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Capital Cost Drivers in Tall Buildings

资本成本在高层建筑中的导向

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Abstract

In land-scarce nations, one of the solutions for land use intensification is to go upwards and downwards in construction. However, how does this affect sustainability and the economics that goes with it? This paper discusses the common Capital Cost Drivers in Tall Buildings. It also critically reviews the sustainability element to Green Mark in Singapore and juxtaposes it to the capital cost drivers. Research studies have shown that there are benefits to employing green design strategies but at a certain capital cost premium. However, it is these cost premiums, coupled by the low holding period and high land cost to land/ buildings that may dissuade developers from quick adoption. Having said, the benefits on the use of these green strategies goes beyond the triple bottom line approach and this paper will conclude on value engineered solutions that are cost effective and sustainable at the same time.

Keywords: Sustainability, Tall Buildings, Green Mark, Cost Drivers

摘要

在土地稀缺的国家，土地集约利用的解决方案之一就是向空中或向地下建设。然而，他是如何影响可持续发展和与之伴随的经济的呢？本文将讨论常见的资本成本导向。同时也批判性的评论可持续性元素以及新加坡的绿色标志和并列的资本成本导向。调查研究表明，采用这些绿色设计策略有好处，但是必须是在确定的资本成本溢价之内。然而就是这些成本溢价，在加上土地／建筑低的持有期和高的土地成本，很有可能有碍开发商的快速运营。尽管如此，使用这些绿色策略的好处也超越了三重底线的做法，本文将会总结成本效率高且可持续的工程解决方案。

关键词：可持续性，高层建筑，绿色标志，成本导向

Introduction

Tall buildings, especially in Singapore, are necessary in order to maximise the value of land by the developer. However, tall buildings do not always come cheap and this paper discusses and examines the cost drivers of Tall Buildings including related Sustainable Cost Premiums. In addition, the additional element on sustainability that could increase the cost of these buildings is apparent and it is because of such capital cost increase that could dissuade Developers from adoption and embracing sustainable design and strategies or may result in point mongering[1]. Table 1 show that there is indeed a cost premium for green buildings, let alone tall buildings.

This paper also looks at the suggestions on how sustainable design and strategies could be embraced with empirical data, to show that Green Tall Building does pay, notwithstanding the premium cost (see Figure 1). For the purpose of this paper, the Cost shall be defined as Capital Construction Cost of the building and shall not regard the cost of land, Life Cycle Cost, Whole Life Cost nor Intrinsic Value. Cost would also be expressed on a $/m^2 of Construction Floor Area (CFA).

引言

高层建筑，尤其是在新加坡，对开发商最大限度的扩大土地价值是非常必要的。然而，高层建筑通常不会便宜，本文讨论和研究了高层建筑包括相关的可持续发展成本溢价的成本导向。此外，可持续性的额外因素是很明显可能提高这些建筑的成本的。这是因为如此的资本成本提高可能阻碍开发商采纳和实行可持续发展设计和策略，或者可能导致一切成为空谈[1]。表1显示的是一个真正的绿色建筑成本溢价，那就更别说高层建筑了。

本文还着眼于可持续发展设计和策略是如何与经验数据相整合，说明绿色高层建筑虽然成本费用低，仍需要支付（见图1）。对于本文的目的，成本应该定义为建筑工程资本成本而不应把土地成本，生命周期成本，整个生命成本计算在内，也不是内在价值。成本应该表示为工程楼面面积（CFA）单位面积的费用。

高层建筑的成本

高层建筑是由几个因素所驱动的，诸如风荷载，功能，机械和电器（M&E）的要求等。建筑本身越高那也会越昂贵。尽管911事件的发生，Code等人（2003）指出目前开发商的兴趣并没有在高层建筑界有所短缺，尤其是土地稀缺的区域。这是因

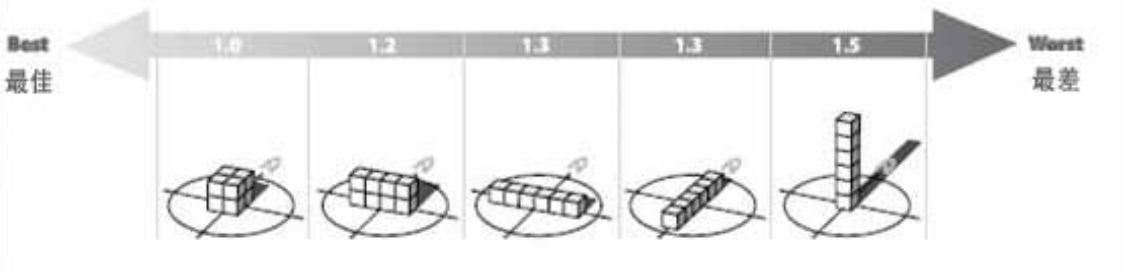

Figure 1. Relationship of cost from the square base building juxtapose to the extreme right model which is a tall building of which cost.
图1. 方形基地建筑同并列其右的高层建筑模型成本关系

Cost of Tall Buildings

Tall building designs are driven by several factors, such as wind loading, functionality, Mechanical and Electrical (M&E) requirements and the like. The taller the building is, the more expensive it would be. Despite the events of September 11, Code et al (2003) has noted that there is currently no shortage of developer interest in tall building, especially in land scarce areas. This is because building tall is the only way that can be used to intensively use a small size of land.

The relationship of building cost with height is complex, reflecting a wide range of variables which on a per-unit basis may vary with the height of the building. However, from a DLS Report[2] on Tall Buildings, it is evident that the efficiency of tall buildings does decrease with height which also corresponds to higher shell and core cost on a $/m^2$.

Collins et al (2008) has also observed that the cost of a 60 storey building could run about 25% over those of a typical 10 storey building[3]. The question is, "do taller buildings also mean better rent?" Code et al (1995) has studied several buildings in New York and have found that rents in taller buildings perform much better than shorter buildings. However, other factors such as locality, age of the building and the sustainability of the building are other factors to be considered. Therefore, it would certainly seem that tall buildings do pay off.

In all projects, Developers mainly look at capital cost juxtapose to capital budgets. In many ways, this is correct as the "bottom line" counts as in most business situations which include Funders and Banks. That is to say, the capital cost will affect the Internal Rate of Returns, Payback and Yield of the development. However, if a myopic view of capital cost is looked at solely at the time the building is built, one is not considering the intrinsic value of other sustainable technologies that are potentially to be incorporated because the capital cost is too high. We shall explore what are the cost drivers of tall buildings and what are the intrinsic values of sustainable features and technologies.

Cost Drivers

Collins et al (2008) have studied the Triple Bottom Line (TBL)[4] approach to tall building economics and has made mention on the studies of

BCA Green Mark Award Type BCA绿色标志奖类型	Green Cost Premium (%) 额外绿色建造成本 (%)	Payback Period (years) 投资回收期 (年)
Platinum 白金奖	2% to (至) 8%	2 to (至) 8
Gold Plus 金奖+	1% to (至) 3%	2 to (至) 6
Gold 金奖	1% to (至) 2%	2 to (至) 6
Certified 认证	0.3% to (至) 1%	2 to (至) 5

Table 1. Cost Premium for Green Buildings (Source : www.bca.gov.sg)
表1. 绿色建筑的额外成本 (www.bca.gov.sg)

为建造得高是小规模土地集约利用地区唯一的方法。

建造成本和高度之间的关系是相当复杂的，反映出许多广泛的变量，对每一个单位可能会基于建筑高度的变化而变。然而，根据高层建筑的DLS[2]报告，高层建筑的效率会因高度而减低，同时也与较高外壳与核心筒每平方米的价格有关。

Collins等人（2008）也观察到一个60层楼的高层建筑的建造成本只比一个10层的建筑多了25%[3]。问题是“更高的建筑意味着更好的租赁么？”Code等人（1995）研究了在纽约的几栋建筑并发现在高层建筑租赁比租用低层建筑更好。然而其他诸如地区、建筑年龄和建筑的可持续性都属于要考虑的因素。因此高层建筑可见是相当有优势的。

在所有项目中，开发商主要是把资本成本和资本预算放在一起看。在许多方面，这“底线”通常都是正确的并出现在大多数商业情况下其中包括资助者和银行。也就是说，资本成本会影响到内部收益率回报，投资回收期和产量的发展。然而，如果资本成本只是目光短浅的只看了建筑被建的这段时间，而不考虑其他可持续发展技术的内部价值，那么在未来有可能由于资本成本太高而被合并。我们将探讨什么是高层建筑的成本动因，什么是可持续发展的特点和技术的内在价值。

成本动因

Collins等人（2008）针对高层建筑经济研究的三重底线（TBL）[4]方法已经在高层建筑内部空间研究中提到，争取尽可能多的能源效率，员工工作效率经营效率等；所有这一切需要融合成一个整体，工作才能为可持续发展建筑的精神作出贡献。Shin等人

[1] Point mongering is frequently referred to as the process of looking at a rating tool, e.g. the Singapore Green Mark rating tool, and find the easiest points to get at the lowest cost instead of looking at overall sustainable strategies for the building.
[1]空谈点是指经常在寻找一个评级工具的工程中，例如新加坡绿色标志评级工具，并找到最简单的点来获得最低成本而不是在寻找建筑的整体可持续性发展策略。
[2] This report was carried out by Steve Watts from Davis Langdon. The study was carried out in conjunction with KPF. This report shows that the efficiency of the building design (Gross space vs Net letable area) falls as the building gets higher due to the core space. This translates to a possible 30% shell and core cost increase.
[2]这个报告是Steve Watts从Davis Langdon处总结出来的。并结合了KPF进行了研究。这份报告显示建筑设计的效率（总面积对净出让面积）的降低随着建筑的升高是由于核心筒面积。这就意味着一个可能30%的维护结构和核心筒的成本增加。
[3] This figure can change with the use of different types of construction technologies, site, situation etc.
[3]这个数据可以根据不同类型的施工技术，现场，环境情况等使用而改变。
[4] Triple Bottom line refers to the 3 major characteristic of Sustainability in general ; Social, Economic and Environment
[4]三重底线是指三个主要的通常意义上的可持续发展的特性：社会，经济和环境。

internal spaces on tall buildings to garner as much energy efficiency, staff efficiency, operating efficiencies etc; all needing to work as one to contribute to the ethos of tall sustainable buildings. Shin et al (2004) have studied the designs of structural floor slabs and have found that for taller buildings, structural cost would increase by 2% or 11.5% if the structure is made of steel. However, with clever planning on floor to floor heights, an additional floor can be created from the same total height of the building[5] which translates to, although additional cost, maximisation of the intensification of the land use. Additional floors also mean additional revenues on the same area of land. But again, this will drive up capital cost but taking a 10 year study, the revenues generated from this additional floor will well cover the additional cost, giving a much earlier payback. A summary of the cost distribution can be summarized in Table 2.

Cost Drivers 成本因素	% of Total Construction Cost 总工程成本的百分比数
Structure 结构	15-20%
Façade 立面	15-20% (Commercial Buildings 商业建筑) 10-15& (Residential Buildings 住宅建筑)
Sky Gardens & Sky Courts 空中庭院和空中场地	Percentage will depend on the size of the Sky Gardens 百分比由空中花园的大小而决定

Table 2. Summary of Cost Distribution for Cost Drivers
表2. 成本因素的成本分配汇总

Structure

One of the main cost drivers of tall buildings will be the structure of the building. The following models are from a study of Davis Langdon & Seah International, together with KPF International. It was found that the percentage efficiency of a building with the same Gross Efficient Area or Net Floor area will decrease as the building goes taller (see Figure 2). The reason is that the core of the building remains mostly the same and the net floor plates for each floor will reduce. This would also translate to approximately 30% increase in shell and core cost of the building due to increase wall to floor ratios, the fixed cost of the core and the fix square meterage of area.

In order to make the structure cost to be more palatable, it is essential to study the efficient use of concrete and how the concrete is used. In Singapore, part of the Green Mark feature is the Concrete Usage Index (CUI) which basically measures the volume of concrete in tall buildings. Tall buildings usually have a CUI of 0.6 which means for every 1m^2 of floor area, there is 0.6m^3 of concrete used. Keeping to this efficient ratio will ensure cost is kept to a manageable level but in order to improve this ratio, higher concrete strength can be used, e.g., grade 70 (similar to the construction of The Sail[6] in Singapore) and this can be infused with the use of low carbon, high strength concrete[7].

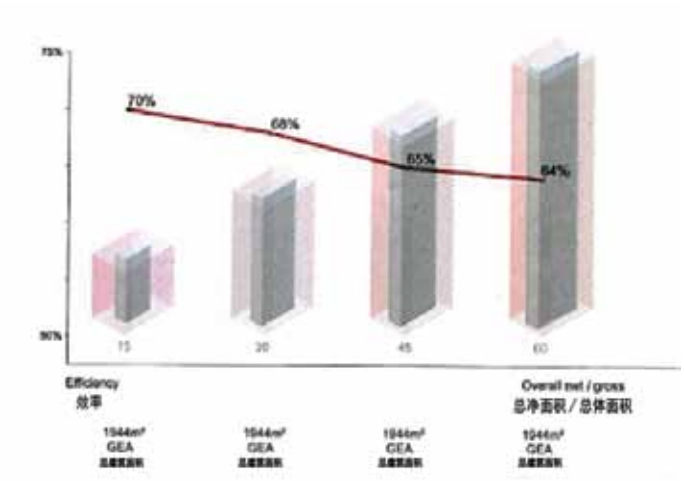

Figure 2. Percentage Efficiency against Building height (Source-DLSI report)
图2. 针对建筑高度的效率百分比（出自：DLSI报告）

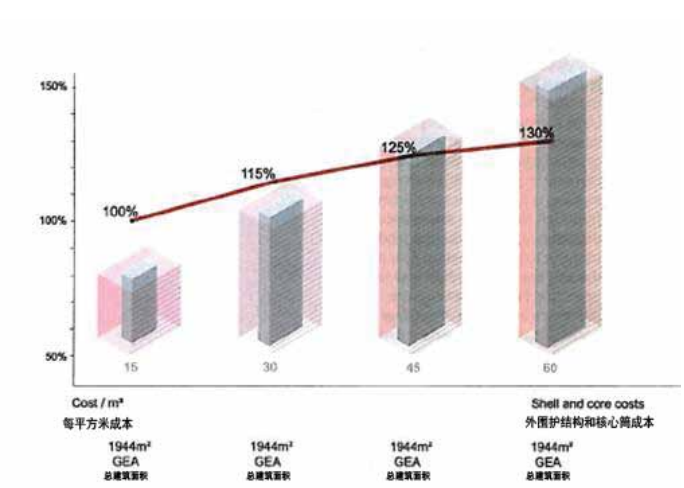

Figure 3. Percentage cost against Building Height (Source-DLSI Report)
图3. 针对建筑高度的成本百分比（出自：DLSI报告）

Façade

Another major cost driver of tall buildings is the Façade. The façade's contribution to environmental control is therefore crucial. These façades will be glazed with high efficiency glass to control heat gain which can be costly, especially in Singapore. A study of the cost of how façade area can be greatly affected by the building height and shape was carried out with HOK International and DLS in 2009. Figure 4 shows that although the GFA/ NFA of the building is similar in all the options, the shape of the building can greatly affect the cost. This is due to the changes to the façade area, among other internal changes such as Mechanical systems and the like. With the use of high performance glass to keep ETTV[8] low or the use of external sun shades, this would send capital costs up.

It is these circumstances that modelling using a Object Oriented CAD or Building Information Model (BIM) can not only produce the results in the façade area, but with the integration with Eco tech and TAS for

[5] This is usually governed by the AMSL or Average Mean Sea Level governed by the Government / Urban Renewal Authority (URA).
[5]这通常是由AMSL管辖的或者由政府或市区重建局（URA）管辖的平均海平面数。
[6] The Sail stands at 245 meter and 70 storey high. It is Singapore's tallest condominium / apartment and is currently one of the top 10 tallest residential buildings in the world.
[6]船帆项目高245米有70层楼高。这是新加坡最高的公寓楼，它目前是全球十大最高住宅之一。
[7] High strength concrete gain strength slower but are much stronger than ordinary concrete (source from Engro / Pan United). This can be easily addressed with extra propping to the underside of slabs.
[7]高强度混凝土获得强度速度慢但是比起普通混凝土要牢固很多（来自Engro / Pan United）。这可以很容易地解决额外的楼板底面支撑。
[8] ETTV stands for Envelope Thermal Transfer Value of the building and is applicable to air-conditioned building spaces with aggregate > 500m2
[8]ETTV就是建筑密封热传导值并且适用于总面积大于500平方米的空调环境的建筑。。

example, we can easily see how the sun angles will affect the design of the façade and the designer can effectively protect the necessary areas of façade.

Vertical Transportation

Core design is the crucial starting point for developing the internal operation of a tall building. The aim of lifts and escalators is to effectively transport the building occupants to their destination in an optimum time. However, this optimum time differs for the different grades of Office Buildings as well as compliance to fire regulations. With an increase in building height comes an increase in strategic options to achieve these targets economically. Fundamental options are sky lobbies, double-decker lifts, zoning of lifts or a combination of both.

From this point, one has to acknowledge that cost analysis studies are needed to integrate design into vertical transportation designs and study the Cost Benefit Analysis (CBA) of using the different options. Having said, the type of lifts can also be a sustainable consideration. Kone Corporation has come up with a Regenerative lift that can generate electricity as it travels along the rails (at a minimum length of 150m). It would cost approximately 15% more for the lift capital cost but with a payback of 6 years. Such excess energy produced can be channelled back into the common areas of office blocks or back to the grid.

Sky Gardens and Sky Courts

Sky gardens and sky courts are design strategies employed by architects to bring in the "City Squares" and recreational areas into the tall buildings. According to Pomeroy (2007, 2009), the effects of sky courts are viable alternative spaces as an accompaniment to sustainable designs that embraces social interaction, basically adding value to the multiplicity of function and adaptive over time through changing socio-economic needs. Distinct advantages would include better values due to views, social connectivity, linkages to different urban fabrics etc, and yet integrating into the tall building design.

However, these spaces, depending on the design of the sky courts and the relevant legislations in the country of origin, are not considered as GFA. This would only mean that the more area spent onto these areas, the $/GFA analysis would be higher. Simply put, these areas incur cost to build and decorate but are not part of the legislated built up area by the authorities. Therefore, there is a balance to be achieved because if there is an excessive design of these sky courts and the overall construction cost of the building is high, these sky court areas will be lessened which may impact the overall reason of having the sky courts in the first place.

It would be interesting to see further studies on the value of these sky courts and gardens (like the sky deck of HDB's Pinnacle and Marina Bay Sands) juxtapose to the construction of the particular element.

Social and Economic Value

Pearce (2003), in his report, mentioned an interesting element on Productivity and Efficacy of buildings. In the report, buildings take up 360 million tons of raw materials of which 90 million tons reappears as construction and demolition waste, implying a conversion efficiency of 75%. Five percent of the UK's energy consumption is used in construction and 2% of all UK Green House Gasses (GHG) are related to construction. The longer a building takes to construct, the more the construction processes would emit impurities in the form of pollution and energy usage. Therefore, productivity and efficiency is the key.

For tall buildings, the construction period is somewhat dictated by the construction cycle of the structural floor and the closing up of the

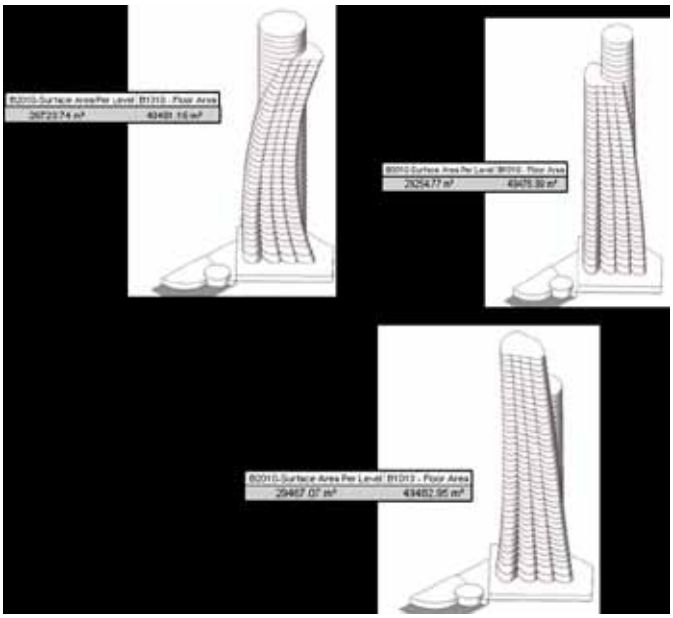

Figure 4. Building Design against Cost (Source-HOK-DLS study)
图4. 根据成本进行的建筑设计（出自：HOK-DLS研究）

（2004）研究结构楼板设计的时候发现为了建造更高的建筑，如果结构是用钢材的话，结构成本将增加2%或11.5%。然而，随着楼板至楼板的巧妙设计，对于同一高度的建筑来说，可以额外增加一层楼板，[5] 也就是说虽然有额外的成本费用，但是可以加强土地利用的最大化。额外的楼层也意味着在同一片土地上的额外收入。这会推动资本成本，但从十年间的研究中，这个因额外楼面而产生的额外收入也可以支付额外成本，使得投资回收期更短。从表2中可以归纳出成本分布一览。

结构

高层建筑的一个主导成本之一就是建筑结构。接下来的一些模型是来自于Davis Langdon与Seah国际的研究，还有KPF国际。人们发现建筑具有同样百分比效率的效总面积或是楼面净面积，会随着建筑的升高而降低（图2）。究其原因是建筑的核心筒基本会保持不变，而绝大部分的净楼板面积将会减少。，由于墙地比的增加、核心筒固定成本和面积的固定计量收费，这也将转化为约为提高30%的建筑外围护与核心筒成本。

为了让结构成本更使人满意，研究混凝土有效利用和如何利用变得非常必要。在新加坡，绿色标志功能的一部分就是混凝土使用指数（CUI），也就是基本测量高层建筑所使用的混凝土体积。高层建筑通常的混凝土指数为0.6，意味着每平方米楼板面积中使用了0.6立方米的混凝土。保持这个效率将保证成本控制在一个合理范围内但是为了提高这个效率，高强度混凝土可以使用70级的（类似新加坡船帆项目[6]的结构），这可以使用低炭高强度混凝土浇铸。[7]

立面

另一个高层建筑的主要成本主导就是立面。立面对环境控制的贡献是至关重要的。这些立面可能是高效玻璃釉面外墙能控制热量的获取，而这很有可能是非常昂贵的，尤其是在新加坡。2009年，一项关于立面可大大受到建筑高度和形态影响的研究，由HOK国际与DLS共同进行研究。图四显示，虽然建筑总面积／净楼层面积每个方案都非常相似，可是形状却极大程度的影响了建造成本。这是因为立面区域的变化从而导致了一些内部变化例如机械系统或者相类似的部份。使用高性能玻璃来控制低密封热传导值[8]或者是使用室外遮阳，这可能会提高资本成本。

在这种情况下，用面向对象cad或者是建筑信息模型（BIM）建模不仅可以产生立面面积的结果，还可以结合Eco Tech和TAS进行分析。例如，我们可以很轻松得看到太阳角度对立面设计的影响和立面所需高效防护设计。

building, that is to say, the installation of the façade systems. Therefore, the faster the building is built, coupled by efficient use of technologies and materials, it would also mean a greener and more sustainable development. Therefore, buildability and constructability is also the key to a sustainable green building.

In Singapore, buildings above 2000m^2 GFA are required to meet certain Buildable Scores. If the project does not meet the Government's minimum score, the building will not be granted permits and it will not be built. This score ensures modularisation and standardisation in construction, ensuring a faster construction period cum cycle. In addition to this, structural engineers may choose to use buildable materials such as Precast or Structural Steel, all of which are more expensive than conventional cast in situ. However, the use of Precast and structural steels, although proving about 3%-6% more expensive, will not only enable the structure to be built faster, but because of the ratio of the material, columns will be smaller. This also constitutes to more net "lettable" area or saleable area. Therefore, if developers only look at the bottom line of construction and do not take into account the whole life cost, they will miss the benefits of using such sustainable materials that promotes social sustainability.

Benefits of a Sustainable Building

According to Code[9] (2003) and Dean (2008), sustainable buildings, especially commercial buildings, will have the following attributes:

- Variable capital cost depending on the level of achievement in the assessment scheme (e.g. Green Mark, LEED, Greenstar etc)
- Higher Occupancy Rates
- Higher Productivity
- Higher Yield and capital gain.

A similar study was conducted by Davis Langdon Australia who validated the data set with the Green Star rating system on their buildings. From the report, similar results were obtained.

Therefore, those sustainable buildings that touch on the triple bottom line approach to the building do produce better yield. However, from the three studies it is also clear that the higher the level of rating, there will be a level of extra-over capital cost. This extra-over cost can affect the budget set for the project and when a benchmark is carried out, the analytical cost on a $/m^2 GFA, would show higher cost than a standard building. This may cause Developers to revert back to standard buildings that have little or no green features[10]. Therefore, the QS Role is paramount to prove through analytical cost models that involve Life Cycle Management techniques that with slightly higher capital cost, the operational and maintenance cost of the building would be lower over a period of time.

In addition to this point, the Construction Industry of Singapore, through the guidance of the Building Construction Authority (BCA), has moved into another element of sustainability; and that is on productivity. Developers and consultants are now trying to understand the delicate balance between the productivity of the project and

竖向交通

核心筒设计的出发点，对于开发高层建筑内部运作起着至关重要的作用。电梯和自动扶梯的目的是有效的运送建筑内的使用者在最佳时间内抵达他们所需抵达的地方。然而这个最佳时间是根据不同级别的办公楼和符合消防法规而不同的。随着建筑物高度的增加，则需要用经济的眼光来改进方式策略。基本选项是空中大堂，双层轿箱，电梯分区或两者兼而有之。

从这点上来说，不得不承认成本分析研究需要把设计结合到竖向交通和使用不同方案的成本效益分析（CBA）研究中一起考虑。尽管如此，电梯类型也是一个可持续发展的考虑。Kone公司已经研发了一种可以通过其穿越导轨而自己发电的电梯（至少需150米以上）。它可能比普通电梯耗资多出约15%但是投资回收期为六年。而过剩产生的能量可以被传输到办公空间、公共区域或者是回到电网系统。

空中花园和空中场地

空中花园和空中场地是建筑师利用设计策略在高层建筑中引入“城市广场”和休闲区的办法。根据Pomeroy（2007，2009）所说，空中场地的效果是种可行的可替代空间，作为涵盖社交互动可持续发展设计的附加物，其实是通过社会经济需求变化为多功能和适应性增值。其独特的优势在于因视野，社会联系，与不同城市层面的连接等而获得的更大价值，并整合到高层建筑设计过程之中。

然而这些空间，由于空中场地的设计和相关国家设计法规规定，将视为总建筑面积。这将意味着更多的空间可能被用作该用途，单位面积的价格当然也会提高。简单地说，这些区域的建造和装饰的支付成本不是授权的法定建筑面积的一部分。因此需要达到一个平衡，因为如果过度的设计这种空中场地的话整体建筑工程成本会很高，空中场地的区域需要减少，因为把空中场地放在首位可能成为会影响整体设计的原因。

如果能看到进一步有关这些空中场地和花园（就像HDB的Pinnacle和Marina Bay Sands的空中平台一样）价值同个别部分建造的研究，那会是一件很有趣的事情。

社会和经济价值

Pearce(2003)在他的报告中提到一个有趣的建筑生产力和效能的元素。在这份报告中，建筑物占用360万吨原料，其中90万吨为建造和拆除时的废料，这就意味着75%的转化率。英国能源消耗中，5%是施工过程中的消耗，2%是与施工相关的英国温室气体（GHG）排放。建筑所需要的施工时间越长，在这个施工过程中所发出的以污染和能源使用形式产生的杂质也会越多。因此，生产力和效率就是关键。

对于高层建筑来说，施工周期是由结构楼板的施工长度和建筑封闭决定的，也就是立面系统的安装。因此，建筑被建造的越快，技术和材料的有效利用越高，这就意味着一个更绿色和更为可持续发展的开发项目。因此，可建性和可施工性也是一个可持续绿色建筑的关键。

在新加坡，建筑面积大于2000平方米的建筑物必需满足一定的可建造分数。如果这个项目没有达到政府所要求的最低得分，那这个建筑将不能被授予建筑许可证也就不能被建造出来。这个分数确定了模块化和标准化建设，确保了更快的施工长度及周期。除此之外，结构工程师还可以选择可建造材料如预制或结构钢材，

[9] This report consists of case studies on several LEED buildings. LEED or Leadership in Energy Efficient Design is one of the most established and earliest assessment system in the world. Therefore, there will be more buildings using LEED in the US coupled by older buildings that can provide more data set.
[9] 这份报告由多个LEED建筑的案例分析组成。LEED或者叫做能源与环境设计先锋是世界上历史最悠久，最早的评估体系之一。因此，结合一些老建筑所提供的数据在美国会有较多的建筑使用LEED认证。
[10] In Singapore, this will not be the case as for all buildings above 2000m2 GFA, it is mandatory to achieve a minimum of Green Mark Certified prior to issuances of the Building Plan permit.
[10] 在新加坡，当建筑的建筑面积超过2000平方米时，情况不是这样的。达到最低的绿色标志认证，并得到优先颁发建筑规划许可证的是强制性的。

cost. Currently, there are business consultants who are studying the business needs and processes of firms and translating them to spaces and places for people. Such studies can be orchestrated into the sustainability model by studying not only the possible productivity gains by designs, but also, the sustainable angle on lesser energy requirements and the socio-economy portion in social equity.

Conclusion

In the series of Mega-structures by Discovery Channel, the hypothetical future tall buildings/ tall city of Extopia Shanghai was discussed. Triple the height of Qing Mao, futuristic equipments and technologies such as linear motor lifts, naturally shaped façades for catching wind and the like were all discussed as technologies that will go into tall buildings. They are not really considered as future dreams as Kone Corporation has already developed the linear motor as well as the regenerative lifts for horizontal travelling; EuroFresh Farms has looked at light weight cellular urban hydroponics farming and The International Finance Centre in Hong Kong has refuge floors built into the building so that the normal requirement to vacate the building fully is not required.

Tall buildings in Singapore are necessary to ensure maximum optimisation of land use. And, because tall buildings are usually expensive due to the size and nature of the building, the capital cost is extremely important for the business plan and case of the project. If construction cost exceeds say 5%, it may throw financial models off greatly and may make the project unviable, depending on the assumptions of the financial model. It is because of this reason that cuts in capital budgets that goes into sustainable design can occur and make the building a standard building rather than a sustainable one.

However, if a total whole life cost of the building that is integrated to the financial model of the building is achieved with integrated cost model by the QS, the business case and plan for the building will prove itself. And although there will be a higher capital cost, the extra-over cost of the building may pay itself over a period of time (depending on the extra-over cost) which will incur savings for the developer in the whole life cycle of the building.

It is also encouraging to see more Green Funds in the industry. Green Funds are fund managers who are interested in funding cum investing in green buildings so long as they satisfy the International Finance Corporation Equator Principle. These principles dictate that the project has to satisfy 10 criteria on social, environment and economic strategies. This encourages all of us to rethink on our business model and strategy which will affect design and sustainable outcomes early in the project brief.

而这都会比常规在现场铸造的都会比较昂贵。然而，使用预制和结构钢虽然要昂贵约3%至6%，但是这将不仅使建造更为迅速，而且由于材料的比例因素，柱子也会比较小。这也形成了更多的净“出让”或出售面积。因此，如果开发商只是看到工程底线而没有把整个生命周期的成本考虑在内，他们将错过促进社会可持续发展的利用可持续材料的优势。

可持续建筑的优势

根据Code[9]（2003）和Dean（2008），可持续发展建筑，尤其是商业建筑，将会有以下几点特性：

- 不同的资本成本取决于方案评估达到的水平（如：绿色标志，LEED，绿色之星等）
- 更高的入住率
- 更高的生产力
- 更高的产量和资本收益

由澳大利亚人Dabis Langdon所做的一个类似的研究，就是在其建筑中，通过绿色之星评级系统来验证其数据。从报告中，也得到了相类似的结果。

因此，那些触及三重底线方法的可持续发展建筑能产生更好的收益率。然而，从这三个研究中也清楚表明，更高一个等级的评定，则需要更高一个等级的额外资本成本的投入。这个额外成本可能会影响到项目预算和何时推出基准测试，而建筑面积的单价分析成本也会比起标准建筑要高一些。这可能会使开发商恢复到标准建筑，有很少或者根本没有绿色功能[10]。因此QS的重要作用是来证明通过有较高资本成本、涉及生命周期管理技术的分析成本模型，可将建设运营和维护成本将在整个建筑寿命中降低很多。

除了这点，新加坡的施工业，通过建筑施工建设局（BCA）的指导已将重点转移到另一个可持续元素上，那是生产力。开发商和咨询公司正试图了解项目生产力和成本之间的微妙平衡。目前，有些在研究企业需求和进程的商业顾问，把他们转化成人们使用的空间与场地。这样的研究不仅可以通过研究设计所获得的可能生产力，还可通过较少的能源需求和社会平等的可持续发展的角度来融入可持续发展模型中。

结论

在探索频道的巨型结构系列中，对上海Extopia高层城市的未来假设进行了讨论。其高度是金茂大厦的三倍，对未来的设备和技术诸如线型电机电梯，抵抗风压的自然塑形外立面等高层建筑技术问题也都进行深入讨论。他们并不只被视为未来梦想，因为Kone公司已经开发出线型电机以及水平发电电梯，EuroFresh农场已着眼于轻质蜂窝城市水培养殖，同时香港国际金融中心也已把避难层建在建筑物内，使得建筑不再需要通常要求的让出空间。

新加坡的高层建筑中，必需确保最大优化土地利用。因为由于建筑的规模和性质，高层建筑通常都是相当昂贵的，对于商业计划和项目案例资本成本是极为重要的。如果工程成本超过5%，很有可能引发金融模型的巨大错位和项目计划的流产，这都取决于财务模型假设。正是由于这个原因，削减可持续发展设计的资本预算会使项目变成一个普通而非可持续的建筑。

然而，如果通过QS实现了结合建筑总的全寿命成本与其金融模型的集成成本模型，那此建筑的商业情况和计划将通过它自己得到证实。虽然会有更高的资本成本，但是建筑的额外成本可能在一段时期内可以自行弥补（取决于额外成本），可在整个生命周期过程中为开发商产生结余。

在这个行业中能看到更多的绿色基金也是很令人鼓舞的。绿色基金是由满足国际金融公司的赤道原则，对绿色建筑投资有浓厚兴趣的基金经理组成。这些原则决定了项目必需满足社会10项准则，环境和经济策略。这鼓励我们重新考虑在设计项目最初期就会影响设计和可持续发展的成果的商业模式和策略。

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