables during project delivery. This crux of the issue must be addressed for practical, tangible outcomes from exercising sustainability on infrastructure. This paper outlines sustainability “hotspots” in the context of infrastructure. A research niche was identified and is being followed through. This is the need to fill the gap between recognized importance of sustainability by the industry and the eventual realisation delivered at project ends. An on-going project is integrating different perceptions and priority needs of infrastructure stakeholders in order to develop a framework of integrated approaches to decision-making on the practical implementation of sustainability strategies during of infrastructure project delivery.
ACKNOWLEDGEMENT

This research is supported by the Construction Research Center for Construction Innovation (CRC-CI), Australia.

REFERENCES


MICROCLIMATE STUDIES FOR HIGH DENSITY AND HIGH RISE SUSTAINABLE PUBLIC HOUSING DEVELOPMENTS IN HONG KONG

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ABSTRACT: Planning and design play an important role in creating a healthy living environment. Hong Kong Housing Authority (HKHA) initiated in 2001 the application of Micro-climate Studies in the planning and design of high density and high rise housing development using latest proven technologies, including computational fluid dynamics simulations, wind tunnel tests and daylight simulation tools, etc. These studies enable holistic consideration to optimize the development potential and enhance the built environment of the neighbourhood. They cover core topics of wind environment, natural ventilation, daylight and solar heat gain, as well as other special topics such as urban heat island effect, pollutant dispersion, etc. In this Paper, the author introduces the following key initiatives in micro-climate research studies for planning and design –

a) Introduction of air ventilation assessment concept to enhance the wind environmental performance in estate planning.

b) Application of computer fluid dynamics (CFD) technology in passive design approach to enhance natural ventilation and pollutant dispersion of the domestic dwellings and public areas.

c) Application of computer simulation technology in sun-shading and daylight studies to enhance the master layout and open space planning.

d) Introduction of environmental façade design concept to mitigate solar heat gain and enhance human comfort for residents.

Micro-climate studies facilitate holistic environmental planning and design of sustainable housing developments. Over 25 public housing projects in Hong Kong have adopted the studies, which provide greater human comfort for residents by enhancing environmental performance of the housing estates with cleaner and greener environment for healthy communities.

Keywords: Healthy Living, Sustainable Community

1. INTRODUCTION

In the high-rise, high-density environment of Hong Kong, environmental performance of buildings has a significant impact on the public. High density living has the advantage of efficient land use, public transport and infrastructure, as well as the benefits of closer proximity to daily amenities. We have more than 7
million people living in 1,100 sq. km of which, only about 200 sq. km is developed and another 400 sq. km is devoted to country parks. There is a global trend in the shift from rural to urban populations and the corresponding increase in population densities and urban consumption patterns is reflected in every urban city.

About one-third of Hong Kong’s population is residing in public housing. Among the stock of over 2,300,000 permanent residential flats, over 674,000 flats are public rental housing stock under the management of HKHA. It is always HKHA’s prime objective to provide healthy living environment in sustainable housing developments. Environmental aspects of sustainable housing design comprises low energy consumption and high performance concept. In 2001, HKHA initiated the application of Micro-climate Studies, based on holistic approach, in the planning and design process of public housing developments to optimize the development potential and enhance the built environment of the neighbourhood. In the ensuing sections of the paper, we present some key features of the micro-climate studies in our planning and design process for enhancing wind profile, natural ventilation, daylight and solar heat gain of the living environment.

2. WIND ENVIRONMENT

We use the micro-climate studies as urban planning tool to optimize estate planning, disposition/orientation of blocks and building permeability to enhance wind environment for the housing development and as-built neighbourhood.

2.1 Site Wind Availability Data

It is necessary to account for the characteristics of the natural wind availability of each housing development site. We make use of wind data from weather stations of local Observatory to qualitatively estimate the prevailing wind directions and magnitudes of the site for evaluation. For sites with weather stations nearby, wind rose with reduced set of prevailing directions covering most of the time in a typical reference year is vital for micro-climate studies whereas for those with specific site
topography and being remote from weather stations, wind tunnel simulation test becomes more appropriate.

\[
VR_w = \frac{V_p}{V_\infty}
\]

\(V_\infty\) is the wind velocity at the top of the wind boundary layer not affected by the ground roughness, buildings and local site features.
\( V_p \) is the wind velocity at pedestrian level after taking into account the effect of the housing development. 

\( \text{VR}_n \) indicates how much of the wind availability of a location could be experienced and enjoyed by pedestrians on ground taking into account of the as-built surroundings.

**Figure 2: AVA diagram**

**Figure 3: AVA Study for Choi Wan Road Housing Development**

With test points allocated at strategic site locations, wind velocity ratios at these points are identified to indicate the effects of different planning options of a housing development for comparison purpose. It is through comparison of different planning options in holistic approach that the optimal solution is derived.
2.3 In Tune with the Wind Environmental Initiatives

In achieving the objectives to optimize estate planning, disposition/orientation of blocks and building permeability, we apply computer fluid dynamics (CFD) analysis to study the wind flow pattern and magnitude at low, mid, high zones of the high rise domestic towers for different enhancement measures in site planning and building design options, external circulation and open spaces, and impact on as-built surroundings. By comparing the micro-climate study results of various green initiatives, the most optimal planning and design option is worked out on both qualitative and quantitative basis in a scientific approach –

![Figure 4: Environmental Performance with and without Wind Corridor](image)

a) Effectiveness of “Wind Corridor” design, in quantitative terms, for enhancing site permeability for prevailing wind is identified by comparing simulation results of ‘Before’ and ‘After’ implementation of the development. The increase in air velocity with wind corridor under the prevailing East wind condition ranges from 18 to 250%.
b) For constraint of narrow linear site configuration, design options for disposition and orientation (deviation up to 10 degrees) of domestic towers are compared to streamline the wind flow across the development and the as-built neighbourhood. The wind speed at open space between domestic towers increases substantially by 100 to 133% by adopting Option 2.

![Figure 5: Environmental Performance with different block orientation and configuration](image)

C) CFD analysis is an effective tool for adjustment of variables in building separation and heights on site platforms at different levels to divert winds to lower levels. The wind speed increases substantially by 122 to 500% by adopting the 4-block option.
Site specific design options “with” and “without” podium are compared for identification of the significant variance in building permeability for air ventilation at pedestrian level. The average wind speed and velocity ratio at street level (leeward side) increases by 13% and 14% respectively without podium.

Figure 6: Environmental Performance with different block number, height and layout

Figure 7: Environmental Performance with and without podium

e) Urban greening filtrates the air flow and provides shade and cooling. A green deck garden is designed at 1/F level of the high rise domestic tower to enhance the building permeability and extend the external garden into the habitable spaces.

Figure 8: Urban greening design approach with enhancement of building permeability
3. NATURAL VENTILATION AND POLLUTANT DISPERSION

We use the micro-climate studies as building design tool to optimize configuration of blocks, detailed architectural layout and window openings to enhance natural cross ventilation in habitable accommodations, public and circulation areas.

3.1 In Tune with Natural Ventilation Initiatives

Functional and Cost-effective Design approach is developed to optimize the life cycle costing of public housing in Hong Kong, while meeting the crucial needs – comfort, safety, health and a quality living environment. By simulating the wind flow pattern and magnitude of typical domestic units, lobby and public areas at low, mid and high zones of the high-rise domestic blocks, and ground floor entrance lobby etc., ventilation coefficients are determined to identify the ventilation performance of each design option at scheme design stage and fine tune the detailed design, in quantitative terms, to enhance natural ventilation with effective pollutant dispersion from toilet accommodations and refuse storerooms etc.

a) Effectiveness of “Cross Ventilation Corridor” design for enhancing building permeability is reflected by quantitative results of ‘With’ and ‘Without’ of the ventilation initiative. The increase in air velocity with cross ventilated corridor at selected points around the development, under the prevailing East wind condition ranges from 18 to 250%.

b) Effectiveness of “Wing Wall as Wind Deflector” for enhancing natural ventilation of domestic blocks at sites with low ventilation rate is reflected by quantitative results of ‘With’ and ‘Without’ of the ventilation initiative. Wing wall increases the air velocity inside corridor under the prevailing wind condition by 2.5%.
c) Effectiveness of “Guiding Panel” for enhancing natural ventilation of re-entrant areas at sites with low ventilation rate is reflected by quantitative results of the ventilation initiative.

\[ \text{Figure 10: Environmental performance enhanced by the wing wall} \]

\[ \text{Figure 11: Ventilation to re-entrant area enhanced by “Guiding Panel”} \]

\[ \text{Figure 12: Ventilation performance of domestic flat modular design} \]

\[ \text{d) Effectiveness of “Modular Design” for enhancing natural cross ventilation of domestic flats is reflected by quantitative results of the ventilation initiative.} \]

4. DAYLIGHT AND SUNSHADING
We use the micro-climate studies as building design tool to optimize daylight penetration in domestic units and public areas of domestic blocks for energy efficiency, comfort and health, and optimize the passive and active open space layout planning within the development.

4.1 In Tune with Natural Lighting Initiatives
Daylight has psychological effects and increases the comfort level of individual space. The amount of daylight on the surface of a building façade is related to the extent of its exposure to the natural environment. In high density and high rise developments, much of the daylight penetrating through window openings at lower floors of the high density, high rise developments come from the reflected light of the surrounding surfaces. We adopt the performance-based approach using “Vertical Daylight Factor (VDF)” (a ratio in percentage of the total amount of illuminance falling onto a vertical surface of a building to the instantaneous horizontal illuminance from an overcast sky) as a design tool for optimizing the natural lighting performance -

a) Effectiveness of “Modular Design” for enhancing daylight penetration into domestic flats is reflected by performance based assessment.

![Figure 13: Natural lighting of modular domestic flats](image)

b) Effectiveness of “Cross Ventilated Window Openings” for enhancing daylight penetration into the public areas of high rise domestic towers is reflected by
performance based assessment. The windows at cross ventilated corridors bring about 13% saving in energy cost.

4.2 In Tune with Sun shading Initiatives

High density and high rise living renders it significant for environmental planning of the open spaces. Simulation of annual 3-D sun path diagram dedicated to Hong Kong context identifies the sunlight and shade pattern at external areas of the proposed housing development at different time of the day and different seasons of the year, taking into account of the site surroundings. It is an integrated design approach for optimizing the sunlight exposure to green areas, morning exercise and outdoor laundry space, sun-shading for leisure sitting, children play and ball courts, particularly for west facing open spaces -

a) Comprehensive performance-based open space planning for a sustainable high density community: Activity areas that desire shading (e.g. children play area and foot massage trial) are planned at adequately shaded area. Area exposed to sun heat most time of the day would be shaded by trees or shelters.

Figure 15: Sun shading analysis for open space planning

b) Detailed study of local landscaping layout by performance based assessment.
5. SOLAR HEAT GAIN

Hong Kong lies in the tropical climate zone. We use the micro-climate studies as building design tool to minimize solar heat gain in domestic units in order to have higher energy efficiency and better human comfort.

5.1 OTTV as an Indicator

The facade of a building is a complex system, comprising a range of components which coordinate to create a healthy living environment. Amount of energy saving resulting from a cost-effective and high performance facade design to maintain a thermally acceptable environment could be quantified through Overall Thermal Transfer Value (OTTV) which relates to fabric thermal mass, glazing, passive solar design, window design and shading devices. We have made use of the OTTV, as an effective indicator, for external wall colour scheme design.

Figure 16: Using Stereographic sun path diagram to plan for external layout

Figure 17: OTTV Diagram for external wall colour tone design
5.2 Environmental Façade Design Initiatives

With the availability of latest proven simulation technology, we apply advanced computer programme which consists of modules of ventilation, thermal comfort and building energy analysis for computing the temperature profile for the internal environment of habitable rooms. Since the façade features that affect cooling load and achievable ventilation rates and daylight illuminance include (but not limited to) wall/roof construction, window/wall area ratio, glazing type, building orientation, configuration and separation, floor level, external wall finishes and colour, shading device etc., it demands an optimization study (e.g. Ant Colony Optimization (ACO) method etc.) taking optimization of the life cycle cost of the high density and high rise public housing blocks. We apply the study to design solar shading devices for reducing solar heat gain both on the building façade and in individual dwelling, to reduce the energy consumption on air conditioning and/or other mechanical ventilation means. In order to optimize the life cycle cost, the shading fins are integrated in the precast façade panels, taking into consideration of the transportation economy and loading for on-site installation.

6. MISCELLANEOUS

6.1 Holistic Environmental Planning and Design Approach

In terms of environmental planning and design, we adopt a holistic approach with balanced considerations on wind environment, natural ventilation and pollutant dispersion, daylight and solar heat gain etc. We apply a scoring system in working out the most optimal solution for the development. On-going researches are being conducted for establishment of local benchmarks. With a common goal and concerted effort by users, academia and researchers, regulators and practitioners, more healthy living environment will be created for now and the future.
Figure 18: Comparison table of simulation results of different environmental aspects

6.2 Calibration of Simulation Tools

Apart from conducting validation on the simulation tools, we fine-tune the software by model calibration. Two completed high rise public housing developments with different micro-climatic conditions are selected for the model calibration, which is composed of two parts, namely on-site measurement for actual field condition and model simulation for predicted field condition. The calibration exercise demonstrates the high accuracy of the simulation results with the software calibrated to local specific climatic conditions. The discrepancy is generally within 10%.

7. CONCLUSION

Public housing in Hong Kong has made an enormous contribution towards the well-being of the community. With the availability of the advanced simulation technology, the micro-climate studies are instrumental to improve the environmental performance for each new public housing development, which have long-term benefits to enhancing the built environment and quality of living of the society as a whole. Given a healthy living environment it helps to achieve a socially sustainable community. The application of the micro-climate studies in urban planning increases the practitioners’ and public awareness of the importance of sustainable development in the society. This is a big challenge as well as an excellent opportunity to bridge the gap between policies and practice for the good
of the coming generations. We need to continue to engage all stakeholders to gain their support as we articulate our strategies and lay out a road map in driving sustainability initiatives.

8. ACKNOWLEDGEMENT

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Ove Arup & Partners (HK) Ltd.

The Center of Housing Innovations, The Chinese University of Hong Kong

9. REFERENCES


[8] Natural Ventilation and Sustainability Designing with Computational Fluid Dynamics - F. Iannone, CLIMA200, Napoli, September 2001

[10] Technical Circular No. 1/06 jointly issued by the Housing, Planning and Lands Bureau (HPLB) and the Environment, Transport and Works Bureau (ETWB) in July 2006

STATE-SPACE APPROACH FOR LUMPED MODELING OF DOUBLE-SKIN SYSTEMS

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ABSTRACT: The application of all-glass smart double skin envelopes requires accurate models for the simulation of their performance. In order to develop and calibrate this model, a simple lumped model is postulated and a parameter estimation technique is used with data from full-scale experiments. It is found that the calibration model is surprisingly accurate and ideally suited for use in the ensuing optimal control and performance studies. It is also concluded that the simulation model should be calibrated depending on the system's configuration (height, cavity depth, glazing, etc.) and local surroundings since no universally applicable accurate simulation model exists at this moment in time. This leads to the next challenge of developing an on-line self-calibration technique.

Keywords: double-skin, parameter estimation, calibration

1. INTRODUCTION

During the past few decades, double-skin systems have been widely introduced. Double-skin systems have the advantage of improving indoor thermal comfort, reduction of energy use, etc. In order to (1) make the best use of, (2) achieve optimal design of, and (3) apply optimal control to double skin systems, a reliable simulation model is a prerequisite to predict the system’s behavior.

There are three approaches to mathematically modeling the system; (1) a whole building simulation tool (Ex: Energy Plus, esp-r, etc.), (2) use of computational fluid dynamics (CFD), and (3) the state space model approach. While the first approach is advantageous for assessing the influence of double-skins on the performances of the entire building, it has limitation to express very detailed physical phenomena occurring in and around the double-skin system involving transient convective and radiative heat transfer and airflow regimes in the irregular 3D geometry. Furthermore, when a discrepancy between the simulation model and the actual system exists, it is difficult to apply parameter estimation algorithm to
the simulation tool. The CFD approach has the advantage of precisely modeling the airflow dynamics in the cavity. However, the mathematical modeling requires numerous assumptions as well as detailed information. Furthermore, extensive modeling efforts and computing time become hindrance for optimal control of double skin systems in real time.

The objective of this study is to develop a simple model that can be applied for real-time optimal control of double-skin systems. The model must be lightweight and accurate enough for predicting the system’s response in real-time calculation. (simulation time in order of seconds). Hence, the paper addresses a state space modeling approach to simulate the system. In order to develop a lumped model capable of predicting the system’s response in real time, a double-skin system was lumped to 2D, and then unknown parameters were estimated using parameter estimation technique. Then, the model was validated with measured states. In the paper, the lumped mathematical model developed for this study was compared with another double-skin mathematical model having a different configuration [1] to explain how a mathematical model should be calibrated according to the system configuration (cavity width, cavity depth, louver color, glazing type, system dimension, etc.)

2. EXPERIMENTAL SETUP
An experimental test facility was constructed as shown in Fig 1. Four ventilation dampers were installed at the top and bottom of the double-skin system. The inside window is double pane (6mm glazing + 12mm cavity + 6mm glazing) and the exterior window is single pane (6mm clear glazing). The test unit is designed so that multiple configurations can be made, e.g., inside window (low-e, clear), cavity depth (250mm, 400mm), louver color (black, white, ivory).

Wind speed, wind direction, direct and diffuse solar radiation, temperature and humidity of different locations were measured using a HOBO weather station and
T-type thermocouples. The wind velocity in the cavity was measured using a hot-sphere flow meter (TESTO) and pressure difference between indoor and outdoor was measured using a pressure transmitter. T-type thermocouples were installed at three points vertically as shown in Fig 2 to measure glazing surface, cavity air and indoor temperatures. The data was collected using a National Instrument data logger. Fig 2 shows elevation of the experiment unit used for the study.

3. MATHEMATICAL MODEL

In order to describe the dynamics of the double skin systems solvable with reasonable efforts, a space-averaged lumped physical model with six state variables was introduced according to (Fig. 3). The state variables represent the space-averaged temperatures in the horizontal and vertical direction of each glazing of the exterior double pane, the cavity air within the double pane glass, the larger cavity air, the louver slats, and the interior glazing. Although this approach
does not render explicit information about the vertical and horizontal temperature gradients, it is assumed to be detailed enough to represent the overall thermal characteristics of any double skin system and in particular for determining optimal control actions.

![Figure 3: Simplified system in 2D (● = state variables)](image)

In mathematically formulating the direct, diffuse and reflected solar radiation and long wave radiation between surfaces, we used the theoretical model suggested by Rheault and Bilgen [2] without much modification. Based on the assumption of a fictitious cavity (Fig. 4) bounded by adjacent louver slats, interior and exterior glazing, the direct and diffuse solar radiation, and its reflection are calculated.

In the modeling of the convective heat transfer, the six unknown convective heat transfer coefficients \(h_{or}, h_{or,1}, h_{or,2}, h_{or,3}, h_{or,4}, h_{or,5}\) (Fig. 4) should be estimated because the literature values of those coefficients presented in [3]-[5] are empirically driven for general cases and thus, can significantly vary according to the system configuration, location, surroundings, the nature of the surface, micro-climatic environment, etc. In the cavity, different vertical and horizontal heat flow patterns will occur with changing temperatures and varying positions of the curved louver slats and bottom and top openings. Unfortunately, there is very limited data available on these behaviors. Thus, these coefficients have to be identified with a suitable parameter estimation technique, based on extensive data points obtained from experiments. This will be discussed in the following section.
The modeling of the airflow in Mode #1-2 (Fig. 5) is discussed in [1]. The average airflow speed in cavity \( u_{ca} \) in the indoor circulation mode (Fig 5 [1], [2]) can be expressed Eq. (1) [1].

\[
u_{ca} = u_{ca,b} = \sqrt{\frac{2OH}{D}} f \sqrt{\frac{gL}{x_{in,x}}} \times \frac{x_{in,x} - x_{in}}{x_{in}} (1)
\]

where \( u_{ca,b} \) is the cavity air velocity driven by buoyancy, \( OH \) is the open height of the ventilation damper, \( D \) is the depth of the cavity, \( g \) is the gravity acceleration, \( L \) is the height of the cavity, \( f \) is the form loss factor, \( x_{in} \) is the indoor air temperature and \( x_{in,x} \) is the cavity air temperature.

The average airflow speed in cavity \( u_{ca} \) in the outdoor circulation mode (Fig 5 [3]-[4]) is influenced by the surface wind pressure as well as the temperature difference. According to the Bernoulli equation, wind pressure \( (p_w) \) is calculated as Eq. (2) and the amount of airflow due to wind pressure \( (Q_{ca}) \) as Eq (3).

\[
p_w = C_r \rho \left( \frac{u_{ca}^2}{2} \right) (2)
\]
\[
Q_{ca} = c (p_w)^\gamma (3)
\]
where $c_d$: discharge coefficient (dimensionless), $\rho$: air density (kg/m$^3$), $u_{out}$: outside air speed (m/s), $c$: Flow coefficient (dimensionless), $n$: flow exponent (dimensionless)

From Eqs. (2)-(3), the airflow speed in cavity due to wind pressure ($u_{ca,w}$) can be expressed as Eq. (4).

$$u_{ca,w} = \frac{c}{A_c} \left( c_d \rho \frac{u_{out}^n}{2} \right)$$

where $A_c$: Cavity cross-section area (m$^2$)

Under the outdoor circulation mode, cavity airflow is affected by the temperature difference and the surface wind pressure simultaneously, and the two factors must be combined. The cavity airflow Eq. (5) represents the airflow amount ($Q_{ca}$) that incorporates both factors, and the airflow speed can be expressed as Eq. (6).

$$Q_{ca} = \sqrt{Q_{ca,b}^2 + Q_{ca,w}^2}$$

if $C_\rho \geq 0$

$$u_{ca} = \sqrt{u_{ca,b}^2 - u_{ca,w}^2}$$

elsif $u_{ca,b} < u_{ca,w}$

$$u_{ca} = \frac{-u_{ca,w}^2 - u_{ca,b}^2}{2u_{ca,b}}$$

elsif $C_\rho < 0$

$$u_{ca} = \sqrt{u_{ca,b}^2 + u_{ca,w}^2}$$

where $Q_{ca,b}$: Airflow rate in the cavity due to temperature difference

The amount of airflow and the cavity air velocity in the diagonal circulation mode (Fig 5 [5]-[8]) can be calculated as Eqs. (7)-(8) using the inside-outside pressure difference ($\Delta p$).

$$Q = c(\Delta p)^n$$

$$u_{ca} = \frac{Q_{ca}}{A_c} = \frac{c}{A_c}(\Delta p)^n$$
The airflow mode [9] in Fig 5 was excluded from the simplified mathematical model because it requires complex modeling and detailed information. Based on the descriptions given above, the mathematical model was expressed with a continuous state-space equation as shown in Eq. (9).

\[ \dot{x} = A(u,t)x + b(u,t) \quad (9) \]

where \( x \): State variable vector, \( A \): State matrix, \( u \): Input vector, \( b \): Load vector

4. PARAMETER ESTIMATION

The mathematical model introduced in the earlier section contains unknown parameters including the convective thermal transfer coefficients (\( h_{oa}, h_{cah}, h_{oa2}, h_{oa3}, h_{oa4}, h_{oa} \)) in Fig 4, the form loss factor in Eq. (1), and the flow coefficient and the flow exponent in Eqs. (3), (7) and (8). The parameter estimation technique is to find unknown parameters which minimize the difference between actual measurement and simulation prediction. The parameter estimation technique can be express as minimizing the objective function(S) as in Eq. (10).

\[
\min \quad S = \sum_{i=1}^{z} [Y_i - \psi_i(\xi)]^T [Y_i - \psi_i(\xi)] \\
\text{s.t.: } lb \leq \xi \leq ub \\
(10)
\]

where, \( Y_i \): observation vector, \( \psi_i \): discrete state vector in discrete state space, \( z \): number of observations, \( \xi \): vector of unknown parameters, \( lb \): upper bounds of the unknown parameters, \( ub \): lower bounds of the unknown parameters

The function 'LSQNONLIN' in the MATLAB optimization toolbox was used to solve for Eq. (10). The function 'LSQNONLIN' is specially designed to solve for this kind of constrained nonlinear optimization problems. The unknown parameters were expressed as equations in Eq.(10) as follows.
5. DOUBLE-SKIN SYSTEMS: SYSTEM 1, 2

Systems 1 and 2 in Table 1 were selected to investigate how the model should be adapted according to configuration of the system. System 1 was used in a previous study by the authors [1], and System 2 was newly developed for this study. By comparing Systems 1 and 2, the effects of system configuration (size, material, color) on the system performance can be assessed. The new double-skin system
installed at Sungkyunkwan University (Fig. 1) campus was designed to examine the thermal characteristics of 20 different configurations by varying system elements, e.g., cavity width, glazing material and louver color, etc. Thermal characteristics of each configuration will be reported elsewhere.

<table>
<thead>
<tr>
<th>Table 1: configuration of system I, II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Louver color</td>
</tr>
<tr>
<td>system 1 yellow</td>
</tr>
<tr>
<td>system 2 Black</td>
</tr>
</tbody>
</table>

* type 1: exterior window(double pane [6mm clear + 12mm air space + 6mm low-e] + Interior window (single pane [6mm low-e]) (Georgia Tech, USA)
* type 2: exterior window(single pane [6mm clear] + Interior window (double pane [6mm clear + 12mm air space + 6mm low-e]) (Sungkyunkwan University, Korea)

6. RESULTS

The parameter estimation consists of five steps as shown in Table 1: 1st-3rd steps are designed to estimate parameters related to airflow modeling such as the form loss factor, the flow coefficient and exponent. 4th step is to estimate convection thermal transfer coefficients with the cavity closed and open (Fig 5).

<table>
<thead>
<tr>
<th>Table 2: five steps of parameter estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>For the estimation of Airflow</td>
</tr>
<tr>
<td>Step 1</td>
</tr>
<tr>
<td>f</td>
</tr>
<tr>
<td>Step 2</td>
</tr>
<tr>
<td>f, c, n</td>
</tr>
<tr>
<td>Step 3</td>
</tr>
<tr>
<td>h_{in}, h_{ex,1}, h_{ex,2},</td>
</tr>
<tr>
<td>h_{ex,3}, h_{ex,4}, h_u</td>
</tr>
<tr>
<td>Step 4</td>
</tr>
<tr>
<td>h_{ex,2}, h_{in,3}, h_{in,4}</td>
</tr>
<tr>
<td>Step 5</td>
</tr>
</tbody>
</table>

The convective heat transfer in the cavity is substantially influenced by the airflow regime. In other words, open ventilation dampers on the top and bottom of the cavity increase convective thermal transfer on the surfaces of glazing and louver
slats. Hence the cases of the cavity closed (Step 4) and open (Step 5) are considered separately.

6.1 Step 1 – Inside circulation (Airflow modes [1]-[2])

Five experiments were conducted on August 1, 2007 (System 2). The sampling time was 1 second, and the number of data points is 1,912 (System 1) and 1,440 (System 2). Table 3 shows the estimated unknown parameters in Eq. (17).

<table>
<thead>
<tr>
<th>Table 3: Unknown parameters in inside circulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>eq.(17)</td>
</tr>
<tr>
<td>$\xi$</td>
</tr>
<tr>
<td>$\xi_0$</td>
</tr>
<tr>
<td>$\xi_1$</td>
</tr>
<tr>
<td>$f$</td>
</tr>
</tbody>
</table>

Table 3 indicates that for both systems, $\xi_0$ is the dominant for determination of $f$. There are significant differences in the values of $f$ between system 1 and 2. This is due to the fact that the friction loss, affecting the airflow in the cavity, is influenced by the height and width of the cavity. The higher and deeper the cavity, the less friction loss. Moreover, the form loss factor is also influenced by pressure drop through the ventilation dampers, e.g. entrance type and opening geometry of the dampers. Thus, the difference in the damper shape between the two systems has also influenced the form loss factor. For these reasons, the two systems have different form loss factors ($f$).

The average differences between simulated and measured airflow velocity in cavity are 6.89 cm/s (System 1) and 4.73 cm/s (System 2). Fig 6 shows the comparison between simulated and measured values.
6.2 Step 2 – Outside circulation (Airflow modes [3]-[4])

Six experiments were conducted on July 31, 2007. The sampling time was 1 second, and the number of data points were 2,510(System 1) and 1,797(System 2). Table 4 shows the estimated unknown parameters of Eqs. (17) and (18). The average differences between simulated and measured values were 8.33cm/s and 5.70cm/s.

<table>
<thead>
<tr>
<th>Table 4: Unknown parameters in Outside circulation</th>
<th>System 1</th>
<th>System 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\xi$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$\xi_3$</td>
<td>31.48</td>
<td>0.2789</td>
</tr>
<tr>
<td>$f$</td>
<td>16.327</td>
<td>0.1793</td>
</tr>
<tr>
<td>$\xi_4$</td>
<td>0.016</td>
<td>0.0628</td>
</tr>
<tr>
<td>$\xi_6$</td>
<td>0.378</td>
<td>0.0898</td>
</tr>
<tr>
<td>$p_w$</td>
<td>-0.101Pa</td>
<td>-0.137Pa</td>
</tr>
<tr>
<td>$u_{av}$</td>
<td>1.28cm/s</td>
<td>1.75cm/s</td>
</tr>
</tbody>
</table>

As in inside circulation, $\xi_7$ is the dominant for determination of $f$ for outside circulation. There is also a significant difference between the two systems.

For the surface wind pressure ($p_w$) of Eq. (18), the negative pressure was dominant for both systems, causing suction out of the cavity (corresponding to cases with $C_p<0$ in Eq. (6)). In general, a higher cavity increases the wind pressure difference acting on the ventilation damper. Since the cavity of System 1 is higher than that of System 2, a higher surface wind pressure ($p_w$) would be applied under general circumstances, given identical outside wind direction and speed. Despite the fact...
that the cavity of System 2 is lower than that of System 1 (Table 1), and $u_{oa}$ are greater because the prevailing outdoor wind direction is perpendicularly acting on the window surface, increasing the surface wind pressure.

As Eq (4) indicates, the cavity depth is inversely proportional to $u_{oa}$. A higher cavity increases the wind pressure difference between the top and bottom damper. In other words, the higher and shallower the cavity, the greater $u_{oa}$ becomes. For want of space, a figure to compare measurement and simulation for outside circulation was not presented in the paper.

### 6.3 Step 3 – Diagonal flow (Airflow mode [5]-[8])

Six experiments were conducted in the diagonal circulation mode (Aug 6-11, 2007). The sampling time was 1 second, and the number of data points were 2,205(System 1) and 1,774(System 2). During the experiments for System 1 conducted in winter days [1], the indoor temperature was higher than outside, and the building was pressurized by HVAC system by about 4 Pa. On the other hand, experiments for System 2 were conducted in summer, so the outside temperature was higher than inside, and there was no pressurization by HVAC system. For these reasons, airflow modes [5] and [6] occurred in System 1 and modes [7] and [8] in System 2. Table 5 tabulates the estimation results of the unknown parameters in Eqs. (19) and (20).

<table>
<thead>
<tr>
<th>Table 5: Unknown parameters in diagonal flow</th>
<th>System 1</th>
<th>System 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\xi_n$ (eq.(19))</td>
<td>0.0729</td>
<td>0.1370</td>
</tr>
<tr>
<td>$\xi_n$</td>
<td>0.1985</td>
<td>0.0959</td>
</tr>
<tr>
<td>$c$</td>
<td>0.0729</td>
<td>0.1247</td>
</tr>
<tr>
<td>$\xi_n(n)$ (eq.(20))</td>
<td>0.2494</td>
<td>0.3435</td>
</tr>
<tr>
<td>$\Delta p$</td>
<td>3.39 Pa</td>
<td>3.14 Pa</td>
</tr>
<tr>
<td>$Q_{oa}$</td>
<td>0.0819</td>
<td>0.180</td>
</tr>
<tr>
<td>$u_{oa}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation</td>
<td>39.01</td>
<td>23.37</td>
</tr>
<tr>
<td>Measurement</td>
<td>31.75</td>
<td>20.13</td>
</tr>
</tbody>
</table>
The $\Delta p$ includes pressures caused by indoor-outdoor temperature difference, surface wind pressure ($p_w$) and pressurization by HVAC system. System 1's cavity air velocity ($u_{ca}$) was affected by all three factors above, and System 2 was affected by the temperature difference and surface wind pressure ($p_w$) without HVAC pressurization.

The flow coefficient ($c$) in Eq. (19) accounts for the efficiency at allowing fluid flow, and is affected by the area, depth and shape of the opening. System 2's flow coefficient ($c$) is greater because the width of the ventilation damper of system 2 is greater than that of system 1, thus helping the airflow. The average differences between the simulated and measured values were 15.89 cm/s (System 1) and 10.23 cm/s (System 2).

6.4 Step 4 – Cavity closed (Airflow mode [10])

The fourth step was conducted for about 85 hours (Aug 18-22, 2007). The sampling time was 1 minute, and the numbers of data points were 4,507 (System 1) and 5,126 (System 2). Table 6 summarizes the results of parameter estimation, and the average differences between the simulated and measured temperatures were 1.59°C (system 1) and 1.06°C (system 2).

<table>
<thead>
<tr>
<th>Table 6: Unknown parameter in cavity closed</th>
</tr>
</thead>
<tbody>
<tr>
<td>System 1</td>
</tr>
<tr>
<td>$\xi_1$</td>
</tr>
<tr>
<td>$\xi_2$</td>
</tr>
<tr>
<td>$\xi_3$</td>
</tr>
<tr>
<td>$u_{ca}$</td>
</tr>
<tr>
<td>$u_{ir}$</td>
</tr>
<tr>
<td>$h_{aw}$</td>
</tr>
<tr>
<td>$\xi_1$</td>
</tr>
<tr>
<td>$h_{im}$</td>
</tr>
<tr>
<td>$\xi_1$</td>
</tr>
<tr>
<td>$\xi_2$</td>
</tr>
<tr>
<td>$\xi_3$</td>
</tr>
<tr>
<td>$\Delta T$</td>
</tr>
</tbody>
</table>
Despite the fact that $u_{aw}$ of System 1 is higher than that of System 2 in Eq. (11), System 2’s $h_{aw}$ turned out to be higher. This is because $h_{aw}$ is more affected by the local surface wind velocity ($u_{aw}$) than $u_{aw}$ (Eq. (11)), and unknown parameter values ($\xi_1 - \xi_3$) that reflect the wind speed, wind direction and nature of surface vary according to the system. Thus, it can be inferred that use of literature values as a function of $u_{aw}$ without making modifications based on considerations of surface material and surrounding environments can make the model inaccurate.

The difference in $h_{aw}$ between the two systems is 2.75 W/m², and difference in $\xi_1$ is 2.223, indicating that $\xi_1$ has a major influence on $h_{aw}$. $\xi_1$ is a parameter to reflect the end effects since most of the literature values are based on the experiments utilizing a guarded hot-plate technique that measures the convective heat transfer only at the center of the test region, consequently excluding the end effects. In case of System 2, it is found that the top and bottom part of the system is well insulated so $\xi_1$ of System 2 is less than that of System 1.

$h_{aw,2}, h_{aw,3}$ account for convection caused by the temperature difference between the cavity air and the glazing surfaces. Therefore, $h_{aw,2}, h_{aw,3}$ of System 1, which has a
significant temperature difference, is greater than those of System 2. In case of $h_{ca,4}$, the temperature difference of System 2 is greater than System 1, but System 1's $h_{ca,4}$ is greater. Apparently, it is because (1) the surface of the louver slats installed in System 1 is rougher than that of System 2, and (2) convective heat transfer between the louver slats and the cavity air is also affected by the relative ratio between the louver slat width and the cavity width.

System 1 has a greater temperature difference, but it also has a higher window, and $h_m$ is similar for both systems according to Eq. (16). Table 7 shows the estimated and literature values of convective heat transfer coefficients.

<table>
<thead>
<tr>
<th>System</th>
<th>$h_{ca}$</th>
<th>$h_{ca,1}$</th>
<th>$h_{ca,2}$</th>
<th>$h_{ca,3}$</th>
<th>$h_{ca,4}$</th>
<th>$h_m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>System 1</td>
<td>9.16</td>
<td>6.17</td>
<td>5.83</td>
<td>8.11</td>
<td>5.73</td>
<td>3.83</td>
</tr>
<tr>
<td>System 2</td>
<td>9.53</td>
<td>1.13</td>
<td>1.31</td>
<td>1.31</td>
<td>2.33</td>
<td>6.77</td>
</tr>
<tr>
<td></td>
<td>11.64</td>
<td>3.95</td>
<td>2.60</td>
<td>3.37</td>
<td>3.63</td>
<td>3.29</td>
</tr>
<tr>
<td></td>
<td>7.53</td>
<td>7.41</td>
<td>9.53</td>
<td>9.53</td>
<td>8.00</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>7.41</td>
<td>6.77</td>
<td>8.00</td>
<td>8.00</td>
<td>3.49</td>
<td>1.78</td>
</tr>
<tr>
<td></td>
<td>9.53</td>
<td>3.29</td>
<td>8.00</td>
<td>8.00</td>
<td>2.65</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>8.00</td>
<td>3.49</td>
<td>8.00</td>
<td>8.00</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>7.53</td>
<td>6.77</td>
<td>8.00</td>
<td>8.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In cases of $h_{ca}$ and $h_m$, there are significant discrepancies among literatures, and the estimated values fall within the range specified in the literatures used for this study. As for $h_{ca,1}$, $h_{ca,2}$, $h_{ca,3}$ and $h_{ca,4}$, the estimated values were greater than those calculated from the literatures. This is due to the fact that the literature values are empirically driven from experiments under specific conditions (both ends of wall insulated allowing only horizontal heat flow). In other words, the literature values do not take into consideration the lateral heat loss that occurs in the cavity, and the literature values are usually valid for solid walls, not for transparent glazing. This shows importance of parameter estimation. It also demonstrates that the
unmodeled dynamics of the system or purposefully neglected dynamics through lumping can be reflected in the lumped mathematical model through parameter estimation.

6.5 Step 5 – Cavity open (Airflow mode [9])

The fifth step was conducted for two days while the indoor, outdoor and diagonal modes were randomly varied (Aug 22-24, 2007). The sampling time was 1 minute, and the number of data points was 3,027. Similar to Step 3, air flow modes 5 and 6 occurred in System 1 and modes 7 and 8 in System 2. Table 8 shows the results of parameter estimation. The average difference between the simulated and measured temperatures were 1.72°C (System 1) and 0.97°C (System 2).

<table>
<thead>
<tr>
<th>Table 8: Comparison The estimated and literature values with the cavity open</th>
<th>System 1</th>
<th>System 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\xi_{i}$</td>
<td>2.20</td>
<td>3.02</td>
</tr>
<tr>
<td>$\xi_{s}$</td>
<td>1.19</td>
<td>2.58</td>
</tr>
<tr>
<td>$\xi_{r}$</td>
<td>0.39</td>
<td>0.48</td>
</tr>
<tr>
<td>$\Delta T$</td>
<td>3.58</td>
<td>2.14</td>
</tr>
<tr>
<td>$h_{\omega,2}$</td>
<td>7.03</td>
<td>6.47</td>
</tr>
<tr>
<td>$\xi_{tr}$</td>
<td>0.26</td>
<td>0.88</td>
</tr>
<tr>
<td>$\xi_{rt}$</td>
<td>0.87</td>
<td>0.52</td>
</tr>
<tr>
<td>$\xi_{i}$</td>
<td>2.62</td>
<td>2.69</td>
</tr>
<tr>
<td>$\xi_{s}$</td>
<td>2.68</td>
<td>1.11</td>
</tr>
<tr>
<td>$\xi_{r}$</td>
<td>1.02</td>
<td>0.25</td>
</tr>
<tr>
<td>$\Delta T$</td>
<td>2.15</td>
<td>0.74</td>
</tr>
<tr>
<td>$h_{\omega,3}$</td>
<td>9.51</td>
<td>3.99</td>
</tr>
<tr>
<td>$\xi_{tr}$</td>
<td>0.26</td>
<td>0.88</td>
</tr>
<tr>
<td>$\xi_{rt}$</td>
<td>0.87</td>
<td>0.52</td>
</tr>
<tr>
<td>$\xi_{i}$</td>
<td>2.11</td>
<td>2.83</td>
</tr>
<tr>
<td>$\xi_{r}$</td>
<td>1.88</td>
<td>2.00</td>
</tr>
<tr>
<td>$\Delta T$</td>
<td>1.01</td>
<td>0.42</td>
</tr>
<tr>
<td>$h_{\omega,4}$</td>
<td>1.02</td>
<td>2.13</td>
</tr>
<tr>
<td>$\xi_{tr}$</td>
<td>7.24</td>
<td>5.62</td>
</tr>
<tr>
<td>$\xi_{rt}$</td>
<td>0.26</td>
<td>0.88</td>
</tr>
</tbody>
</table>
Comparing Systems 1 and 2, System 1 had a higher cavity airflow velocity as well as greater temperature differences except $h_{\text{e},1}$. For these reasons, System 1 for Step 5 had higher convective thermal transfer coefficients as in Step 4. Comparing Tables 6 and 8, it is shown that the convective thermal transfer coefficients in Step 5 are higher than those in Step 4. This is because convective thermal transfer has increased due to airflow movement within the cavity in Step 5. Table 9 shows comparison of the estimated convective heat transfer coefficients with the literature values. Significant discrepancies exist between the estimated and reference values for Step 5 for similar reasons explained in Step 4.

<table>
<thead>
<tr>
<th></th>
<th>System 1</th>
<th>System 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h_{\text{e},2}$</td>
<td>7.03</td>
<td>1.6</td>
</tr>
<tr>
<td>$h_{\text{e},3}$</td>
<td>9.5</td>
<td>1.43</td>
</tr>
<tr>
<td>$h_{\text{e},4}$</td>
<td>7.23</td>
<td>2.47</td>
</tr>
</tbody>
</table>

### 7. VALIDATION

Validation processes were conducted performed to check whether the calibrated model is capable of accurately predicting the system’s response. Park et al [8] explain the validation process for System 1, thus the process for System 2 is only provided here. For the purpose of validation, an experiment was conducted for about 127 hours (Aug 25, 2007 - Aug 30, 2007) with a sampling time of 1 minute. The weather varied significantly from clear to rainy during the experiment. During the experiment, the louver slat angles and the airflow regimes were “randomly” changed and these changes were logged and reproduced exactly in the calculation.
7.1 Validation of state variables

Fig 7 shows the validation result, showing five state variables. Table 10 shows the average difference in temperature between the simulated and measured state variables. The overall average temperature differences were 1.32°C (System 1) and 0.92°C (System 2). Considering the accuracy range (±1.0°C) of the used thermocouples (Omega T Type), the calibrated model proved surprisingly accurate in the prediction of the most relevant state variables. It indicates that the calibrated parameters compensate for errors introduced by the space averaging, other model simplifications and unexplained phenomena. It should be noted that the air temperature (\( x_6 \)) of the small cavity in the interior double-pane was not measured.
Figure 7: Validation of state variables

<table>
<thead>
<tr>
<th>state variables</th>
<th>System 1</th>
<th>System 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_1$</td>
<td>2.10</td>
<td>0.60</td>
</tr>
<tr>
<td>$x_2$</td>
<td>1.09</td>
<td>0.87</td>
</tr>
<tr>
<td>$x_3$</td>
<td>0.89</td>
<td>0.59</td>
</tr>
<tr>
<td>$x_4$</td>
<td>1.25</td>
<td>1.43</td>
</tr>
<tr>
<td>$x_5$</td>
<td>1.32</td>
<td>1.12</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>1.32</td>
<td>0.92</td>
</tr>
</tbody>
</table>

7.2 Validation of cavity air velocity ($u_{ca}$)

Fig. 9 shows the comparison of the cavity air velocity simulated from the calibrated model and measured from the experiment. The average air velocity difference between simulation and measurement is tabulated in Table 11.

Figure 8: Validation of cavity air velocity

<table>
<thead>
<tr>
<th>Airflow regime (fig. 5)</th>
<th>System 1</th>
<th>System 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1]</td>
<td>10.44</td>
<td>11.39</td>
</tr>
<tr>
<td>[3]</td>
<td>2.65</td>
<td>9.09</td>
</tr>
<tr>
<td>[5]</td>
<td>19.43</td>
<td>not occurred</td>
</tr>
<tr>
<td>[6]</td>
<td>27.36</td>
<td>not occurred</td>
</tr>
<tr>
<td>[7]</td>
<td>not occurred</td>
<td>9.70</td>
</tr>
<tr>
<td>[8]</td>
<td>not occurred</td>
<td>17.61</td>
</tr>
</tbody>
</table>
In case of airflow modes [1]-[2], small difference in the prediction of the state variable \( x_s \) makes a significant difference in the simulation of the cavity air velocity in inside circulation. As indicated in Eq. (1), the mean cavity air velocity in inside circulation is dependent on the temperature difference \( \Delta T \) between the cavity air and the room air. Apparently, prediction errors of 1.32°C (System 1) and 0.92°C (System 2) (Refer to Table 10) have caused the corresponding air velocity error, which can be reduced by using measured temperature values rather than simulation results.

In cases of airflow modes [5]-[6], the errors increased because (1) the wind speed sensor used for the experiment had a low accuracy\( \pm 5\) cm/s, (2) airflow velocity prediction was based on simulated temperature values, and (3) a pressure transmitter was not employed (System 1). Using a pressure transmitter for airflow modes [7]-[8], System 2 yields better predictions than System 1. The degree of the error in System 2 can be improved by using on-line self-calibration technique for further study.

8. CONCLUSIONS AND FUTURE WORK
This study aimed to develop a simple model adequate for real-time optimal control of double-skin systems by state-space approach. The model was based on a lumped mathematical model that simplifies double-skin's 3D to 2D. The unknown parameters were estimated using the parameter estimation technique. The mathematical model is capable of accurately predicting system response.

Comparing the mathematical model developed for this study (System 2) and an existing model (System 1), it was shown that a mathematical model must be adjusted according to variations in the system configuration, surroundings and construction elements (pane, louver material, cavity width/depth). It was also shown that as the configuration and other elements of a double-skin system vary,
there are limitations in developing a model solely based on the parameters from the literatures.

There were substantial differences between literature and estimated values. Since most literature values are empirically driven for a specific case, it would be difficult to acquire accurate results if they were used without modification or calibration.

Based on the results of this study, the following studies are on-going: (1) Mathematical modeling and performance analysis according to various system configurations, (2) integrating the model with a whole building energy simulation tools (e.g., Energy Plus, esp-r).

9. ACKNOWLEDGEMENT
This work was supported by the Korea Research Foundation Grant funded by the Korean Government (MOEHRD) (KRF - 2006 - 331 - D00634).

10. REFERENCES


ABSTRACT: Post Occupancy Evaluation (POE) exercise is an effective tool for evaluating the performance of the facilities provided in a building after it is occupied. It also forms effective communication channels among all stakeholders. The paper presents the sustainable design features adopted by the Architectural Services Department (ArchSD), Hong Kong Special Administrative Region Government (HKSARG), the establishment and development of POE in the ArchSD and POE experience gained in some government projects, especially on evaluation of sustainable and energy efficient features. The evaluation also focuses on occupants’ need, energy performance and client satisfaction. During the POE process, information in areas of ‘operational performance monitoring and handover’, ‘energy review’ as well as ‘new technologies’ is systematically collected. The information so gathered, together with the users’ feedback, is systematically analysed, based on which recommendations or improvement initiatives are made.

Keywords: ArchSD, Post Occupancy Evaluation, POE, sustainable design, sustainable features, operational performance monitoring, energy review, performance, feedback.

1. INTRODUCTION
POE is an effective tool to evaluate the performance of the building and building services (BS) systems after the building is occupied[1]. In view of the increasing technical complexity on building and BS systems design and growing public concerns on sustainable and energy efficiency issues, ArchSD considers POE would be a good practice and effective means, especially for those complicated projects, to ensure the sustainable design and other key features are properly implemented and operated to meet the occupants’ need and to assess the performance of such new technologies.
POE exercises have been conducted for six newly built or renovated projects over the past two years. The information and data are usually collected through questionnaires, interviews, meetings, walk-through, audits, surveys, central control and monitoring system (CCMS) and other metering equipment, etc.

Through systematic performance assessment and feedback from end-users, designers are given more insight to the practical use of the innovative and sustainable features, as well as a better understanding on the environmental, social and economic feasibility on building projects. Mutual understanding between the designers and the end-users are much enhanced. The results of these exercises so far have been very promising. More energy has been saved and the daily operations are much smoother. Some improvement proposals have also been identified for future projects. It is hoped that, based on experience gained, a protocol of such assessment methodology and practice can be established or further improved for the industry.

2. EVALUATION OF SUSTAINABLE DESIGN

2.1 Sustainable Design
ArchSD encourages project teams and consultants to explore every opportunity to adopt sustainable design features by setting a list of sustainable design principles, such as sustainable planning, preservation of existing heritage and habitats, energy conservation, waste management, use of materials, operation and maintenance, etc.

Every year, the Department receives recognition for contribution and accomplishment in sustainable design and construction[2].

2.1.1 Targets on energy efficiency
Efficient energy use is the key for developing a sustainable future. In order to minimise the consumption of energy in buildings constructed by our department, a
number of environmental targets for design of buildings and BS systems are set, including:–

- Low Overall Thermal Transfer Value;
- Use of water-cooled heat rejection system for central air-conditioning installations;
- use of occupancy sensors for air-conditioning and lighting installations; and
- use of high efficiency motors, etc.

2.1.2 Sustainable Design Features

Many sustainable and innovative features have been incorporated in ArchSD’s projects in recent years, such as:–

- Green roof design;
- Restriction use of hardwood;
- Timber from certified sustainable forests;
- Low volatile organic compounds paint;
- Recycled aggregate in concrete;
- Pre-cast building/structural systems;
- Long life and low maintenance prefabricated materials
- Environmentally friendly carpet;
- High-efficiency chillers;
- Total energy heat pump
• Heat recovery chiller/heat-pump as energy efficient heat source for hot water pre-heating;

• Heat wheel for waste heat reclaim and economiser control for free cooling adopted;

• Ice-storage air-conditioning system

• Renewable energy, e.g. PV installation, solar hot water systems, etc.;

• Natural light, including sun pipe;

• Natural ventilation;

• Low-e or double glazed window;

• High efficiency lighting systems; and

• Grey water system.

2.2 Performance Evaluation
It is important to evaluate the effectiveness of such design and by means of POE, this objective is fully achieved for the following:-

• As a yardstick to check against whether the building performed to the design objective; and then make adjustment or correction accordingly;

• As a tool to evaluate the effectiveness of any new technologies installed, and then make recommendation on their future uses;

• Information collected to better understand the users’ requirements;

• Lessons learnt to enhance future design;

• Improves building environment that enhance working efficiency of the building occupants; and
Facilitates communication between all stakeholders and hence improves clients’ satisfaction.

In addition to POE exercises, we also adopt the Hong Kong Building Environmental Assessment Method (HK-BEAM), a comprehensive environmental assessment of building, and the Indoor Air Quality Certification Scheme for Offices and Public Places administered by the Environmental Protection Department of the HKSARG, to review the design, construction and management of a building. Such evaluation can act as a benchmarking tool for the environmental performance of our buildings.

3. DEVELOPMENT OF POE IN ARCHSD

3.1 POE in Hong Kong
Despite the fact that there are many potential benefits associated with the implementation of POE to all stakeholders [3] and POE has been put in use for years in many places, it is still not commonly adopted in Hong Kong. The major perceived hurdle is that POE requires extra resources and time.

3.2 Initiation of POE in ArchSD
In view of the increasing technical complexity on building and BS systems design and growing public concerns on environmental issues, ArchSD considers there is a need to implement POE for government buildings, especially for those complicated ones in order to monitor the performance of such buildings. Unlike private commercial buildings with usually multi-tenants, which make the POE exercise more difficult, ArchSD has more options to select buildings with single client department to carry out the exercise. As a start, it is more effective and efficient to collaborate with single client department to consolidate client’s requirements and to convey POE teams’ suggestions. It is also important to ensure the exercise be performed smoothly without causing inconvenience to the client. Several projects with complex nature were selected as pilot in 2005. It was
expected that the experience gained from these pilot projects could help establishing a more solid framework and further strengthening the POE effectiveness.

3.3 Initial POE Framework

3.3.1 Strategic Method

The initial strategic method of post occupancy evaluation focused mainly on BS systems and included the following critical areas[3]:-

- Commissioning and fine-tuning of building services;
- Commissioning and fine-tuning of controls;
- Initial technical information, support and training facilitate operations and maintenance (O&M) team;
- Information and training for non-technical staff of the client;
- Keeping information up to date;
- Feedback from client and O&M team; and
- Enhancing communication among client, design team and O&M team.

3.3.2 Setup of POE Teams

Typically three POE teams with representatives from all stakeholders were formed for each building. Certain functions of each team were also laid down for their specified tasks.

(i) Operational Performance Monitoring and Handover Team

Composition:

-New Works Project Team
-O&M Agent

-Building Management (BM) Agent

Function:

-To convey the design concept, parameters, capabilities and functions of each type of installed BS systems to all concerned parties

-To provide operation and maintenance information (as-built drawings, O&M manuals and testing and commissioning records)

-To conduct operational training and review feedback from operators and building management to formulate manning requirements

-To monitor status of defects rectification and determine any supplementary work and improvements

-To devise specific operation procedure for emergency scenarios like:

  Power Interruption

  Flooding / Water Leaking

  Lift faults / Outage

  False/Unwanted Fire Alarm

  Air-conditioning System malfunction for sensitive areas

Energy Review Team

Composition:

-New Works Project Team

-O&M Agent
- User Representative/Building Management Agent

- Energy Expert from other departments

Function:

- To collect energy data of each type of installed BS systems and carry out energy usage analysis

- To identify energy management opportunities for the building as well as for each group of users to tie in with their specific operational requirements

- To capture and monitor actual energy consumption data for the building and each group of users and give advice to client for equipment selection and house keeping practice

- To recommend design improvements for future projects

(iii) New Technology/Specific System Evaluation Team

Composition:

- New Works Project Team

- O&M Agent

- Experts from the departmental Specialist Support Group and other departments (as required)

Function:

- To establish thorough understanding on the principle of the new technologies/specific system
- To monitor the testing and commissioning of the installation and capture the operational parameters and performance data for verification with the intended performance

- To assess actual benefits yielded and payback period

- To develop expertise in operation and maintenance of the installations

- To make recommendation on the potential applicability in future projects

3.4 Second Stage of Development

After implementing POE on some pilot projects for around one year of full occupancy, the feedback, both positive and negative, collected from client departments and end-users were analysed and a new guideline was issued in 2006 to further enhance steps on various stages of the POE exercise.

3.4.1 Work on Different Stages

The new guideline provides detailed steps and requirements on different stages of the POE exercise in order to ensure the exercise be implemented more smoothly and effectively.

a) Before conducting a POE exercise

It was found that it was very useful to define the duration, scope and programme of a POE exercise before commencing the exercise. Such preparation should also be done before building occupation.

Based on the defined duration, scope and programme of the POE exercise, the resource requirements could be better planned and established.

b) During POE exercise

The new guideline provides more detailed description on the tasks of the three POE teams to facilitate team members to accomplish their tasks. Apart from using CCMS and metering equipment for technical data collection, a questionnaire sample form for Client Satisfaction Survey is also developed to gauge the
effectiveness of the exercise and to identify the area for improvement. The survey form consists of 3 parts:-

i) Part I – Operational Performance Monitoring and Handover
ii) Part II – Energy Review
iii) Part III – Overall Assessment of the POE

c) Post POE exercise
The new guideline lays down the basic information required for the concluding report to keep proper record of the evaluation and to bring out the way forward for any improvement works.

Presentation to other departmental colleagues would also be done after completion of the draft concluding report to collect more suggestions and views for improvement before submission to the client.

3.5 Further Development
In order to further enhance the effectiveness and efficiency of POE exercise, ArchSD will consider employing a consultant to explore the best options to collect view from clients on various building works and BS systems. A more detailed and systematic guideline for POE on architectural works will also be developed to assist the POE teams. Meanwhile, different means or tools are also being studied.

4. EXPERIENCE SHARING
From the several POE exercises, there are already some lessons learnt from these exercises. The paper will focus on some issues related to sustainable features and energy efficiency. The followings are some of the examples.

4.1 Architectural Works
4.1.1 Proprietary Standing Seam Lightweight Aluminium Roof
Proprietary lightweight aluminium alloy standing seam roofing system was adopted in some projects as it could reduce structural loading and save building materials. The prefabricated system can also reduce material wastage on site. However, after the building occupation, there were reports of water penetration after heavy rainfall.

![Figure 1: Details of a typical roofing system](image)

The following causes of the problems were identified by the POE team:

i. “Balloon-type” gratings to roof outlets at the gutters were installed as part of the standard system. Some of the inconspicuous gratings were found to be blocked by leaves and plastic bags blown onto the roof from surrounding areas.

ii. Inadequate fall of the roof for maintenance requirements might have hindered the swift disposal of rainwater, especially after heavy rain during typhoon seasons in Hong Kong.

iii. The standard upturn at the flashing cover was suspected to be too shallow and water ingress was found at some of these locations.

iv. Some damage caused by stepping on the roofing panels and the perimeter flashing by the contractors during construction and subsequently by the maintenance staff after the occupation were discovered. The provisions for the protection of the metal roofing to cater for the routine inspection and maintenance needed to be improved.

The following solutions were adopted:

i. Additional stainless steel mesh grating units of about 2m long were installed over the standard “balloon-type” gratings. Since the surface area of the
grating was enlarged, the risk of debris (e.g. leaves) completely blocking the entire grating was minimized.

Figure 2: Stainless steel mesh grating added to drainage outlets

ii. Additional overflows to prevent flooding were provided and these were positioned at conspicuous locations to alert users and maintenance staff.

iii. Additional flashing was installed on top of the existing flashing in order to overcome the problem of shallow flashing cover. Permanent warning signage was installed to warn maintenance staffs not to step onto and damage the flashing.

Figure 3: Details of additional flashing

iv. In addition to the fall arrest system already installed, additional proprietary walkway system was added in order to further improve the access for future maintenance of the roof.
4.1.2 Ventilated Double-layered Glass Wall

Ventilated double-layered glass wall was adopted recently in a government offices building. For the offices located at the perimeter of the building which were designed to be open-plan, the return air was extracted via the air space between the 2 layers of glass of the double glass window. Some of the open-plan offices were subsequently required to be divided into cellular offices after occupation. On-site measurements indicated that the ventilated double-layered glass wall was very efficient in terms of removing the incident heat and the noise penetration from the external environment. However, a short circuit for the sound transmission between adjacent cellular offices were resulted via the louvers opening along the glass walls.
Moreover, the design of the MVAC system for the offices was such that the supply air was delivered via the raised floor & extracted via the ceiling void, both as an air plenum. While this system had been designed to be more energy efficient as the cooling zone of occupants was limited to around 2m above the finished floor level, the system is generally much quieter than a conventional MVAC system as supply air is delivered via low velocity floor diffusers rather than the conventional high velocity air delivered via ceiling diffusers. The background ‘white noise’ is therefore much lower than conventional offices, exaggerating the effect of cross-talk between adjacent cellular offices.

After studying by the POE team, vertical acoustic separation at the mullions in line with the partition walls were installed to cut off the acoustic path across adjacent rooms via the double-layered glass wall return air void and the problem of noise cross-over was therefore resolved.

4.2 BS Systems

4.2.1 Lighting system

Lighting system usually consumes about 20% of electricity of an office building. To achieve higher energy saving, intelligent lighting control systems, occupancy
sensors and photo sensors are also adopted apart from using the high efficiency lighting, e.g. T5 and electronic ballast. The POE team found the following main points important to satisfy the end-users while optimising energy saving of the lighting installation:

i. Central Intelligent Lighting Control

Although the intelligent lighting control system can provide a more flexible and versatile arrangement to suit the office layout or operation needs, it would also need to take more time to fine-tune the system to meet end-users’ requirements after the occupation. Over reliance on the system would also cause inconvenience to end-users. An example is that one building design relied only on central intelligent control system and occupancy sensors without providing local lighting switches. It drew quite a number of complaints before the central system could be fine-tuned to suit each zone. End-users would usually appreciate the auto control of the lighting system, however, they also prefer certain degrees of self-control on the lighting on-off.
ii. Proper zoning

Since the office layout may not be finalised during design or installation stages, zoning into smaller sectors can provide greater flexibility and more potential for energy saving as users can always switch off those zones not in use.

iii. Motion/Photo sensors

At the initial occupation stage, these sensors would always cause complaint from end-users. Though users were supportive to the idea of automatic sensor control to reduce unnecessary use of energy, they were also annoyed by the frequent on-off or improper and untimely response of the sensor. The problem usually could be solved by adjusting the sensitivity and coverage angle of sensors. The POE team also found that the change of office layout could easily jeopardise the merit of occupancy sensors, and sensor control seems to fit the cellar office more easily.

4.2.2 Air-conditioning(AC) system

In general, AC systems consume about 50% of electricity of an office building. Therefore, POE team would also put more effort on the evaluating the performance of the systems. The measurement and adjustment for air-conditioning would normally take longer time due to the seasonal climate change and the occupancy percentage change. The data collection would usually rely on the installed CCMS. Other metering equipment would also be used to spot-check the accuracy of data collected. Based on the collected data, AC loading and energy consumption would be analysed by using proprietary computer program or self-developed computer program.
Figure 8: Typical metering equipment

i. Air-side

a) Zoning
In one project, although variable speed drive for air handling unit (AHU) and variable air volume (VAV) system had been adopted to suit the operation need and to achieve optimum energy use, it was found that there were also some areas which had different operational schedule after the occupation. Such operation mode provided a good opportunity to further reduce the air supply to unused areas. Therefore, similar to lighting control, the proper zoning into an optimum size to suit the actual operation needs deserve more effort and better planning in the design stage.

b) Occupancy sensor
Some buildings also used occupancy sensors to control the on-off air supply to cellar offices. It proved to be an effective means of saving wasted energy. However, the proper setting of sensor sensitivity and time lag are important to meet the end-user’s requirement. The use of CO₂ sensors for fresh air supply was also proved to be effective to optimize energy use while maintaining a good indoor air quality.

ii. Water-side

a) Chiller control
Water-side of an AC system includes mainly the chillers, which consume the majority of energy of the system. The POE team found that proper setting of chiller on-off could significantly affect the energy consumption. For water-cooled chillers, the electrical energy input, AC cooling energy output and the entering condensing water temperature would be recorded from the CCMS for energy profile analysis. Different types of chillers have different operating efficiency at full and part load. The coefficient of performance, i.e. the operating efficiency, of each chiller would also change significantly under different chiller loading and condensing water temperature. The control of chiller cut-in/cut-out and operation combination becomes complex and significant. It could be site specified to suit different cooling load profiles. The important point was for the POE team to accurately record the actual load profiles at different seasons and to adjust the chiller cut-in/cut-out time. The POE team also found that use of variable speed chillers to meet the AC load requirement was more efficient than the conventional equal load sharing by all operating chillers.

b) Sensors
In the energy and load profile analysis, the accuracy was heavily relying on the data collected through the CCMS. It was found that the location of sensors installed for collection the required information, such as the water flow of a selected chilled-water pump, had significant impact on the accuracy of the data collected and hence the final analysis results. The reliability and accuracy of these sensors also played an important role. The POE team therefore recommended future project teams to allocate more resources on this issue.

5. CONCLUSION
Although ArchSD has commenced POE exercises for only about 2 years, valuable experience and knowledge on evaluation of performance of building and building services installations are already being built up. Through these exercises, better communication channels can be built among the designers, the end-users and the
maintenance personnel so that the building and BS systems can be better designed
and operated to serve the clients’ needs. The exercise can also provide a good
opportunity for POE teams to carry out more in-depth evaluation on the new
technologies for sustainable design and energy efficiency. The exercise proves to
be very useful, especially for buildings with new sustainable features.

6. ACKNOWLEDGEMENT

The authors would like to thank the POE teams for their invaluable advice and
information.

7. REFERENCES

A PRELIMINARY TEST FOR PREDICTION OF CAVITY TEMPERATURE IN A DOUBLE-SKIN ENVELOPE

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² Sustainable Building Research Center, Hanyang University, Ansan, South Korea
³ School of Architecture and Architectural Engineering, Hanyang University, Ansan, South Korea

ABSTRACT: This study examines thermal properties that potentially influence on energy in building with double-skin envelope in order to provide fundamental data that will be used for effective controls of cavity. Field measurements were performed in a three story building that has double-skin on its eastern and western facades. Results imply that cavity temperature was significantly influenced by solar irradiance. The western façade was more influenced compared with eastern side due to direct irradiance and accumulated diffused irradiance as time passed by. Air velocity thorough cavities indicate that natural ventilation occurred effectively.

Keywords: double-skin, solar irradiance, air velocity, natural ventilation

1. INTRODUCTION

Energy consumption in buildings emits chemical compounds that will cause greenhouse effect. It results in serious problems in environment such as global warming. Reducing energy consumption in buildings using natural energy is considered to be a good way to reduce the negative effects.

Curtain-wall structures with high ratio of glazing to wall are popularly used for high-rised buildings, since they have benefit to satisfy visual satisfaction. However, the structures cause increased cooling load since the higher ratio allow solar radiation to penetrate into indoor space. They also have increased heating load due to the weak thermal resistance of glazing. This will be directly connected to energy consumption in buildings and will cause more environmental load.

To diminish the weakness of curtain wall structure, double-skin envelope was applied to building designs and constructed in practice. [1,2] It is considered to be a environment-friendly design since it utilizes natural ventilation so that less...
energy consumption and better comfort can be achieved using cavity and double envelope. It was proved that the double skin façade effectively contributed to electric lighting control using daylight [3].

However, the control for the cavity area still needs to be set up according to the change of configuration of double skin. This study aims at providing fundamental data will be effectively used for the development of control logics in future study. Field measurements were performed in a three-story building that has double skin on its eastern and western facade.

2. RESEARCH METHOD

2.1 Building for measurement
The building used for field measurements is located in Ansan, South Korea (Latitude: 37°17′ Longitude: 126°49′) It was completed in August 2007 and has three floors. The building before the completion of double skin envelope is shown in Figure 1.

The first and second floors are used for experimental facilities of sustainable buildings. The third floor is used for office space for research scientist and administration staffs. The long axis of the building is along the axis from south to north direction. Double skin envelope is installed on the eastern and western side of the building as it is indicated in Figure 1.

The conceptual description of double skin used in this study is shown in Figure 2. Its dimension was 5.7m (width) by 0.5 m (depth) by 13.2 m (height). The internal and external skins were covered with glazing from the first floor to third floor. The vertical side was also covered with glazing. The measured transmittance of glazing was 0.83, but heat transfer coefficient was not determined in this study.

In the internal skin wall exist at the top of each floor and it covered 1.2 m from the top. The walls consisted of masonry and mortar. Venetian blinds were installed on
outside of internal skin in cavity. The distance and depth of blind slot was 2.54 cm (1”). It covered the whole internal skin with no tilt angle.

Opening for air inlet and outlet were installed at the bottom and top of cavity respectively. The whole top and bottom area of cavity was open so that air can be induced into the cavity and naturally ventilated. The opening for air inlet was suspended from ground by 0.3m. All window or opening in internal skin was closed.

2.2 Data monitoring
Data monitoring has been performed on a daily basis from the beginning of September to current time.

Solar irradiance, illuminance, temperature in various positions, and air velocity in cavity were monitored using data logging systems.

Signal for data were generated by sensors in voltage or current. It was converted into practical unit using calibration constants given to each sensor. The data logging interval was one minute.

*Figure 1: View of tested building from west (before completion)*
3. ANALYSIS RESULTS

The result analyzed in this study is based on the data for a specific date, since data monitoring has been performed from the beginning of September to current time. Data monitored under a clear sky day in October are discussed in this paper.

3.1 Sun and outdoor properties

Solar altitude and azimuth for the site, where the building is located, was determined for each one minute using theoretical calculation procedures. The variation of altitude during the monitored day is shown in Figure 3.

The altitude started to increase as the sun rises and it reached the highest value of 45.61° at solar noon. The altitude in afternoon was symmetrical to that in morning. The altitude has the maximum value at the solar noon of summer solstice, which is 76.14° in the site used in this study.

Since the date selected in this analysis was October 9th, the maximum altitude was lower than the maximum altitude by 30.54°. The solar azimuth varied from -79.60° to 79.60° for the data monitoring date.
Under these solar conditions, the irradiance that arrives at the outside surface of external skin varied significantly. The variation is shown in Figure 4.

Those two properties showed similar change patterns during the monitoring period. In morning, the irradiance reached the maximum value of 529.71 W/m² and started to decrease as the sun move toward west through south.

Starting from the condition when the sun was deviated toward east from exact south by 30.05, irradiance and illuminance in eastern side decreased significantly. On the contrary, the irradiance and illuminance on western side increased dramatically.

The maximum irradiance in eastern side was 64.68% of the irradiance in western side. The difference between them was 289.18 W/m². It appears that the influence by direct solar radiation caused the result. The irradiance caused by the sun in western side was greater since it has the direct and diffused solar radiation. As the sun rises from east side, the direct solar radiation was strong factor that cause strong solar radiation in east, since diffused radiation from sky is not strong. However, the radiation in the west side has strong impact from direct sun and accumulated diffused solar radiation from sky as the time period during which the sun was exposed to the earth increased. Hence, it is expected that greater cooling load will be caused in the western side of buildings.

3.2 Temperature variation in cavity

The temperature in the cavity located in the eastern and western side showed different variation pattern due to the variation of solar irradiance. The variation is shown in Figure 5-Figure 6. The cavity temperature in both east and west side had similar variation pattern until the sun rise from east. During this period the lowest temperature was 8.03 °C.

In general, the cavity temperature in west side was greater than that in east side. The greatest temperature difference between the air inlet and outlet was 7.31°C in east side, and 12.82 °C in west side. It appears that this result occurred due to the
duration of time during which direct and diffused solar radiation influence the cavity.

Due to the strong influence of direct sun on east side in morning, the cavity temperature became the highest around 9:40 am. The cavity temperature increased as the height from the bottom of cavity increased. It implies that warm air rose up and cool air moved down, so that natural ventilation occurred.

![Graph of Altitude Variation](image1)

**Figure 3:** Variation of Altitude (Oct. 9, 2007)

![Graph of Irradiance](image2)

**Figure 4:** Variation of vertical irradiance on outside of external skin (Oct. 9, 2007)

The temperature variation of internal and external skin surface is meaningful since it influence on the natural convection near the surface area. The surface temperature of inside of external skin is shown in Figure 7-Figure 8. The change patterns were very similar to that of cavity temperature. The temperature became great as the height from the bottom of cavity increased.
3.3 Velocity variation in cavity
The solar radiation provided source of heat with the cavity so that natural ventilation occurred due to the stack effect. The variation of air velocity in both cavities is shown in Figure 9-Figure 10.

Generally, the velocity at air inlet was the greatest. After the air was induced into the bottom of cavity, its velocity was diminished due to the change of pathway of air movement. The velocity increased as the air travelled near outlet at the top of cavity due to the suction effect from the top of cavity which is exposed to atmosphere. However, its velocity was slower than that at the air inlet.

The statistical summary of air velocity in both cavities is shown in Table 1. It appears that the velocity in the cavity was influenced by solar radiation. The velocity in the west cavity had higher values when the sun was on the west side after it passed south.

![Figure 5: Temperature Variation in eastern cavity (Oct.9, 2007)](image-url)
Figure 6: Temperature Variation in western cavity (Oct.9. 2007)

Figure 7: Inside surface temperature of external skin (Oct.9. 2007, eastern façade)

Figure 8: Inside surface temperature of external skin (Oct.9. 2007, western façade)

Figure 9: Variation of air velocity in eastern cavity (Oct.9. 2007)
Figure 10: Variation of air velocity in western cavity (Oct.9, 2007)

Table 1: Statistical summary of air velocity in cavities

<table>
<thead>
<tr>
<th>Stats.</th>
<th>Inlet</th>
<th>Center</th>
<th>Outlet</th>
<th>Inlet</th>
<th>Center</th>
<th>Outlet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.93</td>
<td>0.22</td>
<td>0.45</td>
<td>0.70</td>
<td>0.38</td>
<td>0.56</td>
</tr>
<tr>
<td>Median</td>
<td>0.85</td>
<td>0.19</td>
<td>0.40</td>
<td>0.58</td>
<td>0.30</td>
<td>0.51</td>
</tr>
<tr>
<td>S.D.</td>
<td>0.42</td>
<td>0.13</td>
<td>0.31</td>
<td>0.47</td>
<td>0.26</td>
<td>0.33</td>
</tr>
<tr>
<td>Min.</td>
<td>0.09</td>
<td>0.05</td>
<td>0.00</td>
<td>0.05</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Max.</td>
<td>2.52</td>
<td>0.72</td>
<td>1.54</td>
<td>3.16</td>
<td>1.11</td>
<td>1.55</td>
</tr>
</tbody>
</table>

3.4 Prediction of cavity temperature

The temperature of cavity causes influence on the heating and cooling load in building, it is necessary to predict the variation of temperature according to outdoor weather condition. In this study, the mean temperature of cavity was predicted using multiple regression method that minimizes Error Sum of Squares (SSE). Solar radiation and outdoor air temperature were independent variables for the regression models. The prediction result is shown in Table 2-Table 3.

For east and west facing façade, two independent variables used for the predictions models were acceptable. The level of significance for outdoor temperature and solar radiation were zero. The coefficient of determination was 0.634 for east facing and 0.85 for west facing-façade. It appears that this occurred since the direct and diffused solar radiation

Table 2: Multiple regression model (east-facing )

<table>
<thead>
<tr>
<th>Unstandardized Coefficients</th>
<th></th>
</tr>
</thead>
</table>
were stronger for west facing condition compared with the radiation under east-facing façade. The regression models were tested using ANOVA. Test results indicate that the models were acceptable since the level of significance was zero for both models.

### 4. SUMMARY AND LIMITATION

This study examined fundamental experimental data obtained from field measurements. It appears that the temperature in cavity was significantly influenced by direct and diffused solar radiation. The cavity temperature caused by double skin envelope could influence heating and cooling loads in building. Multiple regression models showed that solar radiation and outdoor air temperature were strongly related to the cavity temperature.

The air velocity through the cavity showed variation so that natural ventilation may occur. The air circulation is expected to contribute to reducing the loads. Further study is being studied under the authors’ institution.
5. ACKNOWLEDGEMENT

This study was supported by the Sustainable Building Research Center of Hanyang University supported by the SRC/ERC program of MOST (grant # R11-2005-056-01003-0)

6. REFERENCES


A STUDY ON THE INFLUENCE OF THE SEMI-PUBLIC SPACE ON RESIDENTS’ WELL BEING IN THE HIGH-RISE MIXED-USE HOUSING IN KOREA

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ABSTRACT: The super high-rise mixed-use housing is different from the traditional apartment in amenities and in architectural design. An example of variance is the larger semi-public space located in the lower floors. This study aimed: to find a correlation between physical characteristics of the semi-public space and residential individual well-being and to verify the correlation between the semi-public space and the individual well-being when comparing well-being of the super high-rise mixed-use housing with that of traditional apartment housing. The procedures used in the research consisted of four phases. First, a survey is performed on four super high-rise mixed-use housing and four traditional apartment housing to research the resident’s individual well-being. And second phase is to build and evaluate the well-being performance model for the super high-rise mixed-use housing. Results of research are as follows: 1) The comfortable environment influences the psychological stability and health felt by the residents more than to just perform physical exercise in the semi-public space. 2) The residents in the super high-rise mixed-use housing seek psychological safety and comfort in the semi-public space, and interact with the neighbors by participating in exercises and leisure activities. Exercising is the main activity of leisure. 3) When comparing between the super high-rise mixed use housing and the traditional apartment housing, the residents of the super high-rise mixed-use housing are found to be generally more satisfied in health, leisure, and safety in the semi-public space, but the problem with the case sampling makes this finding unreliable. The result identifies the difference in residential value.

Keywords: Super high-rise mixed-use housing, Individual Well-Being, Semi public space

1. INTRODUCTION

Following Korea’s industrialization, multi-family housing, which was introduced with the aim of resolving housing shortages caused by urban population concentration, grew steadily after the 1970s; it reached 5.5 million households in 2001, representing 47.8% of the country’s total housing, and has established itself as a representative residence type of urban residents. As urban population concentration was intensified, multi-family housing developed into high-rise buildings beginning in the late 1970s, and in recent years, a considerable number of super high-rise apartments at over 30 stories have been built. 32 complexes involving super high-rise mixed-use housing at over 30 stories have already been
created in the Seoul metropolitan areas, and if including complexes involving over 25-storied apartments, the figure stands at 47[1]. This indicates that super high-rise housing types are the new mainstream in Korea’s housing market.

In recent years, super high-rise residences are increasingly rising in cities all over the world, becoming popular as a sustainable residence type, differently from the poor residential environment in the past. Binder(2001) insisted that super high-rise buildings represented economic dominance and power, and that super high-rise residences represented the social status of their dwellers, and that the quality of semi-public spaces represented the quality of the dwellers (Yuen, 2005)[2].

Domestic super high-rise mixed-use buildings provided high-revenue opportunities for builders in 1999 when limitations on the size of residential facilities within mixed-use complexes were completely lifted, and this development led diverse urban consumers to have their own residences. This trend, coupled with the demand, furthered the segmentation of demand for housing, facilitating the diversification of demand for housing. Super high-rise mixed-use buildings, which were constructed in the 1990s, provide a new residential space totally different from the previous apartments, thereby serving as a great advantage to high-income housing consumers. Provided within residential spaces are diverse facilities devoted to cultural, entertainment, leisure, convenience, and commercial purposes, making so-called one-stop living possible (Jeong Eun-jin, 2006)[3].

2. DEVELOPMENT OF MIXED-USE HOUSING
The concept of mixed-use development is defined to mean the execution of diverse functions with regard to particular time, and particular places, or a combination of different social and economic functions with regard to the identical land (Priemus, 2001).[4] Generally, the definition of mixed-use development is an inclusive language targeting cities, and the concept itself does not explain a new type of cities, but the mixed-use development has a distinctive concept from a historical
viewpoint, and is deemed important in the area of urban landscaping planning, thereby making it difficult to define it in terms of its universality (ULI, 1987)[5].

The concept of mixed-use development is very inclusive; it ranges from a combination of two social and economic functions in a narrow sense to a combination of over ten functions in a broad sense. Mixed-use development involves diverse sizes and functions ranging from small-scale construction to urban-scale construction; thus, instead of seeking its universal definition, it is important to conduct a thorough analysis of the given land in a project and define the characteristics of the land (Rodenburg, 2004:274-288)[6].

3. QUALITY OF LIFE

Proponents of high-density mixed-use development are conducting research on many relevant cases to verify the superiority of high-density urban residences. These researches postulate that such urban high concentration can remain competitive when it ensures a high quality urban life (Breheny, 1996) [7]. Architect Richard Rodgers supported compact cities with activated cultures in the streets in his 1995 lecture in Reith (Parkinson and Bianchini, 1993; Montgomery, 1995; Breheny, 1996). Compact cities, which are equipped with vitality and diversity, offer urban residents the short walking distances, a reduction in vehicle operation, and saving of energy, thereby providing sustainable urban transportation and diverse urban services, and thus enhance life quality for urban dwellers (Fulford, 1996)[8].

Haughton and Hunter researched into the strengths and weaknesses of high-concentration development in their paper titled Sustainable Cities; they reported that urban safety accidents and crimes are more related to residential vacancy ratios rather than to residential concentration (Coupland, 1997).[9] Masnavi (2000) researched into four factors relating to compact cities and the quality of life; accessibility to urban facilities, use of vehicles, health and social exchanges, on which basis he conducted a comparative analysis of complex urban development,
single urban development, complex suburban development and single suburban development. In conclusion, he reported that high-concentration urban development could reduce the use of vehicles, and make residents satisfied with their health and social exchanges (Masnavi, 2000).[10]

4. PURPOSE OF RESEARCH
First, the purpose of this study is to identify correlations between the physical quality of semi-public space (representative spaces of super high-rise mixed-use housing) and individual residents’ well-being. Second, the research aims to compare the well-being of residents in super high-rise mixed-use housing and ordinary multi-family housing with a view to verifying correlations between the physical differences in semi-public spaces and residents’ well-being. To verify the relation between semi-public spaces and individual residents’ well-being in super high-rise mixed-use housing, the research presents a comparative analysis of super high-rise mixed-use housing and ordinary multi-family housing with a view to verifying hypotheses, and to architectural status of semi-public spaces in modern urban residences, and environmental characteristics.

5. METHODOLOGIES
The research is divided into five steps as follows.

First, well-being indicators and physical quality indicators of residential environments are derived. Well-being indicators suitable to domestic residential environments are selected by analyzing diverse domestic and overseas references relating to well-being and quality of life: health, interaction with neighbors, leisure, safety/security and outdoor amenity. Appropriate physical quality indicators of semi-public spaces in super high-rise mixed-use housing complexes, drawn on a review of existing residential environmental indicators and super high-rise housing-related references: comfortability, size, accessibility and diversity.
Second, the correlation between semi-public spaces in super high-rise mixed-use housing and their individual residents’ satisfaction is analyze to study the effects of individual residents’ satisfaction with semi-public spaces on their well-being. Individual dwellers’ residential well-being is limited to within housing complexes, and its correlation with their satisfaction over semi-public spaces is analyzed on the basis of respondents’ replies with regard to the use of multi-family semi-public spaces.

Third, a comparative analysis is conducted between individual residents’ welling-being in super high-rise mixed-use housing and in ordinary multi-family housing. Urban societal approach is taken to determine what effects the difference in physical environments between super high-rise mixed-use housing and existing multi-family housing have on residents’ well-being, and accordingly the direction to be taken in the planning of semi-public spaces in super high-rise mixed-use housing is presented.

6. MEASUREMENT
In the course of verifying the well-being feature of semi-public spaces, this research sought to compare the well-being difference between the semi-public spaces of super high-rise mixed-use housing and ordinary multi-family housing by selecting housing complexes with similar location conditions so as to control exogenous variables if possible. Controlled variables were the locations of housing complexes and the number of households; however, since, in similar locations, there were not ordinary multi-family housing complexes with dwellers’ occupancy time and the distribution of floor area similar to those of super high-rise mixed-use housing complexes, it was impossible to control the distribution of floor area. However, since the size of semi-public spaces is legally calculated on the basis of the number of households, the most exogenous variable was deemed to be the number of households.
6.1 Selection of Sites

In order to select super high-rise mixed-use housing complexes and their counterparts, ordinary multi-family housing complexes, complexes of similar households in similar locations were in principle selected. Since, the size of semi-public space is generally calculated on the basis of the number of households in relevant complexes, the physical quality of semi-public spaces is determined by the number of households as the most important indicator.

By searching ‘Realty 114’, selected as ordinary multi-family housing area were those complexes with similar numbers of households that were closest to the super high-rise mixed-use housing complexes.

Super high-rise mixed-use housing and ordinary multi-family housing groups are compared as follows.

Comparable housing complex groups were formed; there was a big difference in dwellers’ occupancy time between Gangnam in Seoul and new towns in Seoul metropolitan areas, indicating a difficulty in controlling exogenous variables according to residential time. This is because super high-rise mixed-use housing complexes were intensively built after 2000, and were developed after commercial areas in the cities considerably matured, making it difficult to find ordinary multi-family housing with similar occupancy time in the cities.
Table 1. Super high-rise mixed-use housing and ordinary multi-family housing complexes

<table>
<thead>
<tr>
<th>Complex name</th>
<th>Gangnam, Seoul</th>
<th>Gangbuk, Seoul</th>
<th>Seoul-centered work</th>
<th>New towns in the Seoul metropolitan areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super high-rise mixed-use</td>
<td>Ordinary multi-family</td>
<td>Super high-rise mixed-use</td>
<td>Ordinary multi-family</td>
<td>Super high-rise mixed-use</td>
</tr>
<tr>
<td>Galleria Palace</td>
<td>Pungnap Hyundai</td>
<td>Hanwha Obelisk</td>
<td>Raemian Gongdeok No. 3</td>
<td>Daewoo Trump World 1</td>
</tr>
<tr>
<td>No. of house holds</td>
<td>741</td>
<td>708</td>
<td>662</td>
<td>616</td>
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<td>No. of buildings</td>
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<td>No. of floors</td>
<td>46</td>
<td>15~21</td>
<td>36~37</td>
<td>13~20</td>
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</tbody>
</table>

7. RESULTS

7.1 Correlation between semi-public spaces of super high-rise mixed-use housing and residents’ well-being

*Health*

The correlation between physical characteristics of semi-public spaces in super high-rise mixed-use housing complexes, and residents’ well-being was analyzed, indicating that the comfortability in semi-public spaces had a direct correlation with residents’ health (Table 2). The comfortability has a combined correlation with indicators of physical characteristics such as the size of, accessibility to, and diversity of, facilities, thereby indicating inclusive space quality. This suggests that, to improve residents’ health, it is important to enhance the comfort of complex spaces rather than considering particular facilities and their sizes in semi-public spaces.
Interaction with neighbours

A correlation between the physical characteristics of common spaces in super high-rise mixed-use housing, and residents’ interaction with their neighbours was analyzed, indicating that there was no direct correlation.

Leisure

A correlation between the physical characteristics of super high-rise mixed-use housing and residents’ well-being was analyzed, indicating that accessibility to semi-public spaces had a direct correlation with residents’ use of leisure (Table 5). The fact that there is a correlation between accessibility to semi-public spaces and residents’ use of leisure proves that people today are changing their leisure into home-oriented one (Shin Yeong-suk, 1996). Thus, the location of semi-public spaces in the complexes and accessibility to them are an important element in connection with residents’ use of leisure.

Safety/Security

A correlation between the physical characteristics of semi-public spaces in super high-rise mixed-use housing and residents’ well-being was analyzed, indicating that the comfortability in semi-public spaces had a direct correlation with residents’ safety and security (Table 7). This analysis is consistent with the theories postulated by Newman, Holahan, and Wood, suggesting that semi-public spaces in super high-rise mixed-use housing involve a defense function of semi-public space.

Outdoor Amenity

A correlation between the physical characteristics of semi-public spaces of super high-rise mixed-use housing and residents’ well-being was analyzed, indicating that the diversity and comfortability in semi-public spaces had a direct correlation with outdoor amenity (Table 9). There is a high possibility that external spaces in
case of super high-rise mixed-use housing may be narrow, relaxation spaces may be limited, and comfort may be lowered. This suggests that, with these physical conditions, it is important to diversify facilities in external spaces and create comfortable spaces.

Table 2. Partial correlation between physical quality of common spaces in super high-rise mixed-use housing, and residents’ well-being

<table>
<thead>
<tr>
<th></th>
<th>Health</th>
<th>Interaction</th>
<th>Leisure</th>
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<th>Outdoor</th>
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<td>Comfortability</td>
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<tr>
<td></td>
<td>0.352</td>
<td>0.111</td>
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<td>0.323</td>
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</tr>
<tr>
<td></td>
<td>Sig.</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>0.00</td>
<td>0.253</td>
<td>0.133</td>
<td><strong>0.001</strong></td>
<td><strong>0.001</strong></td>
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<tr>
<td>Diversity</td>
<td>r</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>0.027</td>
<td>-0.011</td>
<td>0.015</td>
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<tr>
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</table>

7.3 Comparative analysis of residents’ satisfaction

7.3.1 Overall Satisfaction

The biggest difference in physical characteristics of semi-public spaces between super high-rise mixed-use and ordinary multi-family housing is that, in the categories of semi-public spaces’ diversity, comfort, scale and accessibility, residents in super high-rise mixed-use housing evaluated the physical quality of their semi-public spaces as superior than those in ordinary multi-family housing did. Semi-public spaces in super high-rise mixed-use housing earned over 3.5 points in all categories, while those in ordinary multi-family housing earned below 3.0 points, an average, indicating a distinctive difference in the physical quality of semi-public spaces.
Figure 1. Residents’ satisfaction with the physical characteristics of semi-public spaces

To determine whether the effect of physical quality of semi-public spaces on residents’ satisfaction with well-being was significant, a multiple generalized linear model analysis was conducted. The analysis results found that a generalized linear model is established as a significant correlation model between residents’ well-being and the physical characteristics of semi-public spaces. It was found that the comfortability of semi-public spaces influences residents’ satisfaction with health, and that the diversity of semi-public spaces influences residents’ satisfaction with their interaction with neighbors. It was also found that there is a correlation between semi-public spaces’ scale and accessibility and residents’ satisfaction with the use of leisure, and that all characteristics of semi-public spaces influence residents’ satisfaction with safety/security.
Table 3. Generalized linear model analysis of residents’ well-being and the physical characteristics of semi-public spaces

<table>
<thead>
<tr>
<th>Residents’ satisfaction with well-being</th>
<th>Physical quality of semi-public spaces</th>
<th>F value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>health</td>
<td>Comfortability</td>
<td>2.443</td>
<td>*0.050</td>
</tr>
<tr>
<td>interaction</td>
<td>Diversity</td>
<td>3.388</td>
<td>*0.011</td>
</tr>
<tr>
<td>leisure</td>
<td>Scale</td>
<td>2.993</td>
<td>*0.021</td>
</tr>
<tr>
<td></td>
<td>Accessibility</td>
<td>3.504</td>
<td>**0.010</td>
</tr>
<tr>
<td>safety/security</td>
<td>Diversity</td>
<td>3.879</td>
<td>**0.005</td>
</tr>
<tr>
<td></td>
<td>Comfortability</td>
<td>4.042</td>
<td>**0.004</td>
</tr>
<tr>
<td></td>
<td>Scale</td>
<td>6.499</td>
<td>**0.000</td>
</tr>
<tr>
<td></td>
<td>Accessibility</td>
<td>7.497</td>
<td>**0.000</td>
</tr>
</tbody>
</table>

7.3.2 Satisfaction with Semi-public Space

*Health*

With regard to residents’ satisfaction with semi-public spaces, the survey asked residents in super high-rise mixed-use housing complexes about their satisfaction with semi-public space within the complexes. Also, the survey asked residents in ordinary multi-family housing about their satisfaction with the ordinary facilities within the complexes since there are a drastically small number of common facilities compared with in case of super high-rise mixed-use housing complexes.

Residents’ satisfaction with health in connection with semi-public spaces was analyzed, indicating that the satisfaction levels of residents in super high-rise mixed-use housing were higher in all categories. Residents in super high-rise mixed-use housing showed higher levels of satisfaction than an average in the categories of physical activity, releasing stress and psychological stability, while residents in ordinary multi-family housing showed lower levels of satisfaction than an average in all categories. This suggests that health-related facilities in ordinary multi-family housing complexes are very lacking or poor. Notably, although, in
case of ordinary multi-family housing, the survey expanded the scope of the facilities to those within the complexes, these results were produced, drawing our keen attention to the issue.

Table 4. T-test of residents’ satisfaction with health in connection with semi public spaces

<table>
<thead>
<tr>
<th>Item</th>
<th>Building type</th>
<th>N</th>
<th>Mean</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>Physical activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Super high-rise mixed-use housing</td>
<td>120</td>
<td>3.875</td>
<td>**0.000</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>119</td>
<td>2.268</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Releasing stress</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Super high-rise mixed-use housing</td>
<td>120</td>
<td>3.341</td>
<td>**0.000</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>119</td>
<td>2.184</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Psychological stability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Super high-rise mixed-use housing</td>
<td>120</td>
<td>3.275</td>
<td>**0.000</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>118</td>
<td>2.245</td>
<td></td>
</tr>
<tr>
<td>Dweller’s occupancy time and the control of floor area (after 2002/20-40 pyeong in floor area)</td>
<td>Physical activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Super high-rise mixed-use housing</td>
<td>44</td>
<td>3.614</td>
<td>**0.000</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>2.500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Releasing stress</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Super high-rise mixed-use housing</td>
<td>44</td>
<td>3.023</td>
<td>**0.001</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>2.300</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Psychological stability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Super high-rise mixed-use housing</td>
<td>44</td>
<td>2.886</td>
<td>*0.011</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>2.400</td>
<td></td>
</tr>
</tbody>
</table>

Interaction

The survey conducted a comparative analysis of residents’ satisfaction with their interaction with neighbors in super high-rise mixed-use housing and ordinary multi-family housing, indicating that residents in ordinary multi-family housing knew names of more of their neighbors. There was a minimal difference in levels – thus no significance - of residents’ satisfaction with their participation in events, and their satisfaction with their friendly interaction with neighbors between in super high-rise mixed-use housing and ordinary multi-family housing, indicating that there is little difference in residents’ interaction with their neighbors through
the use of semi-public spaces between in super high-rise mixed-use housing and ordinary multi-family housing.

The fact that residents in ordinary multi-family housing knew names of more of their neighbors is that it is deemed to be attributable to the fact that, in the sampling, residents in ordinary multi-family housing, lived longer in their residences than those in super high-rise mixed-use housing did in their residences; thus the mere fact of residents knowing names of more of their neighbors could not be interpreted to mean that their community activities were more vital.

<table>
<thead>
<tr>
<th>Item</th>
<th>Building type</th>
<th>N</th>
<th>Mean</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>Knowing neighbors' names</td>
<td>Super high-rise mixed-use housing</td>
<td>120</td>
<td>2.091</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ordinary multi-family housing</td>
<td>120</td>
<td>2.558</td>
</tr>
<tr>
<td></td>
<td>Residents' participation in events</td>
<td>Super high-rise mixed-use housing</td>
<td>120</td>
<td>2.541</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ordinary multi-family housing</td>
<td>120</td>
<td>2.566</td>
</tr>
<tr>
<td></td>
<td>Friendly interaction with neighbors</td>
<td>Super high-rise mixed-use housing</td>
<td>120</td>
<td>2.541</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ordinary multi-family housing</td>
<td>119</td>
<td>2.537</td>
</tr>
<tr>
<td>Dwellers' occupancy time and the control of floor area (after 2002/20-40 pyeong in floor area)</td>
<td>Knowing neighbors' names</td>
<td>Super high-rise mixed-use housing</td>
<td>44</td>
<td>1.864</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>2.767</td>
</tr>
<tr>
<td></td>
<td>Residents' participation in events</td>
<td>Super high-rise mixed-use housing</td>
<td>44</td>
<td>2.523</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>2.733</td>
</tr>
<tr>
<td></td>
<td>Friendly interaction with neighbors</td>
<td>Super high-rise mixed-use housing</td>
<td>44</td>
<td>2.227</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>2.700</td>
</tr>
</tbody>
</table>

Table 5. T-test of residents’ satisfaction with their interaction with neighbors in connection with semi public spaces
Leisure

The survey found that, with regard to their satisfaction with the use of leisure in semi-public spaces and complexes, residents in super high-rise mixed-use housing showed higher levels than those in ordinary multi-family housing, and T-test indicated a significance in all categories. It was also found that residents in super high-rise mixed-use housing used their leisure through semi-public spaces, and enjoyed shopping and cultures. They showed the lowest level with regard to their satisfaction with self development, but the figure was higher than an average, suggesting that semi-public spaces in super high-rise mixed-use housing are effective in residents using their leisure.

Meanwhile, residents in ordinary multi-family housing had far less levels of using their leisure, having opportunities for self-development, and enjoying shopping and cultural life in the complexes, compared with those in super high-rise mixed-use housing, and showed lower levels of satisfaction an average, suggesting that facilities in ordinary multi-family housing complexes very much need to be expanded.

An analysis, which was conducted with residents’ occupancy time and floor area controlled, found that its results were similar to those of the analysis of all cases, proving that, with regard to residents’ use of leisure, the function of semi-public spaces in super high-rise multi-housing complexes is superior.
Table 6. T-test of residents’ satisfaction with the use of their leisure in connection with common spaces

<table>
<thead>
<tr>
<th>Item</th>
<th>Building type</th>
<th>N</th>
<th>Mean</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leisure</td>
<td>Super high-rise mixed-use housing</td>
<td>120</td>
<td>3.583</td>
<td>**0.000</td>
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<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>118</td>
<td>2.381</td>
<td></td>
</tr>
<tr>
<td>Self-development</td>
<td>Super high-rise mixed-use housing</td>
<td>120</td>
<td>3.075</td>
<td>**0.000</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>117</td>
<td>2.102</td>
<td></td>
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<tr>
<td>Shopping and culture</td>
<td>Super high-rise mixed-use housing</td>
<td>119</td>
<td>3.495</td>
<td>**0.000</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>117</td>
<td>2.333</td>
<td></td>
</tr>
<tr>
<td>Dwellers’ occupancy time and the control of floor area (after 2002/20-40 pyeong in floor area)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leisure</td>
<td>Super high-rise mixed-use housing</td>
<td>44</td>
<td>3.227</td>
<td>**0.000</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>2.483</td>
<td></td>
</tr>
<tr>
<td>Self-development</td>
<td>Super high-rise mixed-use housing</td>
<td>44</td>
<td>2.886</td>
<td>**0.001</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>2.233</td>
<td></td>
</tr>
<tr>
<td>Shopping and culture</td>
<td>Super high-rise mixed-use housing</td>
<td>43</td>
<td>3.651</td>
<td>**0.000</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>2.367</td>
<td></td>
</tr>
</tbody>
</table>

Safety/Security

With regard to their satisfaction with safety and security in semi-public spaces, residents in super high-rise mixed-use housing showed higher levels than those in ordinary multi-family housing did. The survey question of “Do you think that semi-public spaces are helpful to safety” showed the biggest difference between the two groups, indicating that semi-public spaces of substructures in super high-rise mixed-use housing complexes sufficiently play a role of defensible spaces and buffer zones against external spaces. With regard to their satisfaction with their children’s safety and security against crimes, residents both in super high-rise mixed-use housing and ordinary multi-family housing showed higher levels than an average, but the finding indicates that the security of ordinary multi-family housing are inferior to that of super high-rise mixed-use housing.
An analysis, which was conducted with residents’ occupancy time and floor area controlled, found that, in the category of children’s safety, there was no significant difference between super high-rise mixed-use housing and ordinary multi-family housing. This suggests that residents’ satisfaction with children’s safety is influenced by the floor area of their residences, and this issue is related to children’s age in households with smaller floor area. However, these results are significant in that, with regard to their satisfaction with their children’s safety, residents in super high-rise mixed-use housing, which are exposed to relatively poor external environments and are located in commercial areas, showed little difference with those in ordinary multi-family housing.

Table 7. T-test of residents’ satisfaction with safety/security in connection with common spaces

<table>
<thead>
<tr>
<th>Item</th>
<th>Building type</th>
<th>N</th>
<th>Mean</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>Safety of semi-public spaces</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Super high-rise mixed-use housing</td>
<td>120</td>
<td>3.758</td>
<td>**0.000</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>116</td>
<td>2.793</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Safety of children</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Super high-rise mixed-use housing</td>
<td>118</td>
<td>3.796</td>
<td>**0.003</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
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<td>3.491</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Security against crimes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Super high-rise mixed-use housing</td>
<td>120</td>
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<td>**0.000</td>
</tr>
<tr>
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<td>Ordinary multi-family housing</td>
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<td>3.470</td>
<td></td>
</tr>
<tr>
<td>Dwellers’ occupancy time and the control of floor area (after 2002/20-40 pyeong in floor area))</td>
<td>Safety of semi-public spaces</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Super high-rise mixed-use housing</td>
<td>44</td>
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</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>59</td>
<td>2.881</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Safety of children</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Super high-rise mixed-use housing</td>
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<td>3.614</td>
<td>0.597</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>3.533</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Security against crimes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Super high-rise mixed-use housing</td>
<td>44</td>
<td>3.955</td>
<td>*0.012</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>3.467</td>
<td></td>
</tr>
</tbody>
</table>
Outdoor Amenity

A comparative analysis of the function of environmental friendship of external spaces found that there was no difference in residents’ satisfaction between super high-rise mixed-use housing and ordinary multi-family housing. With regard to residents’ satisfaction in the categories of landscaping and green areas, relaxation in external spaces, and the comfort of external spaces, ordinary multi-family housing showed higher levels than an average, but the difference in the average is minimal, and T-test found that the difference in the average was insignificant.

Table 8. T-test of residents’ satisfaction with environmental friendship of external spaces

<table>
<thead>
<tr>
<th>Item</th>
<th>Building type</th>
<th>N</th>
<th>Mean</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Super high-rise mixed-use housing</td>
<td>120</td>
<td>3.216</td>
<td>0.214</td>
</tr>
<tr>
<td>Overall</td>
<td>Ordinary multi-family housing</td>
<td>119</td>
<td>3.378</td>
<td></td>
</tr>
<tr>
<td>Landscaping and green areas</td>
<td>Super high-rise mixed-use housing</td>
<td>120</td>
<td>2.950</td>
<td>0.414</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>119</td>
<td>3.067</td>
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<tr>
<td>External relaxation spaces</td>
<td>Super high-rise mixed-use housing</td>
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<td>3.225</td>
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<td></td>
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<td>119</td>
<td>3.411</td>
<td></td>
</tr>
<tr>
<td>Comfort</td>
<td>Super high-rise mixed-use housing</td>
<td>44</td>
<td>3.000</td>
<td>*0.028</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>3.483</td>
<td></td>
</tr>
<tr>
<td>Dwellers’ occupancy time and</td>
<td>Super high-rise mixed-use housing</td>
<td>44</td>
<td>2.682</td>
<td>**0.003</td>
</tr>
<tr>
<td>Control of floor area (after</td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>3.350</td>
<td></td>
</tr>
<tr>
<td>2002/20-40 pyeong in floor area)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landscaping and green areas</td>
<td>Super high-rise mixed-use housing</td>
<td>44</td>
<td>2.841</td>
<td>**0.002</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>3.483</td>
<td></td>
</tr>
<tr>
<td>Comfort</td>
<td>Super high-rise mixed-use housing</td>
<td>44</td>
<td>2.841</td>
<td>**0.002</td>
</tr>
<tr>
<td></td>
<td>Ordinary multi-family housing</td>
<td>60</td>
<td>3.483</td>
<td></td>
</tr>
</tbody>
</table>

However, in an analysis with residents’ occupancy time and floor area controlled, in all categories, residents in ordinary multi-family housing showed significant higher levels of satisfaction than those in super high-rise mixed-use housing. This suggests that the external spaces of super high-rise mixed-use housing complexes are developed through the application of diverse architectural technologies, decks,
penthouse gardens, and sunken gardens, accommodating resident needs considerably, but that they are still inferior to ordinary multi-family housing in terms of enjoying sunlight and scales. However, an analysis of all cases found that there was no significant difference, suggesting that, in response to needs of residents in ordinary multi-family housing, diverse facility plans and measures to activate the use of external spaces are necessary.

8. CONCLUSION
The finding indicates that there is a positive correlation model established between semi-public spaces of urban residential complexes and residents’ well-being, thereby proving Roos’ research results that urban residents highly evaluate convenience as residential value[11]. Notably, it was found that, in super high-rise mixed-use housing complexes equipped with diverse functions and facilities in massive comfortable semi-public spaces, there is a distinctive correlation between residents’ well-being and such semi-public spaces, and that, in the comparative analysis of residents’ well-being in super high-rise mixed-use housing and ordinary multi-family housing, residents in super high-rise mixed-use housing showed high levels of their satisfaction with semi-public spaces, thereby supporting Roos’ research. However, in the comparative analysis of residents’ well-being, there are distinctive differences by each indicator, making it inappropriate to determine the superiority of residents’ satisfaction with particular residential types.

Therefore, the following conclusion is derived.

First, it was found that the physical characteristics of semi-public spaces have a direct correlation with residents’ well-being. Second, the well-being performance of semi-public spaces was verified through the comparative analysis of super high-rise mixed-use housing and ordinary multi-family housing, suggesting that super high-rise mixed-use housing were superior in terms of health and the use of leisure with regard to residents’ satisfaction with semi-public spaces, and in terms of
residents’ satisfaction with safety/security, while there was no significant difference in the comparative analysis of residents’ well-being.

9. ACKNOWLEDGEMENT

“This work was supported by Sustainable Building Research Center of Hanyang University which was supported the SRC/ERC program of MOST(grant R11-2005-056-04001-0)”

10. REFERENCES


ABSTRACT: Residential buildings traditionally are designed to provide environmental controls with static features which do not change their positions throughout the year. For example good solar static shading devices do good to shade the unwanted summer hot sun, but often block daylight in cloudy winter days. Also some dynamic features such as windows, or awnings do not respond in optimal ways to climate changes for optimal use of renewable energies and sources, and air quality which surround the buildings.

Traditional residential buildings are commonly not well integrated and thought of on the use of renewable energies and sources surrounding buildings which are solar energy, wind energy, rain and snow energy.

This paper reports on a new approach for sustainable building design, which is called The SUSTAINABLE RESIDENTIAL BUILDING DESIGN - THE S3P2E2R4 SUSTAINABLE BIREATH APPROACH: Building Integrated Renewable Energies and resources, and optimal AIR quality Total Harvest APPROACH. That is, in addition to fulfilling its normal functions, the building is designed in an integrated manner and used as a harvester to harvest as much as practicable Renewable Energies and sources, and optimal AIR quality which surround the residential unit, for the best benefits of the users of the unit, and for maximized sustainable contribution to the immediate vicinity and worldwide at large. Also the well recognized environmental protection practices of S3P2E2R4 are adopted.

Keywords: Sustainable building design, renewable energy, green building design

1. INTRODUCTION – THE PRESENT ENVIRONMENTAL BUILDING DESIGN STRATEGY

High quality environmentally responsive residential buildings traditionally are designed to provide good insulation in winter and solar shading in summer. Most commonly these features are static features which do not change their positions throughout the year. Therefore good solar static shading devices often block daylight in cloudy winter days.
The most common dynamic micro-climate modulation features for buildings are the windows. We open or close them and fix them for certain percentage of openness as we want them. Also there are some retractable awnings and adjustable solar shading devices in use. Such dynamic features however do not respond in optimal ways to climate changes for the best use of green energies surrounding the buildings.

Common green energies surrounding buildings include solar energy, wind energy, rain and snow energy. Their design and use in residential buildings are commonly not well integrated. For example, windows with clear glass, double or triple glazed, allow good penetration of sunlight during day time in winter, but are not further dynamically insulated, with rock wool for example, for most part of it when the sun goes down to avoid heat loss from the building. Viewing ports with insulated hinged covers should be fitted for minimizing heat loss.

The above example shows the lack of an integrated approach to gain the best of available green energies and minimizes expenditure of energy in residential buildings.

2. THE PROPOSED S3P2E2R4 SUSTAINABLE BIREATH APPROACH: BUILDING INTEGRATED RENEWABLE ENERGIES AND RESOURCES, AND OPTIMAL AIR QUALITY TOTAL HARVEST APPROACH

The United Nations Environment Programme [1] says that major threats to the planet such as climate change, the rate of extinction of species, and the challenge of feeding a growing population are among the many that remain unresolved, and all of them put humanity at risk.

Responding to this report, substantial incorporation of sustainability into building design has to be conducted, leading to priority shifted as: Safety, Health, Sustainability, Comfort.
In addition to providing functional requirements of buildings, the Sustainable S3P2E2R4 BIREATH approach [i.e. BUILDING Integrated Renewable Energies and resources, optimized Air quality, Total Harvest Approach] has also to be used.

**S3** stands for Environmental and ecological, Economical, cultural sustainability, which are elements of sustainability [2]

**P2** stands for Pollution Prevention, preventing generation of pollutants such as carbon dioxide, moisture, and heat from burning gas at home which causes serious local pollution.

**E2** stand for Energy Efficiency. This includes the use of electrical induction cooking facilities which are more energy efficient than electrical hot plates and gas cooking. In the broader sense applied to renewable energies, **E2** includes harvesting renewable energies by building design and operation [i.e. BIREATH approach], and urban design and operation [i.e. CIREATH approach]

**R4** stands for Reduce, Reuse, Recycle, Recover or Regenerate. We can reduce energy use by not using air conditioning because good outside air quality and electrical fans are good enough for thermal comfort which relates to relative building up of habits rather than an absolute yardstick. In fact, when windows are closed carbon dioxide level easily gets to 600 ppm and even above 800 ppm, as indicated by government scales [3]. In fact the 4 “R” are well known environmental protection practices promoted for long time.

BIREATH means harvesting renewable energies which are commonly solar energy, wind energy, by proper operation of the various components of the building. The largest possible surface of the building envelope will be used for harvesting the maximum benefits of direct sunlight, indirect sunlight, daylight and wind, at the same time achieving optimized air quality. The later will help people to live long life, and to strongly induce people open the windows for enjoying the optimized air quality, and not to operate air conditioners. Harvest solar energy can be performed through clothes drying, growing green plants, solar hot water systems, solar

Plants absorbing solar energy can change carbon dioxide to give out oxygen and smells that will contribute to human health, if suitable plants are grown. This, together with moisture given out by green leaves, will contribute to provide optimized air quality. Also some green food plants can be grown using organic means, aiming at providing some food, helping to relieve the demand of farmland. Energy for transportation of food is reduced.

3. APPLICATION OF THE SUSTAINABLE S3P2E2R4 BIREATH APPROACH IN ENHANCING AN EXISTING SMALL HIGH-RISE RESIDENTIAL UNIT IN HK

A small flat having about 11 square meters usable floor area directly connected to about 4 square meters balcony, generally facing north is being designed using the Sustainable S3P2E2R4 BIREATH Approach. This flat also has a flat roof of about 9 square meters directly above it. This flat is located in Sai Ying Pun, at the western part of Hong Kong Island. [Fig. 1, 2, 3] The flat is located at 20th floor, in general above other surrounding building at the front.

Fig. 1 - Location of residential unit
It is intended to convert the unit into a studio flat, [Fig. 4, 5] and to use it as an experimental and demonstration flat for investigating the principles and application of the Sustainable S3P2E2R4 BIREATH Approach.
Fig. 5 - Proposed layout of roof

The design aims at significantly **reducing consumption** of operating energy and water, and harvesting as much **solar energy** [Fig. 6] and **wind energy** as possible, and for providing **food, hot water & optimized air quality** for the residents.

**Fig. 6 – Harvesting solar energy by:**

a. solar hot water panel / solar PV panel, small wind turbine, big Fresnel lens of 1.2m diameter for solar oven

b. 2 layers of green plants at flat roof / balcony:
   i. top layer - fast organic growing of food plants e.g. melons and fast growing vegetables in hot summer for food, which will reduce transportation of food and farmland demand
   ii. lower layer of grass - grows well inless sunshine, to harvest residual sunshine and daylight

c. growing of plants of herbal & h

d. health value for improving AIR quality, so that closing up the façade and operating the air conditioners, rejecting the optimized AIR quality, will surely be a regretful loss.

d. performing TOTAL HARVEST of solar energy by maximizing the surface areas of the façade for growing plants, and intake of daylight by increasing glazed surface and skylight, yet without overheating the interior.

e. solar air chimney

4. sunlight reflecting system by ventilation tube
[Note : Positive contribution to climate change : Converting CO₂ into solid C stored inside food ]

Fig. 7 - Harvesting Wind energy

It is intended to harvest wind energy by [ Fig. 7] by:

a. enlarging the openable areas of the façade, and adding a skylight, which will allow a staircase to connect the studio flat and the roof above.

b. providing “true cross ventilation” i.e. each room will have 2 air passages independently connected to outside surface of the flat

c. wind turbine

[ Note : No air conditioning will be required. Natural ventilation, to be assisted by electrical fans occasionally will provide thermal comfort ]

P2 Pollution Prevention: Gas supply is terminated – no local emission of pollution of combustion gases
E2 Energy Efficiency – and to REDUCE energy use by:

a. No air-conditioning will be required – electrical fans will be provided
b. Heat pump is used for hot water generation if solar hot water is not sufficient, especially in winter days when the roof cannot receive sunshine.
c. Light emitting diodes will be used for illumination as far as practicable
d. Use of energy efficient electrical appliances such as electrical induction cookers

RECOVER of space in the flat is achieved by installing a raised floor with the floor void for storage and for ventilation via the void of the raised floor, which is also used for installation of building services.

Other features include:

a. Harvesting rain by collecting rain for growing plants
b. Flexible interior spatial organization, allowing good day light transmission as desirable and true cross ventilation
c. RECYCLE - collection of grey water for growing plants (subject to filtering) and flushing toilet

It is expected that the initial cost and the running cost will be reasonable. The enhanced flat will certainly be good for living to long life with environmental contribution, hence achieving S3 - Environmental & ecological, Economical, Cultural Sustainability.

5. CONCLUSION

The SUSTAINABLE RESIDENTIAL BUILDING DESIGN - THE S3P2E2R4 SUSTAINABLE BIREATH APPROACH: Building Integrated Renewable Energies and sources, and optimal AIR quality Total Harvest APPROACH, certainly will equip building with good conditions for people to live long life. The building will also contribute positively to mitigate the effect of climate change.
Depending on the envelope area given to it, a building design with THE S3P2E2R4 SUSTAINABLE BIREATH APPROACH can work as a zero energy home. [13]

The same approach in fact can be extended to broader scopes to include the urban scale, cities, villages, etc, thus The Sustainable S3P2E2R4 UIREATH approach – URBAN Integrated Renewable resources and Energy, optimized Air quality, Total Harvest Approach ; The Sustainable S3P2E2R4 CIREATH approach, The Sustainable S3P2E2R4 VIREATH approach. For these extended scopes, the mode of transportation will be renovated, and the land, roads, buildings concerned will all be used to harvest as much renewable energies as possible, for the attainment of optimized Air quality, everywhere, exercising the good practice of S3P2E2R4.

6. REFERENCES


http://www.arch.hku.hk/research/BEER/sustain.htm

3. EPD, HKSAR. Table 1: IAQ objectives for offices & public places.  
http://www.iaq.gov.hk/tables.html#T1


7. Wind and chimney cowls http://www.stovesonline.co.uk/_wood_burning_stoves/Chimney-Cowls.html


10. Wind energy in urban areas http://www.windenergy.citg.tudelft.nl/content/_research/pdfs/ref2002-sm.pdf#search='wind%20velocity%20around%20buildings

11. Climate control system, Green Zone project, Netherlands http://www.greenzone.nu/eng_sidor/climate_control_system.shtml


SUSTAINING HERITAGE TOWNSHIPS IN CHINA: CASE STUDIES: SHAXI, SHAOXING AND CONGHUA

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1. INTRODUCTION:
China is entering a stage of stable development where the social / economic benefits of big cities as well as smaller townships / villages have to be balanced. The enhancement of living standards and economic opportunities of traditional townships / villages have to be carried out within the context of respecting the built heritage and cultural characters.

This essay looks into three case studies representing internationally recognized good practices: Xideng Square township in Shaxi, Yunnan Province, Shaoxing Watertown in Zhejiang, and Qiangang Village in Conghua, Guangzhou. By studying three cases that implement diligent conservations, one hopes to find a way for sustainable developments in traditional societies and built environments in China.

2. SUSTAINABILITY ISSUES OF HISTORIC TOWNSHIPS:
The threats to the traditional township and villages in China are two folds. On the one hand, the physical heritage environment is under growing economic pressures. Rising land prices drive out less financially capable traditional residents to make...
Tourism can be mixed blessings because the economic benefits are sometimes out-weighted by the often mis-guided practices such as over-gentrification, landmark creation, or turning traditional rituals into entertaining shows. Such careless destruction of the very heritage characteristics that originally will not only turn away visitors very soon, but will also tear apart the traditional social cohesion that sustain the practices and communities. Sustainable development for the heritage towns and villages in China should mean a well considered long term strategy to revive a practical mode of economic activities for the traditional community concerned, instead of merely competing with the cities for a fast dollar in sacrifice of the valuable traditions and built environment.

1.1 Xideng Square township in Shaxi, Yunnan Province 雲南沙溪寺登街

Ever since the late Tang Dynasty 唐 in 8th Century, travelers carrying tea from southern China bravely cross the rugged mountain trails in Yuanan into Tibet in
exchange for horses. In the heydays of this Tea and Horse Ancient Trail 茶馬古道, the market village of Shaxi 沙溪, flourished as a key midway stop, where the Horse Gangs rest, gather, and entertain. Elaborate guest houses, theatre towers, and mansions of local entrepreneurs co-existed surprisingly peacefully amongst the villages and fields originally inhabited by the minority tribes of Bai 白族.

The fall of tea and horse trade in the early Republican era allow modernization and industrialization to completely bypass the remote place for nearly a century, until re-discovered in 2000 and now recognized as the most intact ancient market village on the Ancient Trail. Conservation specialists from Switzerland co-operated with the Chinese government. They carry out the various extensive determined tasks, from overall environmental conservation (water / drainage improvement and greening initiatives), and encouraging social sustainable developments (road improvements, managed tourism, assistance to local schools), to meticulous restoration of significant buildings and revitalization of local business activities.

The key is to safeguard the long term intangible heritage of the locals by improving the conditions where they can continue and develop the traditional activities without the need or incentive to sacrifice the valuable and irreplaceable heritage. For example, the ancient theatre in front of the square was well restored with improved facilities and a museum inside, so that it can better serve the traditional function of ritual performance as well as drawing in tourists. The comprehensive conservation approach adopted combines careful historical research, systematic methodology, technical advisory and local craftsmanship.
Another example is that the market streets, now serving electrical appliances alongside traditional medicines are preserved and business further encouraged by better roads and better supporting facilities like restaurants and toilets nearby.

This is the first step in a longer-term multidisciplinary programme in revitalizing remote historical townships, and the model of planning and development framework behind as well the collaboration methodologies can be an excellent example where sustainable tourism was introduced as a means of long-term development for many other similar cases in China. This project won Award of Distinction in 2005 UNESCO Asia Pacific Cultural Heritage Award.

1.2 Shaoxing Water Town in Zhejiang 浙江水鄉紹興

The Yangtze River Watertowns are well known heritage sites of stunning beauty admired internationally since the days of Marco Polo. Shaoxing City in northeastern Zhejiang Province is famous for its meandering waterways, cris-crossing stone bridges, black top boats, rows of houses along the canals, and the significant footsteps of many famous figures in Chinese cultural and political history from the 3rd century to modern era.

Due to its easy reach with the metropolis of Shanghai, pressure to develop into modern city with high density commercial activities is now the biggest threat.

The World Bank collaborated with the local government in an ambitious environmental improvement scheme. The necessary water quality improvement is the key to returning the waterways to be both enjoyable transportational means for tourists and hygienic streetscape relief for residence. The government carries out
extensive re-laying of all gas / power supply and water / drainage services underground, while sensitively re-paving all streets and tidying up all streetscapes with traditional materials.

However the most critical factor is to devise a way to allow residence to carry out their own improvement or development works without diminishing the heritage environment. The Hong Kong University assisted in producing comprehensive guidelines for residents, ranging from how to add air-conditioners on the traditional façade in least obtrusive manner facing the canal and how to build a modern kitchen within a traditional timber framed courtyard house without destroying the historic fabric, to how to open up a new restaurant on the market street with designs compatible with the historic street-scene. This approach is proved to be effective, comprehensive and innovative.

This project successfully demonstrates the viability of the historic town as a living and vibrant showcase of heritage in China. It proves that this model of combination of government infrastructural improvement and well-guided private individual collaborations is the way forward for a sustainable heritage-rich environment China. This project won the Awards of Distinction in 2003 UNESCO Asia Pacific Cultural Heritage Award.

1.3 Qiangang Village in Conghua, Guangzhou and Guangyu Ancestral Hall, Conghua, Guangdong

A seemingly ordinary farming village in the less prosperous far corner mountain areas of Guangzhou belies its honorable history. Chased by the overwhelming
Mongolian armies at the 11th century, the loyal prime-minister Lu Su-fu protected the young last emperor of the Song Dynasty both jumped to the roaring sea to save their dignities in a heroic battle on the Pearl River. The Lu families hided in Conghua and built up the Qiangang Village. They faithfully kept record of historical events and maintained their ancestral hall while waiting for the eventual revival of the dynasty, despite the near destruction of relics in the Cultural Revolution and the temptation of modernization.

With the help of the South China Technical University of Guangzhou, the Lu clan from overseas and the village cooperated to restore their ancestral hall in great pride. In particular, by consciously adhering to the principles of the Venice Charter and the Nara Document on Authenticity, all traces of significant stages in history, including carved dates on timber, half-weathered paintings on walls, half-corroded stone plinths, and Cultural Revolution slogans on wall, were faithfully retained as record of its impressive history. Seen in that context, the restoration of the ancestral hall as the first step in the ongoing reviving of the village can be understood as the continuation of a sustainable development effort. The determination of the decedents of the righteous historic minister, ensured this place as a rare humble example that captured the sweep of a thousand years of Chinese cultural history. This project won the Awards of Excellence in 2003 UNESCO Asia Pacific Cultural Heritage Award.
3. REFLECTION AND PROSPECT:

While the current newspapers are filled with reports of the fast growth of China with images of efficient factories and glittering high-rises, the vast majority of the population is residing and working in smaller townships and villages. The long term progress of China is dependent on the successful social cohesion of the rich mixture of social groups and the acknowledgement of the culture and self-confidence of the people. This is why the respect for traditional practices and heritage environment is an important component for a sustainable China.

The well managed improvement of the living environment and the suitable pace of economic development in the vast hinterland in the context of conserving the historical towns and villages is essential to ensure that such progress does not deprive future generations of its beneficial to present and future generations.
ENERGY EFFICIENCY OPPORTUNITIES IN EXISTING COMMERCIAL OFFICE BUILDINGS IN AUSTRALIA

CHRIS BLOOMFIELD, PAUL BANNISTER

ABSTRACT: Greenhouse gas savings worth approximately 32% of total greenhouse emissions have been identified within a portfolio of Australian office buildings by conducting detailed energy audits. Through this process, opportunities were identified to reduce electricity and natural gas consumption by between 20%-60% with a corresponding drop in greenhouse emissions, an average site payback period of 2.7 years and total cost savings of $550,000 per year.

The primary driver for the audit works was to reduce the greenhouse footprint of the buildings (as measured via the Australian Building Greenhouse Rating), which has become a primary requirement for securing large, A grade tenants in the Australian commercial office market.

The majority of savings identified in these buildings relate to modifications to existing controls algorithms, or rectification and repair of failed sensors. Simple, but highly cost effective opportunities included: the repair of an outside air RH sensor, implementation of an outside air temperature boiler lockout, removal of a malfunctioning ice storage system, and removal of a parasitic 24 hour load from a central building system.

If extrapolated across the Australian office sector could provide a self-funding reduction of 1.2% of national greenhouse emissions.

Keywords: Energy efficiency, commercial office building, retrofit, greenhouse reduction, building controls, Water consumption, benchmarking, office buildings

1. INTRODUCTION

The minimisation of greenhouse emissions has been recognised as a global issue for some time, as indicated by international treaties such as the Kyoto Protocol [1]. In recent years the Australian public has shown increasing greenhouse awareness, combined with a stronger focus on reducing greenhouse emissions. [2].

The commercial built environment is responsible for approximately 14% of Australia’s total greenhouse gas emissions [3]. Whilst this is a comparatively small component of Australia’s total greenhouse gas emissions, the sector has come under increasing pressure to reduce its total greenhouse emissions.
This pressure has resulted in more attention being paid to the greenhouse emissions of commercial buildings over recent years. This trend has been driven by both regulatory/compliance requirements at both the local [3] and national level, along with demand side drivers within the commercial office leasing sector [4].

Within Australia, the Australian Building Greenhouse Rating (ABGR) scheme has become the recognised standard for assessing the performance of office buildings with regards to greenhouse emissions. In general, the scheme has been driven by the demand side of the office sector, from the stakeholders (both tenants and building owners) who have the most interest in ongoing performance, rather than the design and construction community.

Much activity surrounding the reduction of commercial building greenhouse emissions within Australia has been focussed upon improvements of design, implemented largely in new building projects, rather than addressing the existing building stock. Australia has experienced a boom in office building construction rates over recent years. However, in general this has been adding capacity to the sector, rather than replacing the stock of existing office space. The end effect is a comparatively low capital stock turnover rate for office buildings within the Australian market.

The large stock of existing buildings with comparatively poor greenhouse performance provides a significant opportunity for the reduction of greenhouse emissions within the sector. This also results in significant improvements for the operating bottom line of the organisations owning the buildings through the implementation of energy efficiency retrofits.

This paper presents the opportunities identified through detailed energy efficiency audits of base building energy consumption within a portfolio of existing Australian commercial office buildings. All currency terms within this paper refer to Australian dollars.
2. CHARACTERISATION OF THE BUILDINGS AND DATA

2.1 Building Statistics

This study includes data from 9 existing office buildings located in Sydney and Canberra. The buildings ranged from approximately 6,000 to 25,000 square metres of net lettable area, with a mix of medium and high rise buildings. The building ages varied, with construction dates ranging from the 1970’s through to the early 2000’s.

Table 1: Distribution of sample buildings between states.

<table>
<thead>
<tr>
<th>State</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian Capital Territory</td>
<td>3</td>
</tr>
<tr>
<td>New South Wales</td>
<td>6</td>
</tr>
</tbody>
</table>

All buildings were observed in occupied and operating status. They included a range of original and refurbished plant at various stages of commercial life.

Pre-audit energy efficiency had been assessed via conducting base building Australian Building Greenhouse Ratings (ABGR). ABGR is an Australian greenhouse performance rating tool, which assesses greenhouse ratings based upon real building performance. As such, the inputs to an ABGR rating will include energy uses on the site and normalisation factors, such as climate data, hours of operation and floor area. The normalised emissions for the office are used to assign a rating on a 0-5 star scale.

ABGR ratings have been designed to assess three core types of rating, a whole building rating, which incorporates all energy consumption associated with the office building, a tenancy rating, which assesses all tenant light and power associated with the tenancies in the building, and base building ratings, which assess the emissions associated with the provision of base building services, such as HVAC, common area lighting, car parks and vertical transportation.
The ABGR for these buildings pre-audit had a mean value of 2.3 stars and a median value of 2.5 stars. Given that the ABGR scale is defined such that the building population median is set to a rating of 2.5 stars, this sample of buildings is representative of the market average for energy efficiency and greenhouse emissions.

It is the opinion of the authors that these buildings provide a good representation of the population of existing buildings within the Australian commercial office sector.

2.2 *The Data*

Data for this study was gathered through conducting energy audits for each building, compliant with the level 2 requirements of AS/NZS 3598:2000. ABGR ratings were conducted by ABGR accredited assessors. All site work was conducted between December 2006 and June 2007.

Energy and greenhouse data presented in this study relates to base building services only. Typically, this includes energy for heating, ventilation and air conditioning (HVAC), common area lighting, vertical transportation, supplementary condenser loop heat rejection and carpark lighting and ventilation. These studies specifically did not address tenant energy consumption, i.e. tenancy lighting, computer, general office equipment and supplementary air-conditioning loads.

2.3 *Types of building services*

The buildings within this study included a range of building services types. All buildings included central chiller plant with circulated chilled water, some including secondary chilled water loops. Heating methodologies varied through the buildings, including gas fired central boilers to provide primary heating, gas fired secondary heating hot water supplying hot water to terminal reheat coils, some buildings with gas primary and electric secondary heating, and some with all electric based heating systems. Air handling methodologies varied, including a mix of variable volume systems, constant volume systems and ceiling mounted fan
coils with central tempered fresh air only. The majority of buildings included some form of supplementary condenser water loop for tenant use. Some buildings incorporated existing energy efficiency initiatives, such as an ice storage system, or newly installed low load chillers.

2.4 Typical energy costs

Typical electricity tariffs for these buildings were based upon a time of use and peak demand tariff. Gas tariffs reflected either a flat charge per MJ consumed, or a stepped tariff, with consumption charges dropping on a cents per MJ basis as consumption increased. Typical energy costs for buildings in this portfolio were:

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Tariff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak electricity</td>
<td>$0.085/kWh</td>
</tr>
<tr>
<td>Off peak electricity</td>
<td>$0.035/kWh</td>
</tr>
<tr>
<td>Peak demand</td>
<td>$3/kVA per month</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>$0.015/MJ</td>
</tr>
</tbody>
</table>

3. EFFICIENCY DIAGNOSIS METHODOLOGIES

Prior to conducting a detailed audit, a number of techniques were utilised to identify the likely types of savings, and approximate order of magnitude of savings possible for each site. Two primary tools were used for this analysis.

3.1 ABGR

Existing ABGR ratings were available for each of the base buildings, conducted prior to the site inspection. The rating score for each building provided a quick index of the existing building efficiency.

Buildings with existing ratings of 4.0 stars (of the 0-5 star ABGR rating scale) are already at the efficient end of the building population. These buildings are likely to have limited measures available, with the obvious opportunities already
implemented. Whilst buildings of this nature still contain opportunity, diminishing marginal returns generally result in measures that are less financially attractive, or more difficult to detect or implement.

In contrast buildings scoring poorly on the ABGR rating scale, such as a rating of 1.0 stars, are likely to have glaring issues and easy opportunities available within the building.

### 3.2 TIME OF USE ELECTRICITY METERING

Most large electricity consumers within Australia are sold electricity on a time of use tariff, which encompasses different consumption charges for different periods of the day. The methodology used to calculate electricity tariffs using these meters results in the energy retailer recording data for the meter on a half-hourly basis. Access to half hourly electricity data provided a basis to examine the building’s usage profiles through the week, and through the year.

![Figure 1: Weekly electricity consumption profile](image)

*Figure 1: Weekly electricity consumption profile*
Figure 2: Annual electricity consumption profile

Figure 1 presents weekly half-hourly consumption profiles over the year for one of the buildings within the sample. This building included an ice storage system, which can be seen by the early-morning peak in electricity consumption, when the system is in ice making mode. Also of note is the total overnight load, a load of over 200 kW. The high overnight load indicated by this profile indicates that there are substantial overnight operating issues at this building. Later site inspection revealed that central plant, primarily glycol and chilled water pumps were operating to service a small retail bar 24 hours a day, 7 days a week. Figure 2 presents a similar electricity consumption profile, but demonstrates the difference between seasons, rather than days of the week. Within this profile, a clear summer seasonality is exhibited, as should be expected with a building containing a large quantity of electric chiller capacity. However, also evident is that the ice storage system does not undergo significant seasonal change, aside from starting 1 hour later. This suggests that there may be issues with the control of the ice storage system. Indeed, later examination of the ice storage system revealed that the system has substantial operational problems, and substantial energy saving opportunities.
4. ENERGY SAVING OPPORTUNITIES – TECHNICAL
A broad range of energy efficiency opportunities were identified within the building study group. Broadly, the measures fall within the following categories: Chiller retrofit or replacement, controls modification, re-commissioning, improvement in common area lighting power density, improvement in common area lighting control, and improvement of car park lighting and ventilation controls.

4.1 CHILLER REPLACEMENT
In climates with significant cooling loads, the production of chilled water is a significant component of the total energy consumption of a building. In general, the buildings within the study contained chiller plant that was somewhat dated. The wholesale replacement of chiller plant is not cost effective based on energy savings alone. As a result, replacement of primary chiller plant in these buildings was generally not recommended as an energy savings measure. However, if chillers are reaching the end of their economic life, a reasonable case can be made for replacement with high efficiency chillers, rather than a like-for-like replacement policy.

Additionally, many of these buildings contained particularly poor low-load chillers, generally of reciprocating types. Due to the significant number of hours where the building chiller plant is in part load operation, substantial gains can be made from the utilisation of very high efficiency low-load chillers.

Some chiller related savings were identified from the installation of electronic expansion valves on older chillers where these did not previously exist.

4.2 CONTROLS MODIFICATION
Controls modifications were identified as having a higher level of potential savings than any other category of measure. In the main, these modifications were achievable within the existing controls infrastructure and BMS, generally avoiding
the need to install a costly full BMS replacement. The specific controls strategies identified varied considerably from building to building. The relative merit of these different approaches is a topic worthy of a separate paper. A sample of the most common measures is presented below:

**Time of use control:** Perhaps the simplest saving that can be made is turning off a service when it is not needed. Time of use control modifications within these buildings included reduced run hours for central plant, and switchoff achieved by using triggered sensors such as occupancy sensors.

**Condenser water control:** Significant savings were identified through modification of condenser water system controls. Examples include modifying the condenser water temperature to track the wet bulb temperature plus three degrees, thereby improving chiller efficiency, and modifications to cooling tower staging or VSDs.

**Boiler temperature lockouts:** Most buildings within the sample included gas fired boilers. Significant gas and electricity savings were available through locking out the operation of these boilers based upon outdoor air temperature criteria.

**Economy cycle control:** Whilst most buildings incorporated an economy cycle to increase the quantity of outside air above the minimum when conditions were favourable, the methodologies for control often led to substantial losses of energy. For instance, enthalpy based economy cycle controls were controlled based upon a single outside air RH sensor, leading to system failure upon the failure of a single sensor.

**Air handler fan control:** Considerable energy savings were identified from the optimisation of air handler controls. Whilst control points were not generally sufficient to allow complex reset methodologies, such as critical zone pressure reset, a general strategy of resetting air handler pressures based between
commissioned minimum and maximum pressures was achievable, with considerable fan energy savings.

**VSD control:** Variable speed drives on pumps and fans can achieve considerable energy savings. Many of these buildings contained variable speed drives, but with poor, or no configuration. If the VSD does not achieve some turndown of the motor it is attached to, it can actually lead to an increase in energy consumption due to the energy consumption of the drive itself. The buildings within this study included a number of poorly or non-controlled variable speed drives. Savings identified through re-configuration of these drives has been included as a controls saving.

### 4.3 RECTIFICATION OF TENANT SUBMETERING

Base building ABGR ratings assess energy consumed within the base building. However, if other energy is supplied from these meters (for instance to supply tenants), without adequate sub-metering, the energy consumption must be included in the base building emissions.

The majority of these buildings included some non-office areas within the building, such as retail or hospitality spaces. In many cases, these spaces were supplied with services from the office tower, including energy supplies (e.g., electricity, natural gas), and thermal supplies (such as chilled water, condenser water or heating hot water). In some cases cost recovery was achieved through lease outgoings, but in many cases these costs were not recovered.

The ABGR protocol is rather strict in the assessment of energy sources servicing non-office areas of the building. Hence servicing these areas directly from the base building can lead to some degradation in the greenhouse rating of the office building. However, even when the costs are included as an outgoing to the tenant, the outgoings are often insufficient to adequately compensate the base building. An example of this was a chilled water supply to a café from a large office tower.
This was causing equipment designed to service 30,000 m² of office space to run to service a small bar. This phenomenon caused an overnight load in the order of several hundred kilowatts of pumping energy, with substantial financial and greenhouse impacts upon the office building, as seen within Figure 2.

In some other areas, such as gas supplies to cafés, more effective cost recovery is available through the tenant. Furthermore, a direct financial impact upon the tenant in the form of energy costs provides a driver for the tenant to optimise their consumption, whereas if the consumption is grossed into the rental, the tenant has no driver to encourage efficient usage.

This measure was a small contributor to the overall improvement in rating performance (6% of electricity and 9% of natural gas savings). However, whilst this measure resulted in an improvement in base building emissions, it represents a shifting in accounting of emissions between two stakeholders, rather than a genuine greenhouse abatement. As such, savings from this measure type have not been included in aggregate emission abatement calculations.

4.4 DOMESTIC HOT WATER

Domestic hot water is a small end use of energy within most commercial office buildings. However, in some of these buildings, substantial savings were available from the replacement of hot water systems with either gas or electric heat pump systems. Electric heat pump systems were suggested for some buildings where domestic hot water was the only usage of natural gas within the building. Conversion of the gas hot water system to electric would allow for the removal of the gas supply, and allow the building to cease paying significant monthly gas connection fees.

4.5 LIGHTING POWER DENSITY

In Australia, the base building is generally directly responsible for the energy consumption of common area and carpark lighting. The tenant is usually responsible for the energy consumption of general lighting within the net lettable
area. Nevertheless, the operation of lighting within the tenant spaces can add a heat load to the space, increasing the required cooling loads in the building. For the buildings within this study, wholesale replacement of tenant floor lighting systems could not be justified on energy savings from HVAC, and in general was not recommended.

Nevertheless, substantial opportunities were available for the improvement in lighting power density in common area and car park lights. In particular, common areas tended to use a large quantity of low voltage halogen dichroic lighting in lift and lift lobby areas, for which more efficient alternatives are available.

4.6 MAINTENANCE

Whilst the buildings in this study were generally in a good state of repair, a number of maintenance issues had not been properly addressed over the lifetimes of the buildings. Obvious or reactive (to tenant complaint) maintenance appeared to be carried out well. However, some areas exhibited a lack of maintenance, particularly those which did not have a direct impact on occupant comfort but did have a significant impact upon energy consumption. An example would be poor seating of a heating hot water valve. This causes a flow of hot water through the heating coil even when this is not called by the BMS. The unit itself compensates by supplying increased cooling, resulting in the same temperature air leaving the unit. The occupant does not notice any effect, and the problem goes un-noticed, at least until the next energy bills are received. At this point the increased cost of boiler systems fighting chiller systems becomes readily apparent.

4.7 HVAC VSDs

Variable Speed Drives are often used as an energy savings measure, to reduce the speed of fans or pumps. The two primary drivers for the installation of VSDs are for circumstances where a load can be varied, for instance a fan controlled off duct pressure, and for oversized pumps and fans. All too often one will examine a plant room with constant speed pumps, and observe that a large number of the balancing
valves have been partially closed. This effectively results in the pump working hard to maintain a pressure drop against the restriction of a semi-closed valve. The installation of a VSD can allow for the constriction to be removed and the pump speed to be reduced, whilst maintaining the same flow. Whilst this can be an acceptable retrofit solution for oversized pumps in existing buildings, it should not provide an excuse for lazy design, and designers should attempt to achieve correct pump sizing in the first place.

5. AGGREGATE IMPACT OF SAVING MEASURES
The individual measures appropriate for each site varied from site to site. The impacts from measures within each category are displayed within Figure 3.

![Figure 3: Breakdown of identified electricity savings](image)

![Figure 4: Breakdown of identified natural gas savings](image)
The energy saving potential of the measures identified was calculated for each measure on each building. Across the portfolio, these measures have a substantial impact, as detailed in Table 2. Across the portfolio, identified annual savings were approximately 6,800 MWh of electricity and 2,500 GJ of natural gas.

Table 2: Range of impacts for individual buildings

<table>
<thead>
<tr>
<th>Saving category</th>
<th>Average (all units in % of total consumption)</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>33%</td>
<td>49%</td>
<td>9%</td>
</tr>
<tr>
<td>Natural gas</td>
<td>32%</td>
<td>100%</td>
<td>6%</td>
</tr>
<tr>
<td>(only buildings with natural gas included)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GHG emissions</td>
<td>32%</td>
<td>50%</td>
<td>9%</td>
</tr>
<tr>
<td>Energy payback</td>
<td>2.7</td>
<td>7.5</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Note, percentages have been based upon the aggregate of percentages of individual sites, rather than the percentages of the aggregate. This has been applied to prevent measures on a small number of larger sites from dominating the results from the total portfolio. Results would be improved by increasing the overall sample size.

Across the portfolio, the identified energy saving initiatives have an aggregate potential cost saving of approximately $550,000 per year, with total greenhouse abatement potential equivalent to approximately 7,400 tonnes of carbon dioxide.

6. POTENTIAL AGGREGATE IMPACT ON AUSTRALIAN OFFICE SECTOR EMISSIONS

The building stock examined within this study is somewhat representative of typical existing buildings within the Australian office building sector. Based upon the opportunities identified within this study, there is a suggestion that the
wholesale reduction in office sector emissions by 32% may be feasible within the broader Australian market. Indeed, all buildings examined within this study were capable of cost-effective refurbishment to achieve an average ABGR rating of 4.3 stars across the portfolio.

There is a poor quantification of office building emissions within the commercial buildings sector. Indeed, national greenhouse accounts bundle all emissions for commercial buildings (including offices, retail buildings, hotels, hospitals etc) into a single category, responsible for 14% [2] of Australia’s total emissions. An alternate study presents findings that greenhouse emissions from the office sector are responsible for 27% of greenhouse gas emissions within the commercial sector [7]. Whilst there is no guarantee that the classifications are identical between the studies, a broad assumption can be made. Hence, self funding, market driven retrofit solutions to existing office buildings may be capable of achieving a 32% reduction in office sector emissions, equivalent to a 1.2% decrease in national greenhouse emissions. A change of emissions of the order of 1.2% of national greenhouse emissions is significant in itself as a methodology to help achieve overall carbon emission reductions by implementing measures that are currently feasible, and economically rational based on current energy costs.

The fact that such a large economic opportunity exists untapped is characteristic of a typical market failure. The precise root causes of this market failure are somewhat uncertain. However, the nature of the measures identified indicate that the primary drivers for this failure have been due to time lags associated with advancing technology, and incomplete information available to all market participants.

Recent regulatory change and transparency of building greenhouse accounting (through schemes such as ABGR) show promise of achieving market transformation within the sector. Often, the primary driver for building owners is initially to improve the building’s “green image” through reduction in emissions – effectively a market driven penalty for poorly performing buildings. However,
once the process has started, the economic incentives from the available energy cost savings provide an underlying financial motive to drive implementation.

7. IMPACTS FOR EMISSIONS REDUCTION IN OFFICE BUILDINGS IN HONG KONG AND TROPICAL ASIA

The results of this study have focused on buildings located in Australia. However, Australia is not alone in suffering from significant, untapped opportunity within greenhouse emissions from the office sector. Indeed, whilst Australia has one of the highest greenhouse emission rates per capita, the proportion of greenhouse emissions from the Australian commercial sector is comparatively small on an international scale, due to the quantity of primary industry within the energy consumption profile of Australia. To illustrate this, office buildings comprise a total of 3.8% of total Australian greenhouse gas emissions. City dominated areas, such as Hong Kong exhibit much higher ratios, with the commercial sector comprising approximately 59% of greenhouse emissions in 1997, with substantial growth rates [8]. The higher proportion of emissions from the commercial sector indicates a higher level of aggregate opportunity within these centres.

The buildings located within this study are located in temperate climates. Many of the issues identified are related to two primary issues; control issues resulting in conflict between heating and cooling systems, and the poor use of favourable external conditions (such as economy cycles). Whilst these elements are not so relevant to buildings located in tropical climates, there are additional complexities for tropical buildings. In particular, in tropical environments with high air enthalpy conditions, the minimisation of outside air becomes critical. Furthermore, anecdotal evidence indicates that management of the air-side of tropical air-conditioning systems is affected by many of the same maintenance, commissioning and control problems and opportunities observed in the building sample discussed in this paper. It is likely that similar magnitudes of opportunity
exist in tropical buildings, but perhaps focusing on slightly different areas of energy consumption.

Nevertheless, the same conditions that lead to market failure in Australia (technological lag and lack of information within the market) are likely to exist in tropical areas, providing similar issues that need to be overcome through appropriate transparency of information, or regulatory approaches.

8. CONCLUSIONS
The examination of the buildings within this study demonstrated significant potential for energy, financial and greenhouse emission savings within the building stock.

Energy savings were available from a range of measures, with half of total savings being identified through modification to HVAC and lighting control algorithms.

Prior to audit, the sample of buildings within this study was representative of average population performance, when assessed against the Australian Building Greenhouse Rating tool, in both the level of performance and the distribution of building performance. ABGR is directly based upon the real greenhouse emission performance of the Australian office stock. Hence this relationship has been used to draw inference between the results within this portfolio, and the broader existing building population.

Based upon this analysis, there appears to be a total abatement potential available within Australian office buildings, utilising currently commercialised technology and economically rational funding criteria, equivalent to approximately 1.2% of total national greenhouse emissions. This is significant on a national emissions basis.

The presence of this opportunity is symptomatic of a general market failure regarding energy, which is likely to be due to the lag of implementation of new
technology into existing buildings, and to a lack of information available within the market participants. The use of performance rating tools, such as ABGR, appear to be assisting in correcting the informational gap within the market, by improving the transparency of greenhouse reporting. However, the slow change within the market suggests that further policy response may be required to fully correct the market failure, regardless of carbon pricing issues.

9. ACKNOWLEDGEMENT

The energy audits reported within this paper were funded by Colonial First State. The assistance of Jones Lang LaSalle with data collection was invaluable to the outcomes presented within this paper. The assistance of individuals within these organisations is specifically and gratefully acknowledged, along with the contributions of Exergy staff.

10. REFERENCES


IMPLEMENTATION OF GREEN BUILDING IN CHINA

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ABSTRACT: Green building design is becoming mainstream in China. At policy and regulatory level, China has implemented mandatory building energy standard throughout country, aiming to reduce the energy use in buildings by 20% by year 2010. Recently, China has also implemented voluntarily its green building standard issued by the Ministry of Construction, the Assessment Standard of Green building.

Other than the national green building standards, many overseas green building rating schemes such as LEED administrated by USGBC are also gaining their general popularity in China. Their applications in building projects have influenced the standard practices of building designs, making green building design becoming a leading role in the building market. Yet implementing these schemes into the design and construction details is difficult within the context of China. This paper addresses the detail approaches on design strategies and construction site management to achieve the requirements of these schemes, focusing on the differences in requirements among these schemes and design approaches for achieving the label. This paper also discusses the potential that these schemes can help to transform the building industry into a more sustainable construction.

1. INTRODUCTION

Due to the rapid urbanisation in recent years, China is now one of the biggest consumers of oil, gas and coal and the government is eager to see the country back away from a growing dependency on imported energy [1]. Recent studies have also shown China to be the least energy-efficient of the world's major economies, using several times as much fuel for each unit of output as the United States, Japan or European countries[2]. China is also home to several of the world's most polluted cities – mostly due to power plants burning vast amounts of dirty coal to power the country's rapidly growing cities.

In order to change the situation, all of the efforts are being made to build a stable, economical, safe and clean energy supply system which safeguards China's energy security efficiently. The Central government, led by Premier Wen Jiabao and Vice Premier Zeng Peiyan, has setup a team tasked with ensuring the country's energy consumption and pollution reduction targets stated in the Chinese government's
11th (year 2006-2010) Five-Year Plan are met. China has set a goal of reducing energy consumption per unit of GDP by 20 percent by 2010. The National Development and Reform Commission is taking this lead on (1) allocating the target among provinces and industrial sectors, and (2) adopting energy efficiency improvement criteria for evaluating the job performance of local government officials.

As building industry is one of the biggest energy consuming sectors, improving energy efficiency of buildings is pivotal for China in achieving its goal of creating a resource-saving society, according to Minister of Construction (MOC). The MOC indicated that the country will focus on the building energy conservation, targeting at the energy resources, land uses, water and building materials (the four savings or 四节). [3]

To implement the policy, the Chinese Government at different levels are attaching growing importance to energy conservation in building construction, and have worked out several laws and regulations to promote it. The central government has already produced an energy conservation law, and a regulation on building energy conservation, which has been effective for at least four years. A law to encourage the use of renewable energies is expected to take effect this year, according to sources from the industry. The draft renewable energy law encourages the use of solar, wind and bio-bass resources, by fixing a proportion of new energies to be utilized in energy-consuming industries including power generation and construction. The new law will also offer favourable policies to those who use renewable energies.

At the local level, some local governments have taken various initiatives. For example, the Beijing government promulgated a management regulation on energy saving in buildings as early as in September 2001, and other provinces and municipalities also have related policies to promote energy conservation in the construction industry.
In addition to these efforts being made on the policy side, experts suggest rolling out an economic incentive mechanism to bolster the rational development of energy saving in construction. A host of economic measures including taxation, pricing and distribution of extra allowances should be carried out, to drive the energy conservation. If all measures are adopted effectively, energy consumption in building constructions would suffice to save 50 million tons of coal equivalents during the 11th Five-Year Plan period. [3]

2. DEVELOPMENT OF GREEN BUILDING IN CHINA

The China Long and Medium-Term Energy Conservation Plan, drawn up by the National Development and Reform Commission, is divided into two phases: the 11th Five-Year Plan and the period between 2007 and 2020. China will see a construction boom of green, energy-efficient buildings in the coming 15 years. According to the MOC, China will transform all existing buildings into energy-saving buildings by 2020. Buildings built after 2005 will embrace new technologies that could save 65 percent more energy per square meter compared with buildings built now.

With scientific and systematic design, energy-efficient and green buildings can embrace high technologies including natural ventilation, natural lighting and water recycling. Yet, the cost of green buildings, saving 60 percent of the energy per unit, is only five to seven percent higher than the ordinary buildings, but it will greatly reduce energy consumption and environment pollution. Homeowners were expected to spend an estimated $200 bn by 2020 on improvements to meet the new regulations. According to ministry statistics, the energy consumption per unit for Chinese construction is two or three times that of developed countries. Currently, energy-saving buildings in China occupy less than one percent of the country's total construction by square meter. This creates a huge potential for building energy-efficient buildings in China.
Moreover, the Kyoto Protocol, which took effect earlier this year, has provided a golden opportunity for China to develop green, energy-saving buildings. To involve developing countries in reducing the emission of "greenhouse gases," the Protocol includes a Clean Development Mechanism (CDM). Industrialized countries may input funds into projects that cut or avoid emissions in poor nations. The developed countries then are awarded credits that can be applied to meeting their own emissions targets. China's energy-efficient building constructions could be completed through international cooperation in CDM projects. Some Eco-city projects in China are seeking this market solution for implementing the renewable designs to achieve the ultimate objective of “zero-carbon” [4].

Both the policy push and the market pull actions will be the main drivers behind to create a "tremendous market" for energy-saving technology and renovation work in China. To implement the policy effectively, the government is also now considering offering subsidies or tax breaks to help with the cost reduction on adopting green building designs such as the ground source heat pump. Some local governments have built pilot projects to highlight energy conservation in building constructions, and to enhance the public awareness of energy saving.

3. GREEN BUILDING INITIATIVES

Since 2004, China has initiated many plans and actions to implement the policy on energy saving. They were well-received by the building industry, which has helped making the green building design becoming mainstream. Some recent initiatives of the government on green buildings include:

1. Implementing the 《绿色奥运建筑评估体系》 in February, 2004
2. Implementing the 《全国绿色建筑创新管理办法》 was implemented in August, 2004
3. Implementing the《全国绿色建筑创新奖》 in February, 2005
4. Implementing the《公共建筑节能设计标准》 in June 2005
5. Issuing the 《绿色建筑评价标准》 by the MOC in June, 2006

In addition to these initiatives promoted by the government, various local and overseas institutions are working to help China promote voluntary market-pull programs in green buildings that go beyond minimum standards. In particular, overseas assessment scheme such as the LEED, developed by the U.S. Green Building Council, are also becoming popular in the market. Buildings accredited by LEED are now recognised as the truly sustainable by the local and overseas developers. Recent market penetration of green building labelling schemes has now created the momentum to drive the green building in many sectors of properties developments. It has created a value of green building that many developers have adopted it for branding of their developments and the corporation itself. In response to this, the Ministry of Construction and the Ministry of Science and Technology are now considering to adapt and translate some of the international labelling schemes to fit China's needs. The experiences of developed countries on adoption of green building has suggested that the healthy green building industry should be supported by effective design, building assessment and labelling schemes as well as the innovative technologies, put forwarded by these industry standards.

4. GREEN BUILDING DESIGNS

In fact, the implementation of the energy law and the green building standards in the market has encouraged the adoption of energy efficient designs and renewable energy for building design. Green or sustainable buildings are now a key consideration in new building developments in China. State-of-the-art technologies have been tested and adopted in this biggest building market. Fig. 2 shows some of the sustainable building designs that are becoming prevailing in China.
The advance in the green building technology is particularly prominent in the design of the public buildings, which are predominantly non-residential including offices, hotel and institutional buildings etc. The effectiveness on energy saving is more observable due to their higher Energy Use Intensity EUI. For example, the EUI of a typical Grade-A office building in Shanghai is about 120 to 150 kWh/year [1]. The major energy consumption is coming from the HVAC systems, which is designed to provide high quality of thermal comfort environment as shown in Fig 3. This is followed by the lighting systems. In north parts of China, another significant portion of energy consumption of building, however, is for the provision of heating in winter time. For a big country like China, variations in climatic conditions are significant, which demands a holistic consideration for any effective strategy for green development. In particular, integrated designs are
required to establish the optimised strategies on building form, fabric and system energy efficiency. The experiences in practicing green building by the building professionals in recent years have accumulated many valuable experiences for the industry to follow. In particular, many effective design strategies have tested by finished projects and performance verified by measured data. Some of these proven technologies and designs for China are shown in Table 1.

The adoption of these energy saving designs (see Table 1 below) can generate an energy saving of as high as 20% when compared with the energy code compliance buildings. In particular, uses of natural ventilation and free cooling are prevailing for the HVAC design in China, partially due to the favourable climate and also the habits of the local people.

<table>
<thead>
<tr>
<th>components</th>
<th>Energy saving designs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building fabric</td>
<td>Ventilated façade, external shading, air tightness</td>
</tr>
<tr>
<td>Glass selection</td>
<td>Low-e, double skin</td>
</tr>
<tr>
<td>Natural ventilation</td>
<td>Atrium design, wind catcher, openable windows</td>
</tr>
<tr>
<td>Free cooling</td>
<td>Fully fresh air, hybrid ventilation, economiser</td>
</tr>
<tr>
<td>Efficient HVAC</td>
<td>Ice storage, Ground source heat pump, Radiant cooling</td>
</tr>
<tr>
<td>Efficient lighting</td>
<td>Daylighting, T5, LED, lighting sensors</td>
</tr>
<tr>
<td>Renewable</td>
<td>PV, solar thermal ; wind turbine</td>
</tr>
</tbody>
</table>

Table 1: Prevailing green building technologies and design strategies in China.
Apart from the building design, operation of building, in particular occupant’s lifestyles will also have a significant impact on the eventual energy use. Efficient designs have already reduced the building design energy demand to a very low level. Further reductions can only be realised by change in occupant lifestyle. Experiences from around the world suggests that in practice the actual operational energy use of buildings is often much higher than estimated by the design energy use calculations when the occupants are not involved in the whole energy saving process.

Occupants normally choose their own household equipment, and there is a growing trend for large format televisions and music systems in main living spaces, and secondary televisions in other habitable rooms. These are often left on for extended periods, and even when not in use can consume significant energy in standby mode. Likewise, occupants tend to choose white goods, hot water appliances, showers, supplementary lighting, AC and cooking appliances, all of which have a significant impact on overall energy use. Most occupants are unaware of the significance of their choices: a key factor to achieving energy saving target will be educating occupants. This will need to be combined with co-operation from product supply chains who need to ensure there is a full range of clearly labelled, and well marketed low energy products available. This may need to be managed through governance by introducing appropriate incentives and penalties when planning for the eco-city.

Use of renewable energy is also a prime consideration on Green building implementation in China. Under the current urban context of most the cities in China, buildings have the potential to harness significant amounts of both solar and wind power, having a substantial area of roof available that is not shaded by any high-rise buildings. Given the height and likely roof areas available, it is anticipated that 30% of residential and 10% of the non-residential building electricity energy needs will be met using a combination of photovoltaic (PV) solar
panels and micro-wind turbines in approximate proportions of 40% and 60% respectively. The combination of PV and wind turbines will have to be decided by the availability of solar and wind resources for the individual site.

At district level, energy generated from municipal waste residual (after removal of recycled materials) could potentially contribute electrical energy needs from its solid waste stream. While the City waste stream may be modest initially, as city size increases the need to address solid waste residual disposal, and the improving economics of "Energy from Waste" plant increase rapidly. A range of "Energy from Waste" plant configurations is available, including gasification, pyrolysis, anaerobic digestion and thermal combustion. The current practice is for a gasification plant feeding a steam turbine. A decision on which technology to proceed with would be guided by the waste management strategy and the size of the waste catchment area. Options include providing a separate anaerobic digestion "Energy from Waste" system for putrid food and similar waste. This may be in the form of a separated collection system and a dedicated anaerobic digestion unit or alternatively, kitchen waste disposal (macerator) units in sinks throughout the development to allow the sewage piped drainage system to be used to convey the putrid waste to the "Energy from Sewage" plant. The latter arrangement also removes the putrid waste from contaminating otherwise dry waste particularly from residential properties, allowing easier segregation and recycling of the majority of municipal solid waste.

5. GREEN BUILDING LABEL SCHEMES

There are many drivers behind the transform of the building market into green building oriented. Wide adoption of green building labelling schemes is inseparable from such as a change. In recent years, there are many different labelling schemes becoming promoted in the China including the LEED. The number of buildings adopting LEED in China has increase significantly in the past two years. According to the record of USGB [5], the number of LEED registered
buildings has reached 23 as of September 2007, compared with only a few in the years before. This number did not include those buildings that are still under internal processes of documentation. The types of registered buildings comprise of office, residential, retails and industrial facilities. There are many reasons for applying LEED for projects in China. It is found that international corporations/companies are the main users of LEED. Many of them need to acquire green buildings when they are operating in China to fulfill their corporate sustainability requirements. As LEED is widely-recognized internationally, it is easily selected by these companies. To respond to such a market demand, some local and international property developers are also interested to certify their buildings by LEED in order to attract these companies to move in. As more and more companies are now moving into the China market, the demand for LEED certified buildings will be increasing significantly in the coming years.

![Number of Buildings Registered for LEED in China](image)

**Figure 4: Trend of LEED market in China.**

Implementing LEED in China is not a straightforward process. It involves a number of adaptation and localisation processes. As LEED was formulated primarily for the US developments, the requirements and standards are established purely based on the US conditions. Many issues, such as that specified in the planning and material uses credits are not perceived as appropriate under the context of China. For example, the requirement of restoring natural habitat by provided 50% of greenery areas is very difficult to achieve for building development built in the highly densely populated cities. Yet, the adoption of local
material and recycling of construction waste is relatively easy to achieve in China. Credits related to these recycling are readily adopted by the projects in China for certification. Fig5 illustrates the distribution of credits adopted in some of recent China projects of Arup adopting the LEED. It shows the popularity (or applicability to certain extent) of these credits implemented in China. Among all credits, the requirements on reuse of existing building or its components is difficult to achieve due to the relatively poor conditions of current building stocks. Renewable energy is also difficult to implement currently due to its relatively high capital cost at the moment. In general, it is not very difficult for buildings with high design standards to get a good label such as Gold rating in China.

![Figure 5: The distribution of LEED credits adoption in China Projects (based on the summary of 20 projects)](image)

Another major development of green building in China recently on the development of Green Building is the issuance of the Green Building Code. In 2006, Chine has implemented voluntarily its own green building assessment tool called Evaluation Standards of Green Building (《绿色建筑评价标准》) or ESGB. Subject to the acceptance of the market in the coming years, it may become the key green building design standards in China.

Similar to the LEED, the ESGB assessment scheme also use ‘point” base for assessing the performance of the building. All the points are allocated under six categories, namely
• Land Saving and Outdoor Environment
• Energy Saving and utilization
• Water Saving and utilization
• Material Saving and utilization
• Indoor Environmental Quality
• Operation and Management

There are different requirements for different levels of green building labels, namely, 1-star, 2-star and 3-star awards, which are apportioned as shown in Tab 2. In particular, the requirements for 3-star label are very stringent. Effectively, most of the general and priority options have to be complied.

Table 2: Point allocation for various labels of the ESGB

<table>
<thead>
<tr>
<th>General Options</th>
<th>Priority Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land-saving and Outdoor Environment</td>
<td>Energy-saving and Utilization</td>
</tr>
<tr>
<td>Water-saving and Resources Utilization</td>
<td>Material Saving and Resources Utilization</td>
</tr>
<tr>
<td>Indoor Environmental Quality</td>
<td>Operation and Management</td>
</tr>
</tbody>
</table>

The strategies to achieve the criteria are also key for the success in attending to the “3-star” label. In one of the recent high-rise office building in Shenzhen, the integrated solutions for green building design have incorporated the following strategies:

• Suitable site (safety, transport, etc) and building disposition
• Building integrated solar shading
• Natural ventilation
• Natural lighting
• Local plant selection
• Podium Garden / Sky Garden / Green Roof
• Water features integrated with water storage
• Water Recycling (Rainwater, Grey water, Condensate)
• Water saving irrigation Approaches
• Light steel structure
• Recycle content material
• Waste reduction
• Energy conservation system (Heat recovery, Free cooling, etc)
• Energy cost reduction (Thermal storage)
• Renewable energy (solar thermal)
• Improved Indoor environment (IAQ, thermal, visual, acoustics)
• Building management and maintenance

Although the issues addressed by the ESGB are similar to those of LEED, there do exist some significant differences in terms of the detail requirements. One observation is that the ESGB is more comprehensive than the LEED rating system. In particular, it has a category of requirements addressing the issues of operation of building. Also, in material use credits, the ESGB is focusing on how to reduce the consumption of construction materials by means of effective structural design, e.g. high strength steel and concrete or light structure. The requirement of LEED on this issue, however, is mainly on encouraging reuse old building and recycle materials. It has no requirement on materials use reduction.

As most of the standards or designs required by the ESGB had made reference to the relevant Chinese standards, it makes the implementation easier in China. The local designers can provide the designs accordingly. Yet, some credits are difficult to achieve. For example, the provision of 30% window vision pane with operanabe window is difficult to comply with for office building and requires due consideration at planning stage. As shown in Fig 6, natural ventilation design can achieve this and will perform better when high-level openings are provided.
The ESGB is also asking for comprehensive designs for achieving the green building objectives and some of the benefits can be quantified. For the Shenzhen project, the performance to achieve the “3-star” building includes:

- 40% of the site area are pervious for retaining water on-site
- 100% of the plants for landscape greenery are local species
- Energy saving of 25% as compared with the current energy code
- Daylight for 75% of the spaces
- Water saving of 20% as compared with the code requirements
- 10% of hot water demand provided by the solar energy
- 10% of the construction materials are saved due to the provision of effective structure design
- 75% of the construction wastes are being recycled
- 100% construction materials are locally extracted and manufactured
Figure 6: Daylight and solar study for enhancing the IEQ and energy efficiency.

With the implementation of green building label scheme such as the LEED and the local ESGB, the objectives and targets of green building can be realized and be reflected in the design and implemented in the construction process. Wide adoption of these schemes is crucial to create the green building market which can drive the further enhancement on the environmental performances of the buildings. The outcome will help alleviating the side effects of urbanization to the environment and the society as a whole. It is also an effective instrument which helps achieving the targets and goals set by the MOC for achieving a “Saving Society” in China.

6. CONCLUSION

The demand of green buildings in China is increased significantly in recent years due to the policy of China to address the issues of energy saving. A market of green building is formed which drive the market further for more energy efficient buildings. The adoption of local and international green building code, such as the LEED, is an effectively driver (instrument) that leads the industry to the right direction with proven technologies and practices. New buildings, in particular those public building such as offices have already experienced such a positive change and the performance has reached a very high standards, with the energy saving that is comparable with the standard in the developed countries.

Further driving force from the market is required should the national targets is to be achieved throughout the entire China.

7. REFERENCES


[3] Wang Guangtao, The implementation of “four Efficiencies” is the key to building up a fragile society – reflections of the construction of energy-efficient and land-saving housing and public buildings, 1st ICIGBT (2005)


EVALUATION AND APPLICATION OF NATURAL VENTILATION CONCEPTS IN EDUCATIONAL BUILDINGS

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ABSTRACT: The Welsh School of Architecture (WSA) and the Tianjin University collaborate with a programme whose purpose is to encourage expertise interchange between universities and to promote the application of sustainable concepts in real design projects, creating a link between academics and professionals. Based on theses principles, this paper describes one initiative to approach sustainable issues through the use of passive technologies in a new building compound to be constructed for the Shandong Art College. This study refers to the potential of using natural ventilation to improve naturally user’s thermal comfort and safety levels on both external and internal environments, according to different requirements throughout the year. In order to reach these goals, CFD simulations evaluated wind flow factors and effects, ruled by the interaction between both the built volume and the topography with the surrounding microclimate. It aimed at identifying both the resulting wind speed and differences of pressure along the building’s façades for the prevailing wind direction. The capacity for natural air changes and temperature reduction in the internal environment were considered for both healthy and cooling purposes during summer seasons, and included the use of ground cooling systems. The software’s used to perform the simulations and display the results are, respectively, the WinAir-v1.4b, the HTB2 and the ECOTECT v5.5. Eventually, it highlighted several possibilities to ameliorate effectively the thermal performance of this built environment, reflecting in energy consumption reduction without alter the proposed architectonic design. All over the use of these buildings, it is ought to make the students conscious about such features and the benefits it shall bring. In this way, the contribution to the development of a sustainable society may possibly occur in both short and long terms.

Keywords: Sustainable architecture, CFD, Natural Ventilation, Ground Cooling and Heating Systems.

1. INTRODUCTION

China is currently going through a period of continued rapid economic development. It has become the world’s biggest construction site. While it contributes to 15 percent of the world's GDP, China consumes 30 percent of the Earth's steel and half of its concrete. Within China, the construction sector consumes 30 percent of the total energy and results in 35 percent of the total pollution [1].
A modernizing and urbanizing China with limited energy sources has to promote social awareness regarding the necessity of embracing sustainable concepts applied to new developments. This is an issue that deserves the close attention of government, industry and, indeed, a challenge for architects and building engineers.

In line with this panorama, this paper describes an initiative between the WSA and the Tianjin University to apply sustainable issues in new campus buildings, as the new compound to be constructed for the Shandong Art College, Jinan.

In order to reach this purpose, an investigation was conducted to point out the potential of using natural ventilation during summer season to improve pedestrians comfort and safety levels in external areas. Along with this, the use of a natural ventilated ground cooling/heating system to control the internal environment temperature proved to be efficient, minimizing cooling/heating needs for this project and, therefore, acting directly on the energy consumption reduction as well.

2. THE NATURAL VENTILATION ANALYSIS

Computational Fluid Dynamics (CFD) simulations were carried out aiming to identify wind flow patterns amongst built area and site topography, highlighting the wind resources potential and how to build comfortable external environment, predicting the occurrence of breezeways, wind acceleration and still air areas. The purpose is related to avoid wind during winter, making the best use of this natural resource in summer. Ventilation can bring thermal comfort improvement as psychological effect through wind velocity, since it increases makes people to feel cooler [2].

Two spots of special attention on this analysis were the ones designated by “courtyard 01 and 05”, localized in front of and in the rear of the main building, due to the fact that they consist of outdoor meeting point areas, intended to concentrate people during summer time (see Fig. 1).
Other goals were related to the possibility on using natural crossed ventilation in several buildings of this school compound. Therefore, the results were focused mostly in wind direction and speed, in addition to differences of pressure.

![Building compound master plan.](image)

1.1 The Weather Data Parameters.

Two sources of information were cross-referenced in order to provide entire information for the climate parameters used in the CFD calculations: “Chinese Standard Weather Data - CSWD” and the “Chinese Typical Year Weather - CTYW” [3] (Tables 01 and 02). According to this procedure, the climate parameters used were:

| Table 1: Temperature Year Variation (°C). |
|---------|---------|---------|
|         | morning | afternoon | average |
| Spring  | 3.6     | 24.1     | 13.4    |
| **Summer** | **18.5** | **34.8** | **25.4** |
| Autumn  | 6.6     | 26.5     | 13.9    |
| **Winter** | **-9.0** | **11.6** | **-1.2** |

| Table 2: Relative Humidity Variation (%). |
|---------|---------|---------|
|         | morning | afternoon | average |
| Spring  | 47.7%   | 33.2%     | 40.4%   |
| **Summer** | **66.7%** | **56.8%** | **61.8%** |
| Autumn  | 60.7%   | 45.8%     | 53.3%   |
| **Winter** | **55.0%** | **40.0%** | **47.5%** |
The average wind velocity considered for summer and winter are 2.8m/s and 3.2m/s at 10 meters height, respectively, and the equivalent wind profile was considered for both speeds [4]. The prevailing wind directions considered for the summer and winter are Northeast (NE, 27.0%) and Southwest (SW, 23.7%), results comparable to the ones observed in the wind-rose for all year (Fig. 2). Based on this, four wind directions were simulated (NE, SW, SE, and S).

![Wind Rose](image)

**Figure 2: All Year Round Wind Rose (CTYW).**

### 1.1. Building the CFD models.

The software’s used to perform CFD simulation and display results were the WinAir v1.4 [5] and the commercially available ECOTECT v5, respectively.

The WinAir modelling process uses an orthogonal grid, which cells that constitute the domain simulated contain specific information about temperature, humidity, pressure, and air concentration, wind speed and direction.

Each cell is interrelated and exchange information with the immediate surrounding, which can be composed by either other cells or the boundary surfaces of the domain. Buildings, topography and other volumes are modelled as “blocked cells”, what means, cells that does not interact with the surrounding unblocked ones. All the blocked cells must be orientated towards the orthogonal axis.
Based on these concepts, two models were created to allow the simulation of four wind directions, since the air inflow in the domain must be orthogonal to the grid, in order to achieve accurate results. The first model simulated the NE, SE and SW winds, and the second the S condition, as showed in the Fig. 3:

![Figure 3: 3D models and blocked cells.](image)

The total dimension of the domain simulated was a rectangle of 980x720m. The size of the cells varied from 1.5m to 9.0m. In the target area of both models, a central rectangle of 225x150m, that comprises all the buildings, the size of the cells considered was a cube of 1.5m, until the height of 46m. These dimensions increased gradually until the perimeter of the domain, where the maximum size of the cells was 9.0x9.0x9.0m.

1.2 The Analysis of the Results

The best air flow condition observed is related to winds coming from the South (Fig. 4 and 5). In this case, most of this courtyard 01 presented wind speeds from 0.5 to 1.0m/s, with some points over 2.0m/s. On the other hand, as this courtyard is constrained by the surrounding building, the wind conditions in this space is underrate, if compared with the immediate open area in front of it. When this wind reaches the buildings compound orthogonally, part of it is deflected to the left by the built mass and part is decelerated, as comes in between the frontal access.
Figures 4 and 5: S wind flow results ranging from 0.0 – 2.0m/s and 0.0 – 1.0m/s.

As can be observed on the displayed results (Fig. 6 to 9), for winds from NE and SE directions (the first and third prevailing winds respectively), the air flow condition in the courtyard 01 is deficient, prevailing wind speeds below 0.2m/s at the pedestrian level. In both cases the east wing of the Building 01 acts as a physical barrier for this air flow. In the Northeast direction this condition is worsened due to the hilly surrounding topography.

Figures 6 and 7: NE wind flow results ranging from 0.0 – 2.0m/s and 0.0 – 1.0m/s.
Figures 8 and 9: SE wind flow results ranging from 0.0 – 2.0m/s and 0.0 – 1.0m/s.

The results for winds from SW tended to repeat this air flow effect, but deflecting to the right side, instead (Fig. 10 and 11). Inside the courtyard, turbulence can be noticed in the right wing of the Building 01, with speeds over the 1.5m/s. On the other wing the average speed is under 0.3m/s.

Figure 10 and 11: SW wind flow results ranging from 0.0 – 2.0m/s and 0.0 – 1.0m/s.

**Air flow Improvement and Control**

Based on the assessment of the CFD simulations, this paper presents one possibility regarding the creation of a controllable underground passage connecting the front and the rear of this building, which would allow natural cross ventilation between both courtyards as an alternative to increase wind speed on both areas.
This method considers an underground cavity that already exists below the building basement structure, and consists of 15 tubes with 1m of diameter and 17m of length placed alongside under the construction, as shown in the Fig. 12 and 13. Eventually, the potential on using wind turbines inside this passage, for energy generation for this proposition, can be quantified.

![Figure 12: Building 01 ground floor plan showing underground connection.](image)

![Figure 13: Vertical section across Building 01 showing underground connection.](image)

**Building the CFD models.**
The same software was used to perform CFD simulation. A 2D model was created, in order to analyze the air flow effect through the underground passage. In order to reach more accuracy on the results, the size of the cells used on this model varied from 10 to 30cm.

Starting this analysis with the results obtained from the simulation of the wind originating from South (from the right of both images showed on Fig. 15), it is
possible to notice a turbulent air movement area on the windward side in the image on left.

The addition of the underground connection seems to slightly improve air flow on this area. In contrast, pedestrians on the leeward may feel discomfort due to the air stream acceleration, although this flow is pointed to upwards and becomes turbulent, decreasing it velocity.

Figure 15: Building cross-sections for South wind. Results ranging from 0.0 – 5.0m/s.
The chart below (chart 01) shows the increase of air velocity observed in the windward side for winds from South due to the constructive solution adopted. It shows the air velocity variation from the building wall until a distance of 4.0m from the building, for three different heights (0.5m, 1.0m and 2.0m) for both cases: underground connection closed (case 01) and open (case 02).

Chart 01: Air Speed Variation in the Courtyard 01 for South wind (windward).
According to these values, it is possible to verify that, when the courtyard 01 becomes the windward direction, what happens mostly for South winds, the air velocity is already satisfactory, ranging from 1.0 to 1.5 m/s on average at pedestrian level, but decreasing since the height increases. The same results can be visualized in the bottom right of the Fig. 15 previously mentioned.

In this case, the introduction of the underground system would raise the air velocity in around 0.5 m.

On the other hand, the simulation for North winds (from the left side of both images showed on Fig. 16), indicates a concentrated still air area on the courtyard 01, now on the leeward area (the bottom right side). In this case, the underground connection seems to be efficient improving air velocity on the leeward, what during summer season will benefit pedestrians comfort levels in this area.

**Figure 16: Building cross-sections for North wind. Results ranging from 0.0 – 5.0 m/s.**

Now, the results displayed on the chart 02 demonstrates that, for the case 01, the air stands still to less than 0.5 m/s along with the distance taken from the wall, even for different heights. With the addition of the underground system, the air velocity increases considerably, mostly for distances beyond 1 m from the building wall, maintaining it in a range from 1.0 to more than 2.0 m/s at pedestrian height.
Chart 02: Air Speed Variation in the Courtyard 01 for North wind (leeward).

**Wind energy production.**

Due to the channelled wind effect, the air velocity inside the tube reaches up to 7.0 on the case 01 and 4.0m/s on the case 02. According to several authors, it is possible to quantify the kinetic energy generated by air flow through blades of a windmill, determining the potential of this system to generate electricity power, according to the following formula [4]:

\[
E=0.60*\left[\frac{\pi * D^2 * \rho * V^3}{8}\right]
\]

Where:

- E is the Kinetic energy, in Watts;
- 0.60 is the effective efficiency of this system;
- D is the diameter of the turbine (1.0m);
- V is the air velocity (5.5m/s as average)

Based on this, the potential kinetic energy generated by the proposed system is 45W. Some wind turbine manufacturers suggest values from 28 to 120W for equipments with the same characteristics [6 and 7]. This means that the natural ventilation system considered in this project (containing 15 windmills) could
provide from 300 to 1,600kwh per year, if considered a maximum efficiency for electricity generation of 28% in this system and 30% of the day with this prevailing wind direction.

3. THE GROUND COOLING/ HEATING SYSTEM PERFORMANCE SIMULATION

The area where the Art College locates has a climate pattern of hot summer (up to 34.8°C) and cold winter (as low as -9.0°C) as given in Table1. The demand on using coal or electricity for heating in winter and cooling in summer could be considerable, so it is important to find ways to reduce the building energy consumption. A Ground Cooling/ Heating System (GCHS) is recommended here to provide passive heating and cooling services to minimize energy requirement and to provide thermal comfort [8].

The system's basic concept takes advantage of the earth's constant temperature, approximately 12 degrees, to preheat or cool the air entering the building thus reduce heating and cooling energy demand. A GCHS usually consists of air inlet, underground pipes and air outlet. The external air is collected into the air inlet located outside the building, channelled through air pipes planted under ground to exchange heat, and the air then is collected at the outlet before it enters the building (Fig. 17). Usually a nearby large open area (e.g. parking lot or open ground) is needed to plant the pipes. In this project, the buildings are surrounded by green space, so it is not difficult to find a spot for underground pipes.

Figure 17: Ground Cooling/Heating System.
3.1 Computer Model

A computer model is set up using HTB2 [9] to study the thermal effect of GCHS on both cooling and heating demand in the classrooms. Three classrooms in the dance classroom block are chosen for simulation (Figure1, Figure17). Two sets of GCHS systems are tested to see their effect on the heating/cooling loads and indoor air temperatures.

i) GCHS Model I:

The system consists of a set of 12 underground cement air pipes buried 2 metres into the ground, each 0.3m in diameter and 30m in length. The external air collected in the air inlet splits evenly to the underground pipes, exchanges heat with the earth mass while passing through and then enters the building from below to the outlets in each room with an air change rate of 0.2m$^3$/s (Fig. 18).

![Figure 18: GCHS Model I.](image)

ii) GCHS Model II:

A second set of pipes is added to GCHS Model I to allow more heat exchange underground (Fig.19).

![Figure 19: GCHS Model II.](image)
iii) Basecase:

For the purpose of comparison, a third base case model is also structured consisting of no GCHS.

3.3 Simulation Results

1) Air Temperature inside the systems

Temperature change inside the GCHS systems is simulated to test their potential of heating and cooling the room air. As a result, GCHS Model I achieved an extreme temperature drop of 5.1°C on the hottest hour of a year and an extreme temperature rise of 6.0°C on the coldest hour of a year; GCHS Model II achieved an extreme temperature drop of 6.6°C on the hottest hour of a year and an extreme temperature rise of 7.9°C on the coldest hour of a year (Charts 03 to 06).

Charts 03 to 06: Temperature change in the GCHS systems.
2) Air Temperature in the classrooms

The air temperatures of the classrooms are simulated to show the effect of the ground cooling on room air temperature on the hottest day (22nd June) and the coldest day (18th December) of a year. Results show that by adding GCHS to the building’s ventilation system, significant temperature drop and rise are achieved in summer and winter respectively. GCHS Model II has a better performance than GCHS Model I. The average extreme hot day temperature drop comparing with base case in the classrooms is 1.8°C for GCHS Model I and 2.4°C for GCHS Model II; the average extreme cold day temperature rise comparing with base case in the classrooms is 2.1°C for GCHS Model I and 2.8°C for GCHS Model II. Charts 07 and 08 shows the indoor air temperature in one of the classrooms:

![Charts 07 and 08: Indoor air temperature in Room 2.](image)

3) Heating and Cooling Load

Due to its cooling effect in summer and heating effect in winter, the GCHS is able to save on the total heating and cooling energy consumption of the building. The year total heating and cooling load of the GCHS models are shown in Chart 09 with comparison to the base case:
4. CONCLUSIONS

This study is an attempt to tackle sustainable concepts in new buildings by introducing new and reliable means of passive techniques, such as natural ventilation system.

The use of computation tool i.e. WinAir and HTB2 can predict complex CFD simulations and energy performance of the ground cooling/heating systems respectively, allowing the comparison of results and the assessment of different solutions for final decision-making.

The CFD analysis pointed out that controllable underground channel can generate wind channelled effects, acting efficiently in the improvement of wind flow in external areas, necessary to increase the thermal comfort levels of pedestrians.

Alongside with these results, this system can be upgraded with turbines and produce wind energy, with capacity to provide from 300 to 1,600kwh per year.

The ground cooling/heating simulation results indicate that by introducing GCHS Model I, the building can reduce the energy consumption for heating/cooling by 17.3%, by introducing GCHS Model II, the reduction will reach 23.3%. The annual savings on heating and cooling energy are 4,480kwh for GCHS Model I and 6,032kwh for GCHS Model II.
It can be indicated from the results that when the amount of underground pipes increases, the resulting energy saving does not increase proportionally, therefore the choice on the scope of the system will depend on the heating/cooling requirements and is in fact a balance between energy saving and construction cost.

5. ACKNOWLEDGEMENT

This paper is part of ongoing project "International Network - Sustainable Building Design and Operation between the School of Architecture in Tianjin and Cardiff University", and is funded by Leverhulme Trust Foundation.

6. REFERENCES


ENVIRONMENTAL PROFILING OF MASONRY WALL PRODUCTS REGARDING THE MANUFACTURE AND CONSTRUCTION PHASES

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ABSTRACT: This paper deals with the life cycle assessment (LCA) of masonry wall products in general, and the environmental performance in terms of energy consumption and impacts due to manufacturing of pumice concrete and autoclaved aerated concrete blocks in particular. Materials acquisition processes either as raw material extraction or purchasing of processed basic materials, wall block production processes, transporting and plant facility management are studied through inventory investigations carried out at visited plants. Data is collected to analyse the inputs and outputs during the aforementioned processes. Depletion of mineral resources and rehabilitation of rural area and land following the raw materials extraction are other major concerns in LCA studies. The production and construction phases of masonry products are briefly discussed from sustainability point of view. Examination of greenhouse gas emissions based on energy types and consumptions will be the next step of the ongoing research study.

Keywords: masonry wall products, sustainability, LCA, manufacture, building, construction.

1. INTRODUCTION

Sustainable building and construction with respect to environmental and economic considerations are becoming more and more important because of high CO2 emissions attributed to increasing energy consumption in the building and construction sector.

Life Cycle Assessment (LCA) approach is, in general, used as a tool to assess the environmental performance of buildings, and mainly consists of inventory analysis and impact assessment of building products [1-2]. The life cycle of a building product includes five main stages; (i) raw materials acquisition, (ii) manufacturing (iii) construction (iv) use and (v) disposal phases. All stages include transportation. Recent studies indicate that, product manufacturing and construction phases have also important effects on the total environmental impact as well as the use phase of buildings [3-6].
There is a lack of information and knowledge on masonry products which show differences with respect to diverse technologies and methods used during their manufacture and construction according to countries’ specific conditions and different priorities for sustainable construction.

In Turkey, residential buildings are mostly built with in-situ reinforced concrete structural frame and infill external walls made of lightweight masonry such as autoclaved aerated concrete (AAC), pumice concrete blocks and fired clay hollow bricks. External insulation systems are also being increasingly used lately. While some information on LCA of AAC blocks and bricks can be found in the literature, there is very limited information particularly on LCA of pumice concrete blocks. Recently, increasing use of pumice concrete blocks in Turkish construction sector increases the importance of LCA studies about these blocks [7].

The aim of this work is to gather environmental information, and in turn, to make a general model for assessing environmental performance of aforementioned masonry products regarding the raw materials acquisition, manufacturing and construction phases.

2. ENVIRONMENTAL ASSESSMENT
Research work on environmental assessment is principally based on the following key issues:

Energy consumption

Green house gas emission

Rehabilitation of the quarry and the surrounding land

due to raw materials extraction and manufacturing processes of masonry wall products.
Investigations are carried out in order to identify the energy consumptions which is directly related with the technology owned by the plant, transportation methods and distances. The level of greenhouse gas emissions in terms of CO₂ can then be calculated depending on the types and amounts of energy used. Through the protection of natural resources and land goal, depletion of finite mineral resources in production of building materials and disturbance of land by raw material extraction processes are questioned.

Comprehensive information on extraction of natural resources, processing of raw materials, manufacturing and transportation are collected from masonry wall products manufacturing plants and data obtained is systematically organized. One plant for each masonry wall product, namely pumice concrete block, AAC and brick, was visited and their productions were investigated in detail. In this paper, however, only the raw material acquisition and manufacturing phases of pumice concrete and autoclaved aerated concrete (AAC) blocks are presented. Both stages include transportation. Plant facility characteristics are also considered as a factor affecting the environmental performance of factory-made building products.

3. INVENTORY INVESTIGATION OF MASONRY WALL PRODUCTS

Inventory analysis, one of the four main phases of LCA, comprises a process analysis of the Life Cycle of the subject of the LCA. The inventory investigation for a building product generally requires information on five main stages of the life cycle: material acquisition, manufacturing, construction, use, and disposal. In fact, the use phase of the building products plays the most important role in the whole life cycle in terms of energy use and environmental impact; however this subject has been extensively studied and beyond the scope of this primary work presented in this report.
3.1. Plant Facility Characteristics

Plants are generally located in the vicinity of the main raw materials sources in order to shorten the distance for transportation to plant and thus to save energy, and in turn save transportation costs. On the other hand, it is also considered not to be located so far from the construction areas where the products will be delivered in order to reduce the transportation costs. Big company plants are mostly operated continuously with a 24-hour three-shift system which is directly related with their capacity. The number of employees is dependent on the technology used in the factory (i.e. automation and/or whether based on machine or manpower) and the capacity of the plant. In general, factory and office workers live in the nearest residential areas and their transportation is practically provided by shuttles. There are usually only a few private cars used by the staff. Facility management, mainly of factory and office spaces, on heating, lighting, ventilation, sanitary equipment, food service, waste, and maintenance management (repair, cleaning etc.) of buildings have influences on the total energy consumption and therefore need to be taken into account. Power is supplied by sources like electricity, fuel, coal and natural gas.

3.1.1. Pumice concrete blocks manufacturing plant facility characteristics

The factory visited and investigated is located in the mid Anatolia, within the Cappadocia region rich with volcanic tuffs including pumice reserves. There are total 148 employees including 15 office workers, 4 workers in the quarry, 8 for cleaning of pumice, 15 in the atelier and mould work, 12 loading, 28 in the logistics, 6 in the restaurant and security, 60 workers in the production of blocks. One bus for 60 passengers and one mini bus for 25 passengers serve as shuttle for the employee. Shuttles are travelling total 340 km per day. There are 8 private cars used by the personnel. The capacity of the plant is 30 million blocks per year. There are two production lines operated parallel in the plant. Electricity is used for the operation of machines while coal is used for heating the buildings. The consumption of coal is 250-300 tons per year. The annual electricity consumption
of the whole plant including block production is 1.8 million kWh. 240 tons of water is consumed in the administration building.

3.1.2. AAC manufacturing plant facility characteristics

The factory visited and investigated is about 60 km southeast of Istanbul within the territory of Kocaeli city and is located at coastal zone. There are total 31 employees including 8 office workers, 3 in the laboratory and 20 workers in the production of blocks. One mini bus for 20 passengers serves as shuttle for the employee working in the production. The capacity of the plant is 100,000 m³ per year. Natural gas is used for heating the buildings.

3.2. Materials Acquisition

Material acquisition phase covers all activities and processes required to obtain all the raw materials, energies, and other material requirements for the product system [2]. Raw materials can be supplied either by extraction from the quarry or purchased in the processed form from other companies. In both cases, transportation matters in terms of energy. Regarding the extraction from quarry, the depth of the material deposit, removal of overburden and backfill after the excavation should be further considered.

3.2.1. Raw materials acquisition of pumice concrete blocks

Inner materials used in pumice concrete block production are: pumice aggregate, cement, water, and iron oxide as pigmenting agent. The auxiliary materials/products required in association with block production of the factory are: timber pallet, steel and plastic strip, and kraft paper protection cornerpieces for packaging. Pallets are made of local wood and are supplied from the neighbour towns. Pallets used in the production line are repaired in the atelier of the factory and thus can be used for some years. In the investigated factory all materials other than pumice and water are purchased from outside manufacturers, and information relevant to inventory analysis is summarised in Table 1 and Figure 1.
Water is supplied from wells bored at the factory site reaching to 170 m. depth using diver pumps operated by diesel electric generator. Water is used for cleaning and sorting pumice aggregate, and in the mixture of block in production in addition to sanitary purposes.

Pumice is excavated from three different areas; the main quarry is located at the factory site and the other reserves are 4 and 10 km far from the factory. Pumice is usually found close to the surface and as 4-5 metres thick bands. No extra process like blasting is required to loosen the pumice deposit.

Pumice aggregate preparation for block production is consisted of (i) excavation and loading of pumice, (ii) transportation to cleaning / sorting bunker, (iii) cleaning and sorting of pumice, and (iv) transportation to production bunker processes.

| Table 1: Figures for Material Acquisition in Pumice Concrete Block Production |
|-------------------------------------------------|---------------------------------|---------------------|-----------------|
| Processed basic materials                        | Annual consumption* | Supplied from (distance) | Transportation method/capacity | Transportation energy |
| Cement                                           | 30,000 t          | 65 km                  | Truck / 40 t                | Diesel fuel         |
| Iron oxide                                       | 84 t              | 797 km                 | Truck / Vary                | Diesel fuel         |
| Iron oxide                                       |                  | ~8000 km              | Ship / Vary                 | Diesel fuel         |
| Timber pallet                                    | 150,000 pieces   | 70 km                  | Truck / 40 t                | Diesel fuel         |
| Steel strip                                      | 150 t             | 797 km                 | Truck / 40 t                | Diesel fuel         |
| Plastic strip                                    | 70 t              | 797 km                 | Truck / 40 t                | Diesel fuel         |
| Kraft protection                                 | 35 t              | Vary                   | Vary                         | Vary               |
| Extracted material                              | Annual consumption* | Extraction processes | Machine used in processes | Energy input       |
| Pumice                                           | 300,000 t         | Excavation             | Wheel loader                | Diesel fuel         |
|                                                 |                   | Transportation (~4.5 km) | Truck                       | Diesel fuel         |
|                                                 |                   | Cleaning / Sorting     | Sieve                       | Electricity         |
|                                                 |                   | Loading                | Wheel loader                | Diesel fuel         |
|                                                 |                   | Transportation (~0.5 km) | Truck                       | Diesel fuel         |
| Water - block production                        | 95,000 t          | Pumping                | Water pump                  | Diesel fuel         |

* Consumption amounts are based on annual production of 30 million blocks having a density of about 600 kg/m$^3$. 

Water is supplied from wells bored at the factory site reaching to 170 m. depth using diver pumps operated by diesel electric generator. Water is used for cleaning and sorting pumice aggregate, and in the mixture of block in production in addition to sanitary purposes.

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3.2.2. Raw materials acquisition of AAC blocks

Inner materials used in aerated concrete block production are: sand, cement, lime, gypsum, aluminium powder and water. The other materials associated with block production of the factory are timber pallet and polyethylene wrap for packaging.

In the investigated factory all materials other than lime and cement are purchased from outside manufacturers/providers. Lime is provided from company’s in-house division located at the same site, and it is directly taken from the lime production facility and is stored in block manufacturing silo. Cement is provided from a sister company which is also located at the same site. Aluminium powder, as the air voids producing agent, is used in very small amounts in the mixture. It contains an enormous amount of energy, thus there is the risk of dust explosions and therefore is classified as dangerous goods. In its production aluminium foil is grinded in the ball mills and the flake obtained is filtered and stored in order the powder is to be oxidized. It is shipped from abroad, in this case from Sweden.
Water is supplied both from city water supply network and water wells located at the same site. Information about materials, relevant to inventory analysis is summarised in Table 2 and in Figure 2. Raw material consumption figures in the table are determined by calculations based on annual production of the factory and AAC recipe obtained from product literature [8]. Aerated concrete paste recipe is for a density of 500 kg/m$^3$.

**3.3. Manufacturing of Masonry Wall Products**

Manufacturing phase of a building product covers intermediate manufacture, product fabrication and/or assembly, packaging, and distribution activities. Additionally, it can cover raw material conversions not accounted for in the material acquisition stage [2].
Internal transportation within the plant, either indoors or outdoors, and between the quarry and the plant is also included as a sub-process. In the distribution phase, blocks are either provided directly to the end customers/construction site in order to shorten the distance or to the subsidiary sellers.

An important item for the manufacturing process is the maintenance and repair of machinery and moulds. Factories are usually closed for about 1-3 weeks in a year in order to have a proper maintenance.

3.3.1. Manufacturing of pumice concrete blocks

The processes of pumice concrete block production in the investigated factory are mainly: (i) mixing, (iii) moulding, (iv) drying, (v) packaging, (vi) storing, and (vii) distribution. Sometimes an additional crushing process prior to mixing process takes place when pumice aggregates are stored in the production bunker without a sorting process.

In the mixing process, pumice aggregate transported by a conveyor and an elevator, cement supplied from the silo located at the top of facility and water supplied by pipeline system are mixed in an automatic-controlled mixer. Sensors in the mixer measure humidity and required water is added to the mixer automatically. Iron-oxide used for colouring is manually added to pumice aggregate while being transported on conveyor.

In the moulding process, pumice concrete paste coming from the mixer is injected and pressed into steel mould and placed by vibration. Following this shaping process, wet blocks are burred and transported to drying chamber by automatic controlled transport tower. Moulds have to be replaced twice in three months. They are made in the metal atelier of the factory.

In the drying process, wet blocks remain in the drying chamber for 72 hours. In the summer period, wet blocks dry naturally. In the winter period, air temperature in the chamber is preserved at a minimum of 15°C by heating. Following the drying
of blocks, they are transported to packaging area by the automatic-controlled transport tower.

In the packaging process, as the initial step faulty blocks are determined by the help of sensors and removed manually while they are being transported to loading area. In the loading area, blocks are stacked onto trailers by a robot and tied by steel and plastic strips with manually operated tools. As the last step, trailers containing block packs are transported to storage area by tractors.

Broken/faulty blocks detected after drying process are used as pavement filler material in the factory area to cover the pumice dust lying over the ground.

In the storage process, block packs are unloaded by a forklift and stored in an open-air area until their distribution.

In the distribution process, block packs are loaded to trucks by the help of a forklift and transported either to subsidiaries or directly to construction sites.

The machines and equipments, and energy used in the manufacturing processes of pumice concrete block are summarised in Figure 3.

3.3.2. Manufacturing of AAC blocks

Manufacturing processes of autoclaved aerated concrete block production in the investigated factory are mainly: (i) crushing, (ii) mixing, (iii) moulding, (iv) cutting (v) steam-curing, (vi) packaging, (vii) storing, and (viii) distribution.

In the crushing process, sand transported by a conveyor, gypsum coming from the silo mounted on the top of the facility and water are fed to the wet ball mill. This mix is then transported and stored in slurry tanks having internal stirring devices with additional water.

In the mixing process, slurry from tanks, return slurry from an auxiliary tank, aluminium powder, lime and cement from silos mounted at the top of the facility,
and water are weighed and fed to mixer by automatic-controlled devices and mixed.

In the moulding process, the mixture is filled into the moulds which were earlier cleaned and oiled, and is waited for fermentation to expand and to gain sufficient stiffness. In this stage, aluminium powder reacts and released H₂ forms the porous structure. Thus the material increases in volume about 3-5 times depending on the density of the final product. About 70 minutes later, stiffened AAC cake is de-moulded and transported to waiting area to gain additional stiffness for cutting.

![Diagram of Pumice Concrete Block Manufacturing Processes](image)

**Figure 3:** Manufacturing processes of pumice concrete blocks.
In the cutting process, the cake is initially cut horizontally, then side-profiled by vertical cutting. Following these, top layer of the cake is removed by a vacuum device for top-profiling and cut waste is water-driven to auxiliary return tank. Profiled and cut cake is then transported to waiting area. After production of 30 cakes, they are transported to autoclaves for steam-curing.

In autoclaving, blocks are steam cured at 200 °C and 12 bar for about 10 hours. Then blocks are transported to packaging area.
In the packaging area, cut and cured cakes are transferred from railcars to timber pallets of the packaging conveyor, and transported to separating machine for detaching blocks from each other. Following these processes blocks are stacked manually on timber distribution pallets according to their dimensions. Finally each pallet of blocks is manually shrink-wrapped into packs with polyethylene sheets.

In storage process, each block pack is transported from packaging area to storage area by forklifts.

In the distribution process, packs of blocks are loaded to trucks by forklifts and distributed directly to construction sites.

Broken/faulty AAC blocks detected after curing process is stored in a waste area and sometimes used as pavement filler. Recycling of these blocks by grinding and adding to mix production is planned for the near future.

The machines and equipments, and energy used in the manufacturing processes of AAC block are summarised in Figure 4.

### 3.4. Construction

Wall blocks delivered to the construction site are unloaded from the trucks and are usually deposited inside the building which blocks will be used. Pallets used for shipping the products are usually left in the construction site and treated as waste material.

Wall blocks are lifted up to the upper floors by means of a (tower) crane in high-rise and mass buildings construction while a mechanical load carrying pulley is used in smaller buildings and construction sites. During loading, unloading and carriage of blocks to the place where the wall is to be built in the construction site, 1% wastage may occur.

Wall blocks are usually laid using a trowel by a mason. A thicker cement and lime based mortar is applied for bonding pumice blocks while a thinner cement based bed mortar is applied for bonding AAC. Block units need to be cut to fit in at
edges. AAC blocks are usually cut with a handsaw while an electrical cutting machine is preferred for cutting the pumice blocks. Half pumice blocks are produced for using at corners/sides which makes the wall to be built easier by saving working time and effort. Unavoidable material breakage and losses either during unloading from the vehicle, storage or construction of the masonry wall are treated as waste.

The transportation of masons to the construction site may be mentioned but this and the use of hand tools and smaller machines can be neglected in the environmental assessment, due to their very low impact on total energy use.

4. **CONCLUSION**

Energy and resource consumption and associated environmental impact as a result of raw materials acquisition, manufacturing and transportation of building materials and products are examined when assessing environmental performance of building products. From a sustainability point of view, the world reserves including non-renewable mineral resources are increasingly consumed in construction sector and the natural state of the landscape is destroyed leaving back a permanent change.

After pumice extraction, there is the opportunity to use these lands for planting vegetables by replacing the overburden top soil. In the rented quarries of the investigated factory, this option is frequently preferred by the land owners. However, quarry lands owned by the manufacturer are sometimes left without any rehabilitation.

Pumice concrete being produced as hollow blocks, and AAC being expanded in volume as a result of generated pores, both save material and thus give less harm to natural resources. Despite their contribution to energy efficiency (with their low thermal conductivity) during the operation (use) phase of buildings, extended durability and service life of these products gain importance in reducing the
depletion of natural resources by decreasing the need for new building construction.

Briefly, profiling the environmental performance of building products in terms of aforementioned key issues according to sustainability approach, and bringing the assessment results in discussion may help;

to encourage the use of energy efficient technologies in production,

to develop methods for minimally processed materials,

to recommend measures for reducing the impacts and costs,

to select alternative products/materials on environmental performance,

to plan production waste management,

to rehabilitate quarry and the surrounding land.

Investigations on LCA of masonry wall products are still going on. Examination of greenhouse gas emissions based on energy types and consumptions will be the next step of the study.

5. REFERENCES


EDUCATION FOR SUSTAINABLE DEVELOPMENT THROUGH HERITAGE CONSERVATION

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ABSTRACT: In order to cope with the challenges of the 21st century and the demands of our rapidly developing knowledge-based society, both school students and teachers nowadays are required to be equipped with a broad base of knowledge, high adaptability and independent thinking. In the recent few years students and teachers in Hong Kong have been involved with the architectural and planning/design professionals in various lectures, workshops, visits, and design activities, through collaboration from the universities and research institutes in these events, to expose various issues related to heritage conservation and stimulate their interests and concern. Such provide an interesting arena of the promotion of education for sustainable development in Hong Kong.

With the emerging awareness towards the importance of heritage conservation in Hong Kong, this paper demonstrates recent programme “Transforming Our Community Heritage – Schools, Parents, Community, Professionals and Government Partnership in Enhancing Sustainable Development of Our Community” organized by the Centre of Architectural Research for Education, Elderly, Environment and Excellence Ltd. (CARE) on how to promote education for sustainable development on heritage conservation and will be good reference for both Hong Kong and Mainland educators. Schools teachers and students can easily practice the general procedures, skills and techniques on their teaching and learning activities.

Keywords: Education for Sustainable Development, Heritage Conservation

1. EDUCATION FOR SUSTAINABLE DEVELOPMENT (ESD) - TREND IN THE WORLD AND HONG KONG

Moving towards the goal of sustainability requires fundamental changes in human attitudes and behaviour. Education is the key to moving society toward sustainability. Agenda 21 (UNCED 1992, Chapter 36, p.2) states clearly that:

“Education is critical for promoting sustainable development and improving the capacity of the people to address environment and development issues… It is crucial for achieving environmental and ethical awareness, values and attitudes, skills and behaviour consistent with sustainable development and for effective public participation in decision-making.”
In December 2002, the 57th Session of the United Nations General Assembly adopted a resolution to declare the United Nations Decade of Education for Sustainable Development from 1 January 2005 to 31 December 2014 and designated the United Nations Educational, Scientific and Cultural Organization (UNESCO) as lead agency in the promotion of the Decade of Education for Sustainable Development.

Governments and organizations around the world are now working on measures to implement the Decade of Education for Sustainable Development in their respective educational strategies and action plans.

Hong Kong is going through a transitional period. For Hong Kong to survive and prosper in the 21st century, the community needs caring citizens and professionals who will be team players and effective leaders: citizens who are willing to contribute to the society and environment that they share. We need to foster an integration of all these sectors of our community. Our young generation must expand their mental horizons and develop their potential as well-rounded individuals. In addition, in order to have a vision and direction for the future, it is necessary for young people to understand the past as well as care for the community. This will be reflected in an exploration and research for a new architecture and planning.

2. REORIENTING EDUCATION TO SUPPORT SUSTAINABILITY

ESD by nature is holistic and interdisciplinary and depends on concepts and analytical tools from variety of disciplines. ESD is more than a knowledge base related to environment, economy, and society. It also addresses learning skills, perspectives, and values that guide and motivate people to seek sustainable
livelihoods, participate in a democratic society, and live in a sustainable manner. As a result, cross-curricular approach will undoubtedly become the mainstream approach for ESD in schools.

In response to the call for integration of learning and development of core competencies and life-long learning among young people for the 21st century, the rationale of ESD coincidentally goes in line with the trend of curriculum reform in Hong Kong. The reforms are not just about changing the academic structure for secondary education, but also for primary and pre-schools education; they are about adopting a “whole new way of teaching and learning”, which are the golden opportunity to integrate ESD into the curriculum. Both the rationale of ESD and new curriculum structure aim to liberate the young mind, to develop broad knowledge base for students, to help them to understand the importance of contemporary issues on different levels from multi-perspectives, and ultimately to help them to become critical, reflective and independent thinkers and informed and responsible citizens.

3. ENHANCING TEACHING PROFESSION - NECESSITY FOR FURTHER COLLABORATION WITH PROFESSIONALS FROM DIFFERENT DISCIPLINES

Reorienting education to address sustainability should not only bind within the formal education system, but also include non-formal education sectors, for example professionals, NGOs, community organizations, and etc.. In our further curriculum reform, formal education and schooling provides opportunities for students to make explicit connections among different disciplines and examine issues from multi-perspectives. Non-formal educational sectors also take role to share the responsibility to further enhance the connections with various professionals and work cooperatively with the formal educational sector for education of people in all generations and walks of life.
ESD is a lifelong process, fostering broad cooperation and engaging outside assistance is essential to long-term and widespread success. To enhance teaching profession, the formal and non-formal educational sectors should work together to accomplish local sustainability goals.

4. HERITAGE CONSERVATION – THEME FOR GOOD PRACTICE OF ESD

In past, people used to compartmentalize our living environment within broad areas of concern (environmental, economic and social). These compartments however have to dissolve. This applies in particular to the various problems (population, air pollution, income disparity, etc) that have seized public concern. These are not separate problems but all one. Reorienting education to sustainability requires recognizing that traditional compartments and categories can no longer remain in isolation from each other.

The inherent complexity of sustainability however is difficult to communicate in simple messages. It is important for those promoting ESD to choose those cases and examples that are most easily understood by the students. Start with issues that students feel and understand at the local level. That is both valuable knowledge in itself and, if need be, a basis for moving on to more complex and global understandings.

The programme “Transforming Our Community Heritage” hence adopts the theme of “Heritage Conservation” as a platform to bring together schools, parents, community and professionals in transforming our community heritage and its context/surrounding to enhance sustainable developments. Heritage buildings and landmarks which form part of our living environment, also contribute to an attractive townscape. They should be preserved to provide a variety of building designs, to sustain memories of the past and to foster a sense of belonging and identity for the community. The key to building a quality living environment is to
formulate development strategies based on the principle of sustainable development which requires that we balance social, economic and environmental needs so that a vibrant economy, social progress and better environmental quality can be achieved simultaneously.

It is a good learning process of evaluating present conditions, identifying problems areas, and bringing about a community-wide consensus on how to overcome existing problems and manage change. Through the process, by learning about its strengths and weaknesses, students, teachers, parents, professionals, district organizations and government as part of the local community can decide together what it wants to be and then develop a plan that will guide decisions toward that vision.

The programme provides opportunity of integrated participation from school communities to explore with professional by introducing different study aspects, such as architecture, urban planning, urban design, environment, energy-efficiency, history, preservation, and etc. Through the exploration of students’ neighbourhood, local community, district and the society, students are able to recognize the traditional way of life in Hong Kong, to identify the opportunities and inequities phenomenon in the society, to inspire students how to transform our heritages and ensure sustainable development through the practice of “Design Laboratory”.

5. “TRANSFORMING OUR COMMUNITY HERITAGE – SCHOOLS, PARENTS, COMMUNITY, PROFESSIONALS AND GOVERNMENT PARTNERSHIP IN ENHANCING SUSTAINABLE DEVELOPMENT OF OUR COMMUNITY”

The two-year “Transforming Our Community Heritage” programme patronized by Sustainable Development Fund and sponsored by the Home Affairs Bureau, is coordinated and launched by CARE. The programme aims to provide an opportunity for integrated participation by school communities and professionals
to develop creative design proposals for conserving our built heritage with a view to better integration with the community. Through an interactive, participatory process, students' research and ideas provide stimulating, spontaneous and original contributions to the District Councils, Government and the community; and students learn from the process the value of a commitment to sustainable development, which will be as important as the “products” of the programme. Moreover, the integrated and participatory creative workshop process fosters ideas on the possibilities for transforming historical buildings and sites into economically and socially sustainable entities for the community.

- Students as Team Members to comprehend the characteristics and enhance the identity of our Community Heritage and to take part in developing Creative Transformation Proposals
- The community, parents, schools and professionals as partners to enhance the Transformation of our Community Heritage
- Developing Sustainable Environmental Agenda for Neighbourhood Environments and Community Districts
- Preparing documents, a webpage and research and design projects to enhance community influence

More than 70 schools/community organizations and 1,000 participants took part directly in the programme. Participants including primary & secondary students / teachers / parents were grouped into 13 to study various community heritage sites in Hong Kong. Meanwhile, volunteer mentors were recruited from tertiary institutes to assist in the execution of the project.

5.1 Workshops
13 rounds of thematic Workshops were organized for the participatory schools/organizations to explore design possibility for various heritage sites in Hong Kong. Each round of thematic Workshop was comprised of 4 tiers of activity
to let the participants to construct sense of sustainable development for heritage incrementally. They are namely:

-Community Heritage Sites Visit cum Fun Fair Day (社區文物導賞團暨遊樂日): a one day programme for participatory students to grasp the concept of sustainable heritage conservation through games and site visit.

-Community Heritage Dream Workshop (社區文物夢工場): a half day programme for participatory students to share their findings from their previous study with others. They also worked with architects, urban planners, district council members to explore different ways of heritage conservation in the activities.
-Individual Group Follow-up (小組個別跟進): 2 rounds of follow-up activities including school visit and sharing session to provide guidance and assistance for the participatory students on their design of selected heritage sites.

-Community Heritage Fashion Show (社區文物花生騷): a half day programme for the students to present their rational and way of conserving heritage in front of other groups and invited guests.
5.2 Exhibitions

2 thematic exhibitions, namely tHIRD HORIZON (新地平綫) and TRACES & THREADS (綫・索) were held to display participatory students’ works and models. The exhibitions included series of joint events collaborated with universities, government departments, professional institutes and NGOs to review the programme result. The events included seminar, sharing session cum recognition ceremony, and exhibitions.

Guest speakers were invited including legislative councillor, government officials, district councillors, representatives of community organizations, professionals and academic shared their experience with the participatory schools/organization to broaden their knowledge in heritage conservation and sustainable development. More than hundreds participants from government, professionals, academic, local community groups and schools took part in the seminar to discuss the topic and the importance of promoting sustainable community development and design.
6. PROGRAMME IMPACT

It is fully anticipated that some of the students’ design proposals may not be realistic, but their researches and ideas will be stimulating, spontaneous and original as valuable contribution to the “team” as well as to the District Councils, Government and the community; and students will learn from the “process” of enhancing the value of commitment to sustainable development, which will be more important than (if not as important as) the design products. Ultimately, through this programme the participating and other informed student body will develop a sense of identity and belonging to their “own designed” community heritage.

The outcome of the programme may not be an one-off exercise, but more significantly could become the start of the mechanism initiated for community
building with parents and students, as well as district leaders (such as District Council Members, involved Organizations’ representatives, etc.) providing the holistic support and care to the “continuous” process for the sustainable development of our community heritage. The scale of the design project proposals can range from colour scheme for repainting a heritage building, conservation of rural districts and historic relics… to transforming a historical building into a restaurant, turning a historical district into a tourism attraction…etc – all depending on the needs of individual districts’ and participants’ responses. But it is not the intention of this programme to provide fully detailed schemes for immediate construction and alterations.

In fact the impacts and outcomes of the project are far more reaching and virtually benefit and have impacts on all existing and future proposals for conservation of our community heritage, as it is also the objective of this programme that the experience, processes and products are readily shared by the other schools, more professionals and the public, as well as providing inspirations to innovative designs and transformation proposals and their future users, thereby assembling valuable sustainable development design database for the policy decision makers and related government departments.

The project provides a model of “community participation design process” undertaken and promoted by schools in Hong Kong involving the active participation of students together with their teachers, parents, alumni, community representatives and professionals; this would be a powerful, stimulating, and innovative teaching – learning model as well as promoting capacity building for sustainable development in the community, incorporating the important features of:

from classroom to the real world: where students’ own neighbourhood environment become the “laboratory” for their intervention;
from passive to active: where students (in fact motivating the whole school) become actively involved in the creation process;

from one way to interactive: where students engage in the interactive process of community participation and design exploration;

from individual to collaboration: where students learn not only individually, but also collaboratively as members in teamwork, and further develop values through community engagement;

from products to process: where students involve in the process to search for different approaches and possibilities, rather than one single solution to the identified problems/needs.

A significant outcome from the project is a paradigm shift in the culture of participating partnership schools – to be open and participatory, and that students take on a contributory role hand-in-hand with their teachers and communities.

7. CONCLUSION

“Transforming Our Community Heritage” shows success in professionals-schools-government-community partnership in providing schools into an inspiring environment full of learning capacity and creativity. The programme responds to the needs for further support for the promotion of ESD on heritage conservation. It has established an “ESD Network” for school sector to conduct collaborating activities with the education sectors and professionals. The outcomes will enhance invaluable foundation to support the promotion of ESD on heritage conservation and help contributing to the process to move Hong Kong towards a more sustainable city.
8. REFERENCES


