DEVELOPING A FRAMEWORK FOR ASSESSING SUSTAINABILITY OF TALL-BUILDING PROJECTS

By

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"There is a sufficiency in the World for man's need but not for man's greed."

Gandhi

Abstract

The main goal of this research is to develop a *'Sustainability Rating System'* that specialised for tall-building projects. The System can be used as a managing tool to compare and improve the sustainability features of tall-building design schemes; or can be used to evaluate the sustainability of existing tall-building projects. The name of the System is: **TPSI – Tall-building Projects Sustainability Indicator**.

The TPSI Rating System comprises of two components: the 'Technical Manual' (in form of a booklet) and the 'Calculator' (in form of an Excel tool). The users will claim 'credits' for their tall-building project by demonstrating compliance with the assessment criteria that are detailed in the 'Technical Manual.' The achieved credits will be inputted into the 'Calculator' accordingly. The 'Calculator' will then produce assessment results in form of ratings (percentage), charts, graphs, and issues checklist.

The market place of the design and construction of high performance buildings is dynamic and evolving. Professionals throughout the building industry use assessment/rating systems to evaluate and differentiate their products or designs. After more than 20 years of development, sustainability rating systems have become inevitable, as sustainable development is now the global trend. Among the extensive development of hundreds of rating tools, tall-buildings' sustainability evaluation is a neglected area. As there is no specialised rating system for tall-buildings so far, most of the existing systems are used for all type of projects, which causes major inappropriateness and inaccuracy.

This research aims to improve the quality of tall-buildings' sustainability assessment activities by filling these gaps in the new developed system. It is expected to be an original and practical contribution to the development of sustainable architecture in general and tall-building sustainable design in particular; as well as other academic, social and commercial benefits

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Thank you, Lien, for filling my heart with love and joy, and for being by my side regardless of what would happen.

I offer eternal gratitude and love to my Mum Mai and my Dad Ha for giving me everything.

And thanks to my big little brother Linh of course!

Declaration

I declare that this thesis is a sole production of mine with full originality and it has not been previously submitted to this or any other University.

Binh Nguyen Khanh

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CHAPTER 1: INTRODUCTION

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1.1. RESEARCH BACKGROUND

1.1.1. Sustainable Development

> *"...The past 20 years have seen a growing realisation that the current model of development is unsustainable. In other words, we are living beyond our means. From the loss of biodiversity with the felling of rainforest's or over fishing to the negative effect* our consumption patterns *are having on the environment and the climate. Our way of life is placing an increasing burden on the planet – this cannot be sustained."*

The above statement of Dr. Keith Jones (2010) very well summarises the Built Environment in particular and our environment in general during the last decades. The increasing stress we put on resources and environmental systems such as water, land and air cannot go on forever. Especially as the World's population continues to increase and we already see a World where over a billion people live on less than a pound a day, more than 800 million are malnourished, and over two and a half billion lack access to adequate sanitation (Jones, 2010).

So what is Sustainable Development? In 1987, the Brutland Report[1] (WCED, 1987) defined sustainable development as *"development which meets the needs of the present without compromising the ability of future generations to meet their own needs."* This is a widely used and accepted international definition. Although the idea seems simple, the task is substantial. In May 1999, the UK Government published 'A better quality of life: a strategy for sustainable development for the UK,' which identified four simultaneous objectives in order to achieve sustainable development (Transport & Region Affairs Committee Environment, 1999):

a. **Social progress that recognises the needs of everyone:** everyone should share in the benefits of increased prosperity and a clean and safe environment. We have to improve access to services, tackle social exclusion, and reduce the harm

[1] **The Brundtland Commission**: formally the World Commission on Environment and Development (WCED), was convened by the United Nations in 1983. The commission was created to address growing concern about the accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development. **The Report of the Brundtland Commission** - 'Our Common Future' - was published by Oxford University Press in 1987. It deals with sustainable development and the change of politics needed for achieving that.

to health caused by poverty, poor housing, unemployment and pollution. Our needs must not be met by treating others, including future generations and people elsewhere in the World, unfairly.

b. **Effective protection of the environment:** we must act to limit global environmental threats, such as climate change; to protect human health and safety from hazards such as poor air quality and toxic chemicals; and to protect things which people need or value, such as wildlife, landscapes and historic buildings.

c. **Prudent use of natural resources:** this does not mean denying ourselves the use of non-renewable resources like oil and gas, but we do need to make sure that we use them efficiently and that alternatives are developed to replace them in due course. Renewable resources, such as water, should be used in ways that do not endanger the resource or cause serious damage or pollution.

d. **Maintenance of high and stable levels of economic growth and employment:** so that everyone can share in high living standards and greater job opportunities. The businesses must produce the high quality goods and services that consumers throughout the World want, at prices they are prepared to pay. To achieve that, we need a workforce that is equipped with the education and skills. And we need businesses ready to invest, and an infrastructure to support them.

Unfortunately, it is a global fact that we are not even meeting the needs of the present let alone considering the needs of future generations. The quest to meet the goal set out by the Brutland Report is currently one of humankind's biggest concerns. Unless we start to make real progress toward reconciling the contradictions, we all, wherever we live, face a future that is much less certain and less secure than we have enjoyed over the past fifty years. A decisive move toward more sustainable development is crucial, both because it is the right thing to do, and because it is in our long-term best interests. It offers the best hope for securing the future.

1.1.2. Sustainability Measurement

Since sustainability itself is already an abstract conception, *should we* even find a way to quantify such a non-figurative factor? And *Could we*? The answer is: *Yes, indeed!* 'Sustainability Measurement' is a term that denotes the measurements used as the quantitative basis for the informed management of sustainability. The metrics used for the measurement of sustainability (involving the sustainability of environmental, social and economic domains, both individually and in various combinations) are still evolving. These metrics include indicators, benchmarks, audits, indexes and accounting, as well as assessment, appraisal and other reporting systems. They are applied over a wide range of spatial and temporal scales.

Some of the best known and most widely used sustainability measures include *corporate sustainability reporting*, *Triple Bottom Line accounting*, and estimates of the quality of sustainability governance for individual countries using the *Environmental Performance Index* and *Environmental Sustainability Index*.

a. Corporate sustainability reporting

Corporate sustainability reporting has a long history going back to environmental reporting. The first environmental reports were published in the late 1980s by companies in the chemical industry that had serious image problems. The other group of early reporters was a group of committed small and medium-sized businesses with very advanced environmental management systems. Non-financial reporting, such as sustainability and CSR (Corporate Social Responsibility) reporting, is a rather recent trend that has expanded over the last 20 years. Many companies now produce an annual sustainability report and there are a wide array of ratings and standards around. There are a variety of reasons that companies choose to produce these reports, but at their core they are intended to be 'vessels of transparency and accountability' (Bristow, 2011). They also often intended to improve internal processes, engage stakeholders and persuade investors.

Organisations can improve their sustainability performance by measuring, monitoring and reporting on it, helping them to have a positive impact on society, the economy, and a sustainable future. The key drivers for the quality of sustainability reports are the guidelines of the Global Reporting Initiative (GRI). The GRI Sustainability Reporting Guidelines enable all organisations worldwide to assess their sustainability performance and disclose the results in a similar way to financial reporting (GRI, 2011). The largest database of corporate sustainability reports can be found on the website of the United Nations Global Compact initiative.[2]

b. Triple Bottom Line accounting

The 'Triple Bottom Line' - abbreviated as 'TBL' or '3BL,' and also known as *'people, planet, profit'* or the *'three pillars'* - captures an expanded spectrum of values and criteria for measuring organisational (and societal) success: economic, ecological and social (Bader, 2008). With the ratification of the United Nations and ICLEI[3] TBL standard for urban and community accounting in early 2007, this became the dominant approach to public sector full cost accounting. In the private sector, a commitment to corporate social responsibility implies a commitment to some forms of TBL reporting.

In practical terms, Triple Bottom Line accounting means expanding the traditional reporting framework to take into account ecological and social performance in addition to financial performance. Spreckley (1981) first established the Triple Bottom Line notion in his book: 'Social Audit - A Management Tool for Co-operative Working 1981,' in which he described what Social Enterprises should include in their performance measurement. The phrase was actually coined by Elkington (1998) in his book: 'Cannibals with Forks: the Triple Bottom Line of 21st Century Business.' The 1988 marked the foundation of the 'Triple Bottom Line Investing Group' by Robert J. Rubinstein, a group advocating and publicising these principles.

The concept of TBL demands that a company's responsibility lies with stakeholders rather than shareholders. In this case, 'stakeholders' refers to anyone who is influenced, either directly or indirectly, by the actions of the firm. According to the stakeholder theory, the business entity should be used as a vehicle for coordinating stakeholder interests, instead of maximising shareholder (i.e. owner) profit.

[2] **United Nation Global Impact initiative**: <http://www.unglobalcompact.org/>.

[3] **ICLEI - Local Government for Sustainability** is an international association of local government and national and regional local government organisations that have made a commitment to sustainable development. It is the largest association of local government worldwide working on sustainable development. <http://www.iclei.org/>.

c. The Environmental Performance Index (EPI)

The Environmental Performance Index is a method of quantifying and numerically benchmarking the environmental performance of a country's policies. This index was developed from the Pilot Environmental Performance Index, first published in 2002, and designed to supplement the environmental targets set forth in the U.N. Millennium Development Goals (Wikipedia, 2010a). The EPI was preceded by the Environmental Sustainability Index (ESI), published between 1999 and 2005. The ESI was developed to evaluate environmental sustainability relative to the paths of other countries. Due to a shift in focus by the teams developing the ESI, the EPI uses outcome-oriented indicators, then working as a benchmark index that can be more easily used by policy makers, environmental scientists, advocates and the general public (Esty *et al.*, 2008).

d. Environmental Sustainability Index

The Environmental Sustainability Index (ESI) was published between 1999 to 2005 by Yale University’s Center for Environemntal Law and Policy in collaboration with Columbia University’s Center for International Earth Science Information Network (CIESIN),[4] and the World Economic Forum.[5] The ESI is a composite index that tracked 21 elements of environmental sustainability covering natural resource endowments, past and present pollution levels, environmental management efforts, contributions to protection of the global commons, and a society’s capacity to improve its environmental performance over time.

1.1.3. Sustainability Indicators/Rating Systems

Sustainability Indicators/Rating Systems represent a family of sustainability measurement methods, which derive from the essence of the Environmental

[4] **Center for International Earth Science Information Network (CIESIN)**: <http://www.ciesin.org/>.

[5] **The World Economic Forum** is an independent international organisation committed to improving the state of the World by engaging business, political, academic and other leaders of society to shape global, regional and industry agendas.

Performance Index (EPI). They try to express the sustainability of a building/project by quantifiable values (i.e. rankings, points, ratings,). Indicators/rating systems for monitoring progress towards sustainable development are needed in order to assist decision-makers and policy-makers at all levels and to increase focus on sustainable development. Beyond the commonly used economic indicators of well being, however, social, environmental and institutional indicators have to be taken into account as well to arrive at a broader, more complete picture of sustainable development. Sustainability indicators/rating systems are signposts that can point the way to sustainable development.

While there is still no precise definition of sustainable development, such indicators/systems can help to show whether we are moving in the right direction. Unifying economics and environment in decision-making may be the key to understanding how well we are navigating the course to sustainable development. To move toward sustainable development, decision-makers need information. Such information include:

- Where they are at the moment;
- Developing trends and pressure points;
- The impacts or effects of interventions or policies put into place;
- Which adjustments to make to speed up or slow down the effects of their interventions;
- Milestones achieved or failures that frustrate progress.

Sustainability indicators/rating systems are useful because they point to trends and relationships in a concise way. They provide meaning beyond the attributes directly associated with them. In this sense, they are different from primary data or statistics, providing a bridge between detailed data and interpreted information. Indicators and rating schemes have been used for many years and are common in planning and economics where indicators such as GDP, the unemployment rate, the literacy rate and the population growth rate are widely monitored. Sustainability rating systems can be used for many purposes such as measuring progress towards pre-established targets and goals or simply getting a picture of where things stand at a particular point in time. They can help to guide national policies for sustainable development and facilitate national reporting on measures to implement sustainable development.

The notable contemporary sustainability indicator/rating systems include:

- The Building Research Establishment Environmental Assessment Method (BREEAM);
- The Civil Engineering Environmental Quality and Assessment Award (CEEQUAL);
- ARUP's Sustainable Project Appraisal Routine (SPeAR);
- The DTI's Movement for Innovation (M4i) eight indicators;
- DETR's (now DEFRA) 'Quality of Life Counts' indicators;
- The Leadership in Energy and Environmental Design (LEED);
- CASBEE (Comprehensive Assessment System for Building Environmental Efficiency);
- Green Star;
- High Quality Environmental (HQE);
- Envest 2;
- SBTool/GBTool.

More reviews of sustainability indicators, rating systems and tools, as well as their issues, are presented in Chapter 3.

1.1.4. Tall-building: the Definitions

What is a tall-building?

Tall-building is the object of this research, and certainly it is important to understand the related notions. Officially, there is no absolute definition of what constitutes a 'tall-building' or 'high-rise building.' According to the Council on Tall Buildings and Urban Habitat (CTBUH),[6] a tall-building is a building that exhibits some elements of 'tallness' in one or more of the following categories (CTBUH, 2011):

[6] **CTBUH: the Council on Tall Building and Urban Habitat** based at the Illinois Institute of Technology in Chicago, is an international not-for-profit organisation supported by architecture, engineering, planning, development and construction professionals, designed to facilitate exchanges among those involved in all aspects of the planning, design, construction and operation of tall buildings. <http://www.ctbuh.org/>.

a. Height relative to context

A tall-building is not really defined by its height, but by the context in which it exists (i.e. with respect to the height of the surrounding buildings). If the majority of the buildings in a city were three or four stories, then a 12-storey building would be considered tall. In locations such as New York or Hong Kong, a tall-building is considered at least 40-storey high (see Figure 1.1).

Figure 1.1: Tall-building notion - Height relative to context

Source: (CTBUH, 2011)

b. Proportion

Again, a tall-building is not just about height but also about proportion. There are numerous buildings that are not particularly high, but are slender enough to give the appearance of a tall-building, especially against low urban backgrounds. Conversely, there are numerous big/large footprint buildings that are quite tall but their size/floor area rules them out of being classed as a tall-building (see Figure 1.2).

Figure 1.2: Tall-building notion - Proportion

Source: (CTBUH, 2011)

c. Tall-building technologies

If a building contains technologies that may be attributed as being a product of 'tall' (e.g., specific vertical transport technologies, structural wind bracing as a product of height,), then this building can be classed as a tall-building (see Figure 1.3).

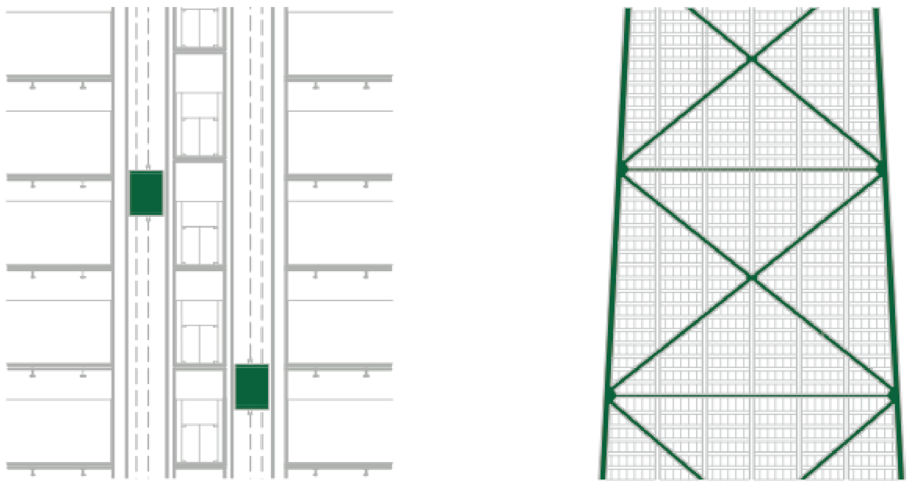

Figure 1.3: Tall-building notion - Technologies

Source: (CTBUH, 2011)

Although number of floors is not the best indicator of defining a tall-building due to the changing floor to floor height between differing buildings and functions (e.g. office versus residential usage), in the context of this research, it is a convenience way to classify projects. *In this thesis, a tall-building is defined as 20 stories or more*. The reasons behind this choice of threshold are discussed in Section 6.2. The tall-buildings considered here are assumed to be office, commercial, residential, hotel health-care, education and mixed-use buildings, with a requirement for building services, not industrial processes or multi-storey car parks.

What is a 'Skyscraper'?

The CTBUH defines 'Skyscraper' or 'Supertall' as a building over 300 metres (984 ft) in height (see Figure 1.4). Although great heights are now being achieved with built tall-buildings – in excess of 800 metres (2,600 ft) – at the mid-point of 2011, there are only approximately 54 buildings in excess of 300 metres completed and occupied globally (CTBUH, 2011).

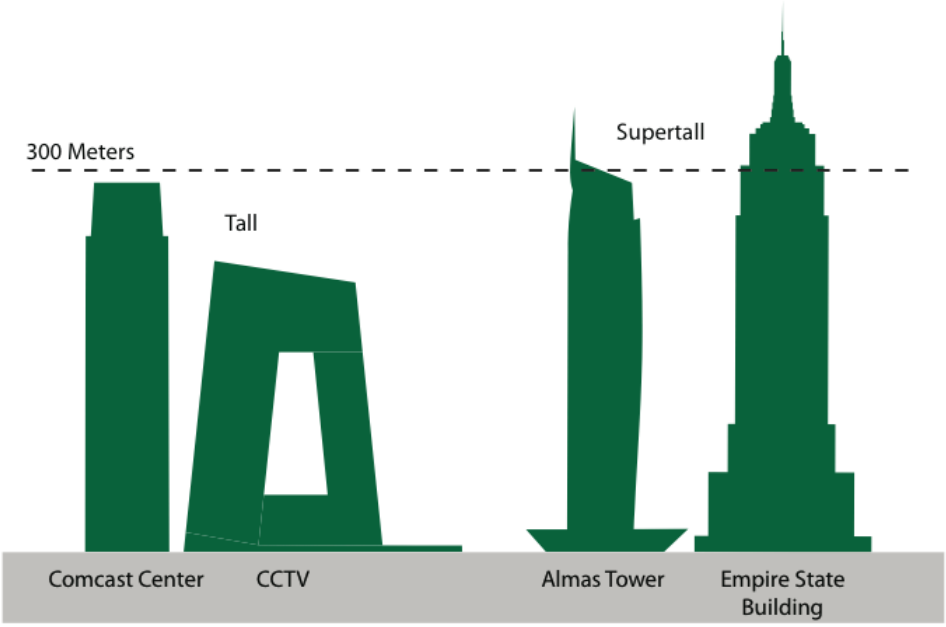

Figure 1.4: Skyscraper notion

Source: (CTBUH, 2011)

1.1.5. The Brief History of Tall-buildings

Skip through the ancient and classical high-rise structures, modern tall-buildings emerged in the late 19th Century in the United States of America. Originally, they have solely one purpose: *to archive more spaces with the same footprint*. They constituted a so-called 'American Building Type,' meaning that most important tall-buildings were built in the U.S. First modern tall-buildings were made of brick, stone and wood - materials with low structural performances. Brick, stone and wood structure reached its topmost in 1891 with the 17-storey Monadnock building, Chicago (Architect: Burnham and Roof – see Figure 1.5). To touch the height of 215 ft, the walls in the ground floor had to be 7 ft thick, consuming 15% of overall footprint. The Monadnock building did make a long-lasting impression with its simplicity and straight-forwardness.

In 1885, American engineer William Le Baron Jenny laid the ground for the development of skyscrapers by realising tall-buildings can be built entirely from different materials other than traditional ones. The Home Insurance building (see Figure 1.6) in Chicago with the height of 185 ft is the first building that adopted steel structural frame. Immediately after this, steel structures became popular. In 1892, the steel framed Masonic Temple building (see Figure 1.7) in Chicago (also designed by Burnham and

Root) reached the height of 305 ft (21 stories). This is the first building that claimed the title ‘the tallest building in the World.’ Chicago is considered the birthplace of modern high-rise buildings.

Figure 1.5: Monadnock building, Chicago

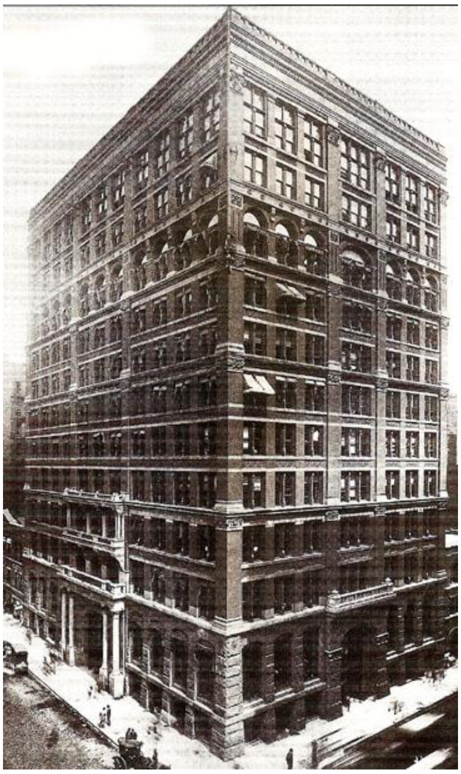

Figure 1.6: Home Insurance building, Chicago

Figure 1.7: Masonic Temple building, Chicago

From the late 19th century, along with Elisha Graves Otis' invention of the elevator in 1853, modern steel structure started the era of high-rise building. Most of high-rise buildings during this time were built for commercial purpose. As the economy developed, the race to the highest became furious.

During the transition years from 19th to 20th Century, the Wall Street area of New York surpassed Chicago to become the most important financial centre of the U.S. Many steel-supported buildings were built, giving New York the unique architectural feature like we see today. The most famous buildings include: Flatiron building (Daniel H. Burnham, 21 stories, 290 ft – see Figure 1.8); American Surety building (Bruce Price, 21 stories, 303 ft – see Figure 1.9); St. Paul building (George B. Post, 26 stories, 314 ft); and Park Row building (R. H. Robertson, 29 stories, 390 ft).

Figure 1.8: Flatiron building, New York

Figure 1.9: American Surety building, New York

In 1913, Woolworth building (see Figure 1.10) in Manhattan (designed by Cass Gilbert) was the first building that reached the height of 60 stories (807 ft). This neoclassical building - also called 'Cathedral of Commerce' because of its Gothic looks - was the standard for New Work tall-buildings after World War I. Woolworth Building was once the tallest building in the World until it was surpassed by the Chrysler building (77 stories, 1064 ft – see Figure 1.11). Said Walter P. Chrysler, this building was *"dedicated to a commercial and industrial World."* This was also the spirit behind many high-rise buildings built around this time, when buildings get higher not only because they need to, but also to affirm the owner's massive power.

The race for height reached its peak in 1931 with the inauguration of the Empire State building, New York (designed by William Lamb, 102 stories, 1270 ft plus a 225-foot-antena – see Figure 1.12). Afterward, the downward trend of U.S. financial system had a tremendous effect to the development of tall-buildings. Not until 1973 that the next tallest building was built. The World Trade Centre (Minoru Yamasaki – see Figure 1.13) broke the record of the Empire State building by reaching the height of 1390 ft (110 stories) before it was defeated by the Sears Tower (Skidmore, Owings & Meril, 110 stories, 1477 ft – see Figure 1.14). The Sears Tower remained to be the tallest building in the World for the next 22 years, until the construction of The Petronas twin-tower in Malaysia, 1996 (Cesar Pelli, 88 stories, 1500 ft – see Figure 1.15).

Figure 1.10: Woolworth building, New York

Figure 1.11: Chrysler building, New York

Figure 1.12: Empire State building, New York

Figure 1.13: World Trade Centre, New York

Figure 1.14: Sears Tower, Chicago, S.O.M

Figure 1.15: Petronas twin-tower, Malaysia

1.1.6. Recent Development of Tall-buildings

The Petronas twin-tower is not a very special building in term of design or structure, but it was a milestone in the development of tall-buildings. The Petronas was built in 1996 - around the time when we witnessed the economic rise of Asia and the Middle East as well as a major shift of economical balance of the World. As a result, after Petronas, the World has seen an exponential increase in size, height and number of high-rise structures. More importantly, there has been a major shift in the distribution of tall-buildings - especially skyscrapers - as well as tall buildings' functions.

By the end of 2007, there were 34 supertall buildings in the World. But by the end of 2010, just three years later, this has more than doubled to 82 supertall buildings globally (CTBUH, 2008). Also according to CTBUH, also by the end 2010, 59 of 100 tallest buildings in the World as documented in 2006 - only four years beforehand - are new. The new tallest building Burj Dubai, with the height of over 828 meters (2717 ft), made a 60% leap in height increase over the previous World's tallest building (CTBUH, 2008). Figure 1.16 shows the height incremental changes in the development of the World’s tallest buildings historically by the end of 2010. Figure 1.17 shows the average height of 100 tallest buildings in the World by the end of 2010.

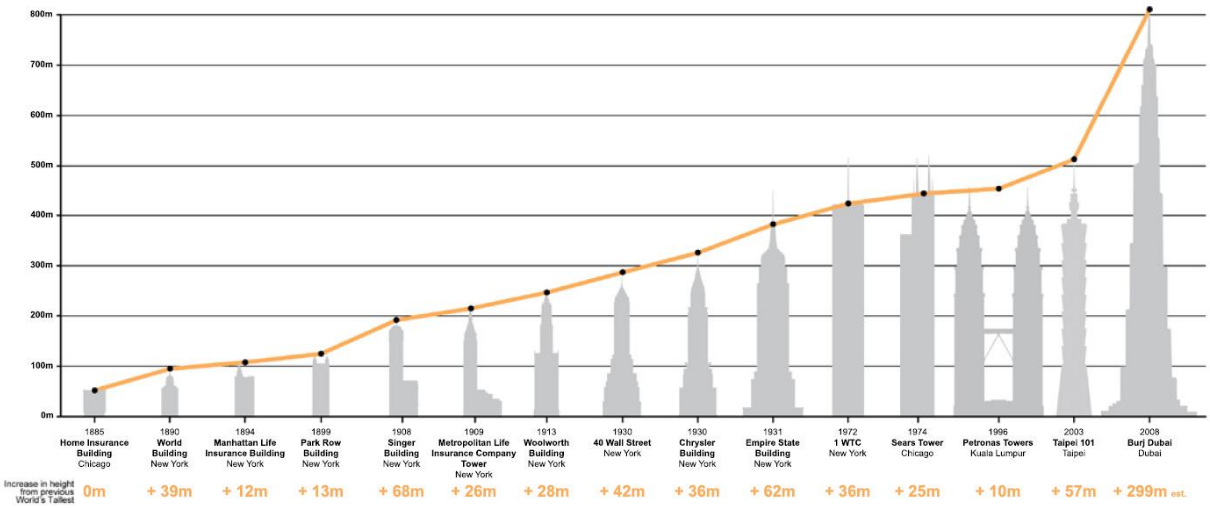

Figure 1.16: The height incremental changes in the development of the World’s tallest buildings historically

Source: <http://www.ctbuh.org/>.

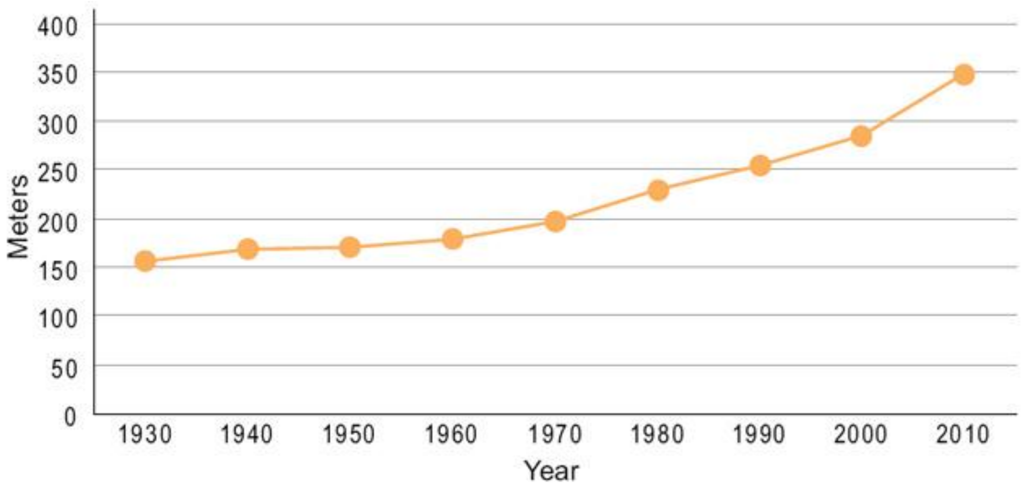

Figure 1.17: Average height of 100 tallest buildings in the World

Source: <http://www.ctbuh.org/>.

For a significant period of time, North American towers have dominated the 100 tallest buildings in the World. This is rapidly changing due to the global boom in tall-building related activities, with a dramatic increase in the number of skyscrapers located mostly in Asia and the Middle East. There is a fact that after Petronas, most of the notable skyscrapers are built in Asia and the Middle East, such as the Taipei 101 Tower and the

Burj Dubai Tower. In 1930, 99% of the 100 tallest buildings were located in North America with 51% in New York City alone. By 2010, that has decrease to only 22% and 5% respectively (CTBUH, 2008) (see Figure 1.18 and Figure 1.19).

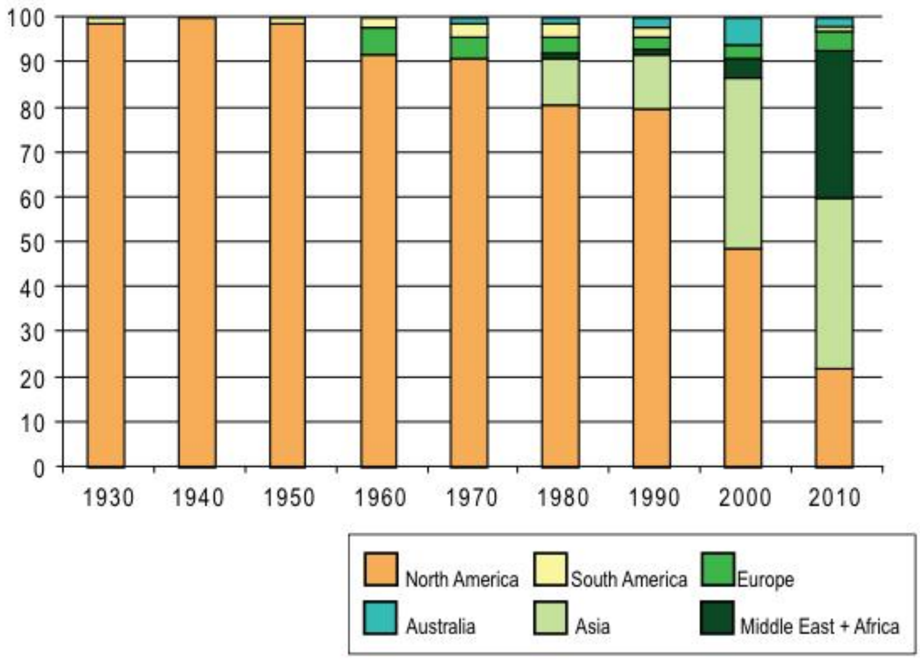

Figure 1.18: 100 tallest buildings in the World by function

Source: <http://www.ctbuh.org/>.

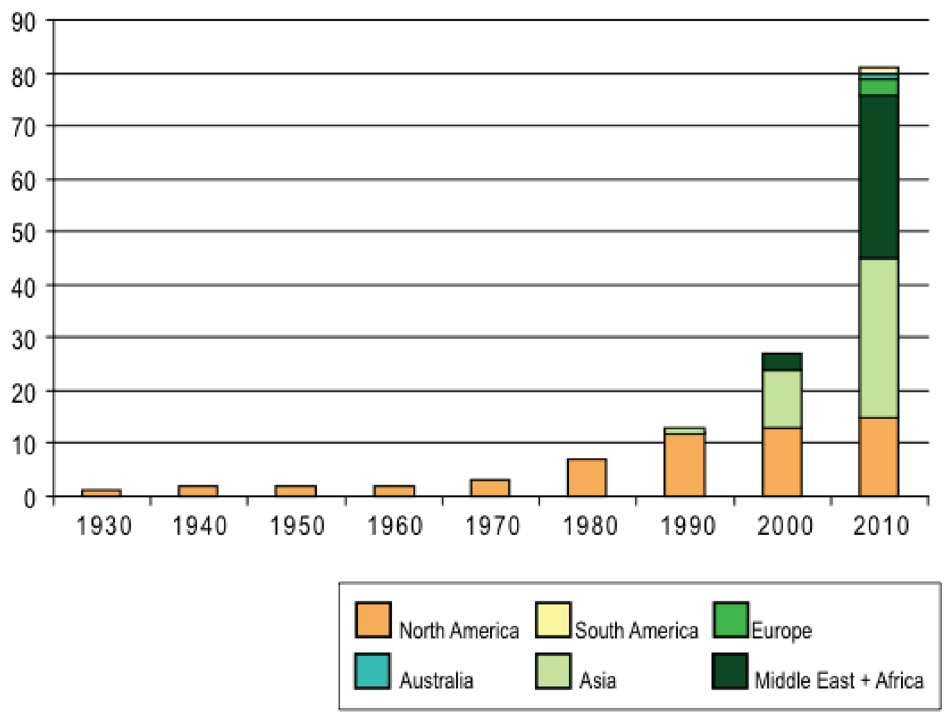

Figure 1.19: Total number of skyscrapers by region

Source: <http://www.ctbuh.org/>.

Figure 1.19 shows a significant increase in tall-buildings number in the last two decades and especially during the last 10 years. The above figures also confirm that tall-building is now the global norm and will dominate the Built Environment in the years to come. We all know the huge effects of the construction, operation and demolition of skyscrapers to the environment. Without any strong reaction, their effects will be devastating in the very near future. Remarkably, most of new skyscrapers concentrate in Asia, the Middle East and Africa countries, where environmental issues and people's living standard are not being adequately regarded. The effects of tall-buildings on the environment in these areas can therefore be much more serious than in Europe, the UK, or the U.S.

Another noteworthy point is, the effects of high-rise buildings to our life-style is becoming overwhelm as there are more and more tall-buildings being built for residential purpose. This can easily be seen in big cities of China, India, Vietnam, and Hong Kong, where people live miserably in high-rise residential buildings. By the end of 2010, less than half of the 100 tallest buildings in the World are office tower, with the majority instead accommodating residential and mixed-used functions (see Figure 1.20 and Figure 1.21).

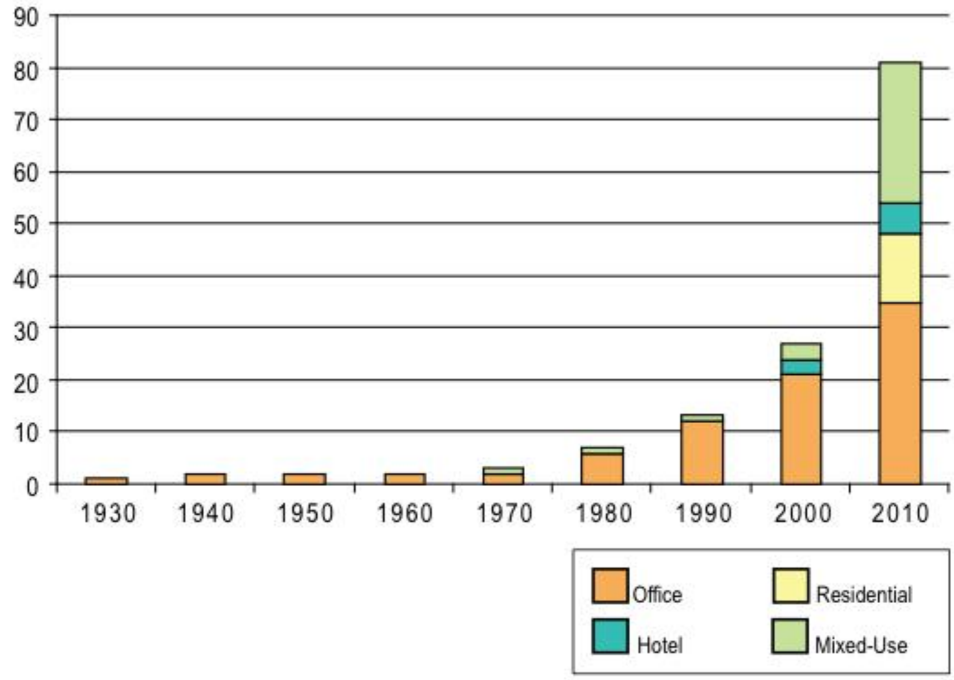

Figure 1.20: 100 tallest buildings in the World by function

Source: <http://www.ctbuh.org/>.

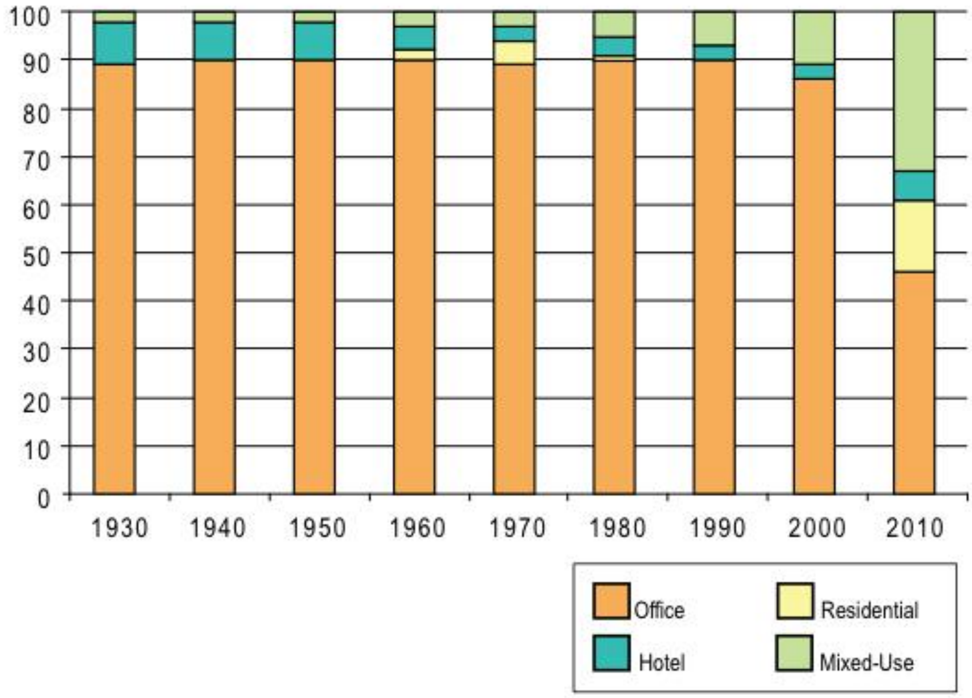

Figure 1.21: Total number of supertall buildings by function

Source: <http://www.ctbuh.org/>

1.1.7. Sustainable Tall-buildings

There is no doubt that sustainability considerations need to be incorporated into building design for both legislative and moral reasons. At the same time, high-rise buildings are required for sound commercial reasons such as:

- A requirements for more office accommodation;
- Their efficiency with respect to land use;
- The ability to serve many people from existing transport and services infrastructure;
- Occupied demand for prestigious locations.

This leads naturally to a demand for sustainable tall-buildings to satisfy both of these requirements. There are still debates about whether or not tall-buildings - with their characteristics and embodied environmental disadvantages - can be truly sustainable. Yet during the last 20 years, the notion of sustainable tall-buildings (or green tall-buildings, ecological skyscrapers, etc.) has already become prevalent. Sustainable high-rise building is a big step of mankind on the way to protect the environment and to live a healthier, more-intelligent lifestyle. Environmental sustainable high-rise buildings are an irreversible trend nowadays and in the near future.

So what is a sustainable tall-building? Wilson and Cromton (2011) has defined a sustainable building as *"one in which the design team have struck a balance between environmental, economic and social issues at all stages – design, construction, operation and change of use/end of life."* This may involve greater emphasis on different aspects at different stages in the building's life, for example energy for building services and transport of building users and occupants and associated CO_2 emissions are key to sustainable operation. Also according to Wilson and Cromton, a purist's definition of a sustainable tall-building is one that 'emits no pollution to air, land and water, and can be economically occupied throughout its design life, whilst contributing positively to the local community.'

So the challenge is to achieve sustainability and build high-rise buildings. There are specific aspects where tall-buildings are less sustainable than low rise, e.g. in their requirement for operational energy, their questionable natural ventilation and indoor environmental quality, their imposed safety and fire risks, etc. However, there are others where they undoubtedly have advantages, e.g. utility of land in densely populated urban areas, the economic and social advantages, etc. So the advantages need to be capitalised on, and the disadvantages minimised or mitigated (Wilson & Cromton, 2001). Design team should work with their clients to develop a vision, and challenges the reasons why that vision can't be realised (there are bound to be some good commercial and practical reasons) rather than start with a conventional design and apply small tweaks. This way, our journey towards more sustainable tall-buildings will be much shorter.

1.1.8. Assessing the Sustainability of Tall-buildings

Environmental rating systems/tools have a long history of development. There is a plethora of tools on the market that dedicate to evaluating sustainability performance of projects. However, many of them have very specific uses. Despite the vast number of environmental assessment processes, design tools and key performance indicators for sustainability, none of them are specifically intended for high-rise construction (relevant at the time of writing this thesis – see Section 4.3).

The notable rating systems that have been used in tall-building projects include:

- The Building Research Establishment Environmental Assessment Method (BREEAM);
- The Leadership in Energy and Environmental Design (LEED);
- Comprehensive Assessment System for Building Environmental Efficiency (CASBEE);
- Hong Kong Building Environmental Assessment Method (HK-BEAM);
- Green Star (the Australian official rating system).

These rating schemes allocate different weightings to the significance of issues, and therefore the same building will score differently depending on which system is use. For example, a design that has a very low operational energy may result in a high score in one scheme, whereas in another scheme this factor might be given less weighting, and so result in a lower overall score. More importantly, most of existing tools divide projects *by functions, not by height*. There is no specialised rating system for tall-buildings recorded. Therefore most of existing systems are used for all types of projects regardless of their tallness. This causes major inappropriateness and inaccuracy (see Section 5.4.2) due to the special characteristics of tall-buildings. While low and middle-height buildings, regardless of their functions, are similar in many ways, tall-buildings are totally different, especially in the following aspects:

- Design, construction, operation and demolition process;
- Indoor environmental quality strategies;
- Building services;
- Economic aspects;
- Energy and consumptions;
- Environmental impacts;
- Social impacts and other effects to surrounding areas;
- Material aspects.

The gaps in existing rating systems when applying to high-rise buildings are studied and discussed in details across Chapter 3, Chapter 4, Chapter 5 and are summarised in Section 5.4.

1.2. SCOPE OF THE RESEARCH

This research aims to improve the quality of tall-buildings' sustainability assessment activities by filling the gaps in existing rating systems. The core of the research will be the development of a new sustainability rating systems named 'TPSI –Tall-building Projects Sustainability Indicator.' The new rating system will be specialised for high-rise projects only. It can be used as an *all-in-one* 'managing tool' or 'checklist' to compare and improve the sustainability and environmental features of tall-building design schemes, or can be used as a 'assessment tool' to evaluate the sustainability of existing tall-building projects.

TPSI System will be available in form of an Excel tool (i.e. the 'TPSI Calculator') and a booklet (i.e. the 'TPSI Technical Manual'). TPSI users will claim 'credits' for their tall-building project by demonstrating compliance with the assessment criteria, which are detailed in the 'Technical Manual.' The achieved credits will be input into the 'Calculator' accordingly. The 'Calculator' will then produce assessment results in form of ratings (percentage), charts, graphs, and issues checklist. The research will also establish a set of standards for sustainable tall-buildings, which can be utilised for many purposes; as well as other outcomes (see Section 1.3).

1.3. SIGNIFICANCE OF THE RESEARCH

The research will be an original and practical contribution to the development of sustainable architecture in general and tall-building sustainable design in particular. It is believed to be beneficial in many ways, as shown in Figure 1.22.

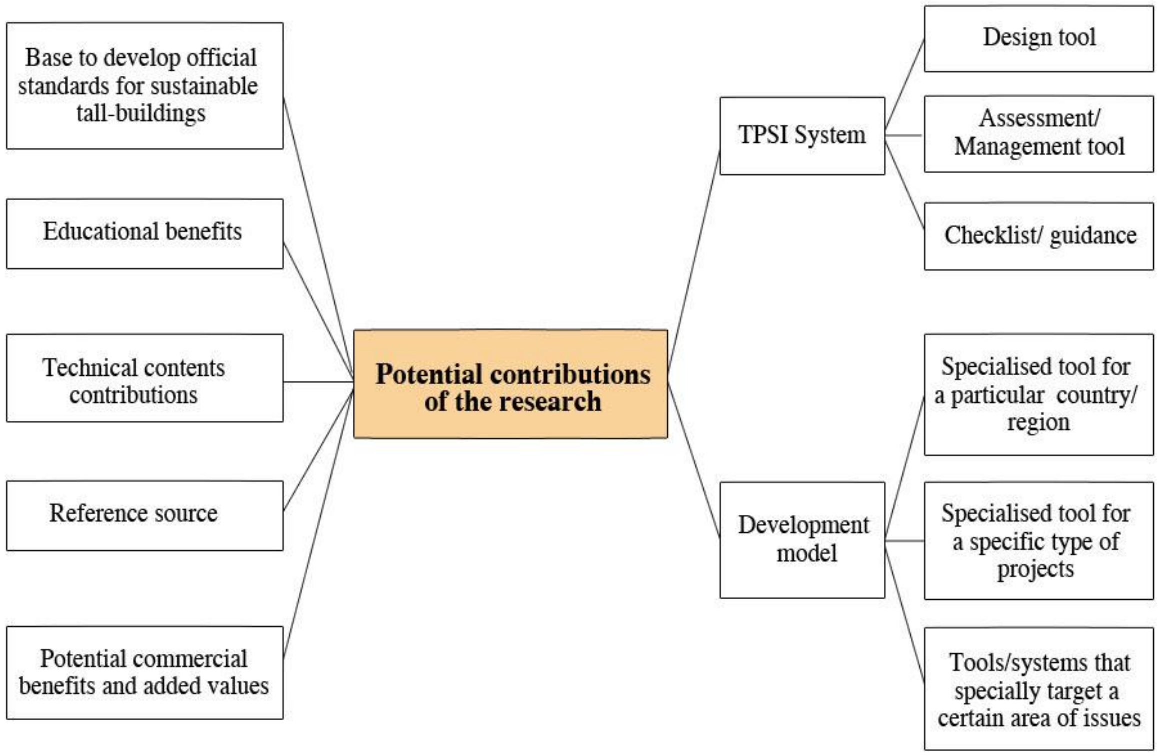

Figure 1.22: Potential contributions of the research

Apart from creating a new rating system, as importantly, the research also offers a development model/framework which similar studies and research can base on. It also set up a completed set of standards for sustainable tall-buildings that can serve multiple purposes. It would provide referencing, technical, and educational benefits, as well as bringing commercial potentials. The contributions of the research are summarised in Section 10.2.

The parties that can benefit from the outcomes and applications of this research include:

- Architects and designers who want to improve the performance of their sustainable designs, or to look for a holistic sustainable design guideline, or to compare the sustainability of different design schemes.
- Developers and project managers who want to improve sustainable performance of their projects (reduce environmental effects, manage the project in a sustainable manner, and increase the economy of the project).
- Individuals, organisations and governors who want to develop a standard for tall-building projects, or to develop a new rating tool for all type of projects.

- Anyone who wants to look for a complete reference source on sustainable design, especially sustainable tall-building design.

1.4. THESIS STRUCTURE

Due to the purpose of the research - to develop a new sustainability rating system, this thesis is divided into two volumes:

- Volume I: the main thesis;
- Volume II: the completed first version of TPSI System (TPSI 2012 Version), which consists of two components:
    - The full Technical Manual (TPSI Technical Manual 2012 Version); and
    - An Excel Tool (TPSI Calculator 2012 Version).

Volume II is structured - and can be used - independently from Volume I. The main thesis (Volume I) consists of 10 chapters as summarised in Table 1.1.

Table 1.1: Chapters summary of the main thesis

Chapters	**Summaries**
Chapter 1: Introduction	Introductions to the research, research background, scope of research, significance of the research, and thesis structure.
Chapter 2: Methodology	Describe the research questions and their importance, possible approaches and their pros and cons. Explain the research methodology and research framework.
Chapter 3: Review of Sustainability Rating Systems	Overview of existing sustainability rating systems and tools, the historical development of sustainability rating systems. Brief speculation into how rating systems are used in high-rise projects.
Chapter 4: Screening Analysis of Sustainability Rating Systems	Identifies and reviews the existing sustainability rating systems. Presents the Preliminary Screening Analysis to cross out unsuitable tools. Presents the Intensive Screening Analysis to find out the most suitable rating systems to assess tall-building projects.
Chapter 5: Top Five Sustainability Rating Systems for Tall-building Assessment	Summaries and comparative reviews of the Top Five rating systems. 'Part A – Reviewing' summary and conclusions. Identifies the gaps in existing rating systems and the visions for the development of TPSI.
Chapter 6: Theoretical Foundations for the Development of TPSI	The theoretical and literature foundations for TPSI's development. Main issues when developing a new rating system.
Chapter 7: TPSI – Tall-building Projects Sustainability Indicator	The development of TPSI. Introductions to the structure of TPSI, the assessment criteria system and the 'TPSI Technical Manual,' the assessment methodology, the assessment process and the 'TPSI Calculator,' TPSI issue summary, and other features of TPSI. 'Part B – Developing' summary and conclusions.
Chapter 8: The Trial Period	Presents the Self-testing Phase, the External-testing Phase (interview process), questionnaire format, list of interviewees and case studies, analysed results and conclusions drew from the interview process.
Chapter 9: TPSI in Practice	Further testing and validation of TPSI. Introductions to the Proof of Concept Funded TPSI Project. Cooperation with major firms in the Built Environment. 'Part C – Developing' conclusions and summary.
Chapter 10: Conclusions	Research executive summary and conclusions. The validated values and contributions of the research and TPSI system. Future potential, research and development.
Appendices	Thorough reviews of 29 applicable rating systems and tools, data fields, sample assessment results, survey related documents, publications as part of the research.

CHAPTER 2: METHODOLOGY

2

2.1. CHAPTER INTRODUCTION

Many countries have introduced new rating tools over the past few years in order to improve the knowledge about the level of sustainability in each country's building stock (see Section 3.5). On one hand, it can be argued that the individual characteristics of each country, such as the climate and type of building stock, necessitate an individual sustainability rating tool for that country. The downside is that, to varying degrees, the rating tools for different countries are constructed on different parameters. This in turn has created complications for many stakeholders, including investors, architects, mangers, and governors. An understanding of the many differences between each market has been increasingly harder to understand (Dixon *et al.*, 2008). The development methodologies of popular rating systems such as BREEAM and LEED are very complicated procedures. They are also always hidden from general users and researcher by the large firms that own them.

In order to develop TPSI, this research investigates the evolution of global building rating tools, with a concentration on tall-buildings assessment. Consideration is given to the different rating tools for sustainable buildings in each country. Furthermore, it examines how rating tools have evolved over time and which countries and their respective rating tools have contributed to their global uptake (see Chapter 3, Chapter 4 and Chapter 5). As the result of these studies, the methodology and framework of TPSI's development were established. This chapter describes the research questions that have to be answered during the development of a new rating system, which lead to the choice of overall approach. This approach, in turn, shapes the research methodology and research framework that created TPSI.

2.2. RESEARCH QUESTIONS

Unlike developing a commercial tool, developing a sustainability rating system as a PhD research requires the satisfying of extra concerns. The first and foremost issue is that the newly developed system must be an original one, and must bring something new that no existing tool offers. In other words, it has to be confirmed that currently there is no specialised rating system for tall-buildings. Nevertheless, worldwide there are many tools that are not designed specifically for tall-buildings but are still being used to assess tall-building projects anyway (see Section 3.6). This leads to further interpretations such as: 'What can TPSI do that no other rating tool cannot, or cannot do better?' or 'How can TPSI improve on these existing systems? What systems should be the foundations for these improvements?' This issue indicates that reviewing of existing rating systems is not enough. The literature review process therefore has to identify a large number of systems and *comparatively review* them to find out the best systems to assesse tall-buildings. Tool developing also requires referencing of many rating systems and standards, and the literature review should also aims to produce a reference system as one of the results.

The other issue is: not only the research has to come up with a methodology of creating a rating system; it also has to provide the means to prove that system's advantages over existing systems. These two tasks have to be in sync to provide a theoretical consistency. In other words, the 'developing' process and the 'proving' process have to base on the same criteria.

To summary, there are three main questions - which are equally important - to be answered throughout the research:

1. Is there already any rating system that specialised for tall-building projects? Among existing sustainability rating systems, which ones are the most suitable and accurate to assess tall-building projects? What are their advantages and disadvantages? What are the factors that make them inappropriate and inaccurate?
2. How to develop the new rating system?
3. Testing the performance of the new system in real-life, how to prove its values and advantages in comparison to other existing rating systems?

2.3. OVERALL APPROACH

While it is accepted that there are no identical parcels of land in the world (Australian Property Institute, 2007), in a similar manner every country is also unique. However, there are common approaches to appraising or valuing land/ buildings and analysing property values in each country, although it appears that rating tools have not followed this trend. On appearance, they are relatively complex. While it is possible to directly compare the value of an office building in New York City, Berlin, London or Melbourne using, for example, a ten-year discounted cash flow approach (after allowing for exchange rate variations), making a similar direct comparison of the sustainable features and rating of the same building is quite complex. In the past it appears there has been an unwillingness to compromise or admit a particular rating system may not be the possible best tool, which in turn has been a barrier to developing a global rating system (see Section 3.5).

However, as Reed (2009) pointed out, there is a similarity between rating system development methodologies all over the World. Very often a rating tool can be linked back to common aspects with other systems, depending largely on the particular influences on each property market. Sustainability rating system development is an inheritable process where new systems are developed based on one or several existing systems. Almost all of existing rating systems were developed this way. Many rating tools have been modified and adopted from earlier models that were originally developed in other countries. For example, it is possible to trace many systems back to the Leadership in Energy and Environmental Design (LEED) and BRE Environmental Assessment Method (BREEAM) building rating systems (see Table 4.3, Section 4.5.1).

The benefits of having a common foundation with LEED and BREEAM may assist with moving towards an internationally accepted rating tool, especially when there are recent signs of change and compromise. It also offer other advantages such as the inheritance of long-established and validated standards, or the benefit of hindsight that would prevent the mistakes made by previous systems.

2.3.1. Possible Approaches

To answer the research questions above, the most important tasks are to find an effective approach to develop a system that can be proved better than hundreds of other systems on the market, and *how* to prove it. In other words, this thesis presents the whole process of developing a completed rating system, from the initiation to the final trial/testing. This process is as important an outcome as the system itself. Initially, there were four possible approaches that were considered. They strayed from each other at different points:

1. *Approach I*: Developing the new rating system (TPSI) from scratch: come up with a brand new assessment criteria system, assessment method, user experiences, system format, etc. This is the case of highly technical-driven tools such as CASBEE (see Section 5.2.3), Envest, and SPeAR (see Appendix A).

2. *Approach II*: Developing TPSI based on just one rating systems, only modifying the assessment criteria and/or the weighting of them to serve the purpose of tall-building assessment. All other rating systems are ignored. This is the similar approach to that of many existing systems such as LEED, Green Star, LOTUS, HQE, EEWH, and DQI. (see Appendix A). This is also the most popular approach.

3. *Approach III*: Developing TPSI based on one rating system but adopting a different format than the Software - Manual system. Keep everything else such as the assessment criteria, assessment method and other features. This approach is similar to Approach II but not as popular. The systems that adopted this approach include SE Checklist, SBAT (see Appendix A), BRI LCA (Japan), and GOBAS (see Section 4.3.3).

4. *Approach IV*: Finding out the most suitable rating systems for tall-building assessment, and the develop TPSI based on them. Adopt the best features (i.e. assessment criteria, assessment mechanisms, etc.) of these systems, design a new format, structure and assessment process to utilise all these features. It is difficult to trace back to the systems that adopted this approach, but it can be seen systems such as Green Mark, HK-BEAM and NABERS (see Appendix A).

2.3.2. Pros and Cons of the Possible Approaches

All of these possible approaches have their pros and cons:

1. *Approach I*: This approach would create a tool with great originality. However the amount of works and technical contents required make it virtually unrealistic for a PhD research. Beside, it would be extremely difficult to prove that such tool is better than renowned systems such as BREEAM and LEED. Not to mention the fact that the credibility of self-developed assessment criteria will never be as strong as long-established standards.

2. *Approach II*: This approach would substantially reduce the amount of works. However it would just create another version of the adopted system and therefore could not make use of all other systems' features and advantages. Plus, it would raise serious questions about the originality and intellectual property. Such a system is not likely to gain a good share in the market, and most importantly does not leave much room for the integration of original and innovative features.

3. *Approach III*: This approach has the similar pros and cons to Approach II. Keeping all the assessment criteria, methodologies and assessment mechanisms means no academic and technical contributions. Plus this would prevent the use of the Software – Manual format, which is very well established and has been proved to be efficient in reality.

4. *Approach IV*: This approach would create a strong tool that inherits the best qualities of popular rating systems. It would certainly be an improvement from existing tools, thus provide good bases to prove its advantages at later stages. The amount of works and resources needed are also appropriate for a PhD research. Moreover, it would preserve a good balance between originality and credibility. Most importantly, it provides the freedom to the introduction of original features and technical contents that needed to create a tall-building specialised tool. On the other hand, because of the multiple development bases, this approach would require the synchronisation and systemisation of different standards, which is a substantial task.

All factors considered, Approach IV was chosen as the final approach. A multi-strategy research methodology is designed from an integrated perspective and different research methods/activities are introduced to the main stages according to their specific features and desired outcomes (see Section 2.4).

2.4. RESEARCH METHODOLOGY

According to Approach IV, TPSI was developed as a 'second-generation' (derives directly from 'first-generation' systems such as BREEAM and LEED) assessment method that built on the limitations of existing methods, and confronted areas of building performance assessment that were previously either ignored or poorly defined. The structure and scope of the assessment framework explained in this section went through several changes over a two-year development period involving the collective input of the repeated literature review process.

2.4.1. The Three Dimensions of TPSI Development

In the rapidly evolving field of building environmental research and practice, many players have different agendas and requirements. This inevitably creates different expectations of an assessment tool. This was particularly evident during the GBC process (see Appendix A.23) where the National Team members involved in the assessment process consisted of academics, researchers and practitioners. A primary role of a building environmental assessment method is to provide a comprehensive assessment of the environmental characteristics of a case-study building. Cole (1998) – a key participant of GBC movement - broadly established the three distinct roles of building environmental assessment methods as followed:

- Providing a common and verifiable set of criteria and targets so that building owners striving for higher environmental standards will have a means of demonstrating that effort, i.e., a mechanism to influence market receptivity and demand for higher environmental performance standards.
- Providing the basis for making informed design decisions, i.e., a design tool that can provide direction and guidance at all stages during the design development

by highlighting priority issues and suggesting the possible trade-offs between options.

- Providing an objective assessment of a building's impact on the environment, i.e., a tool to evaluate energy and mass flows between built and natural systems and provide a common yardstick for measuring progress toward sustainability.

It is necessary that TPSI can offer guidance in all of these three areas. This research accepts the idea that evaluating the environmental merits of both completed buildings and of evolving designs is an important endeavour. However, it is the contention of the research that having a clear idea of the overall intention of an environmental assessment and its anticipated audience is critical to its ultimate success. This requires making a distinction between the three roles identified above and making the distinction explicit in the structuring of the assessment method.

Conceptually, the creation of TPSI is determined by three dimensions: the *Data dimension*, the *Vision dimension*, and the *Theoretical dimension* (see Figure 2.1). These three dimensions mutually rely on, and affect, each other. It is also critical for the development of TPSI that they are closely linked. These three dimensions can also be described as in Figure 2.2.

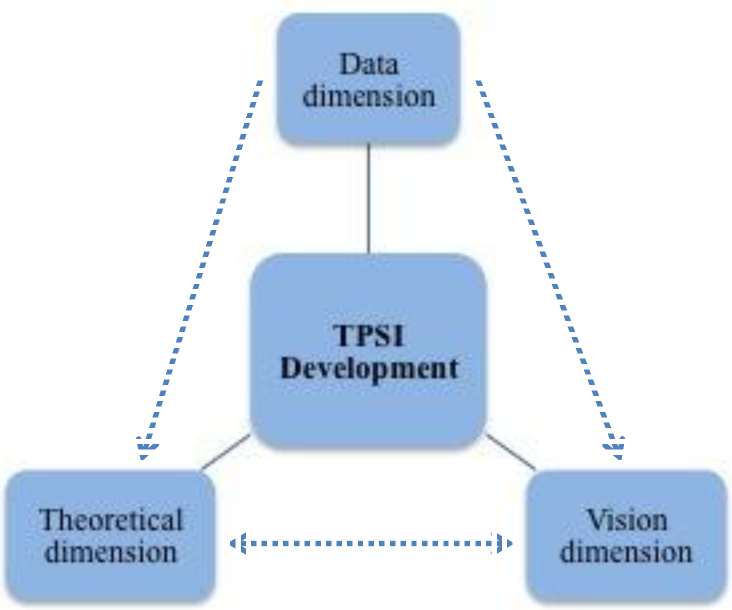

Figure 2.1: The three dimensions of TPSI development 1

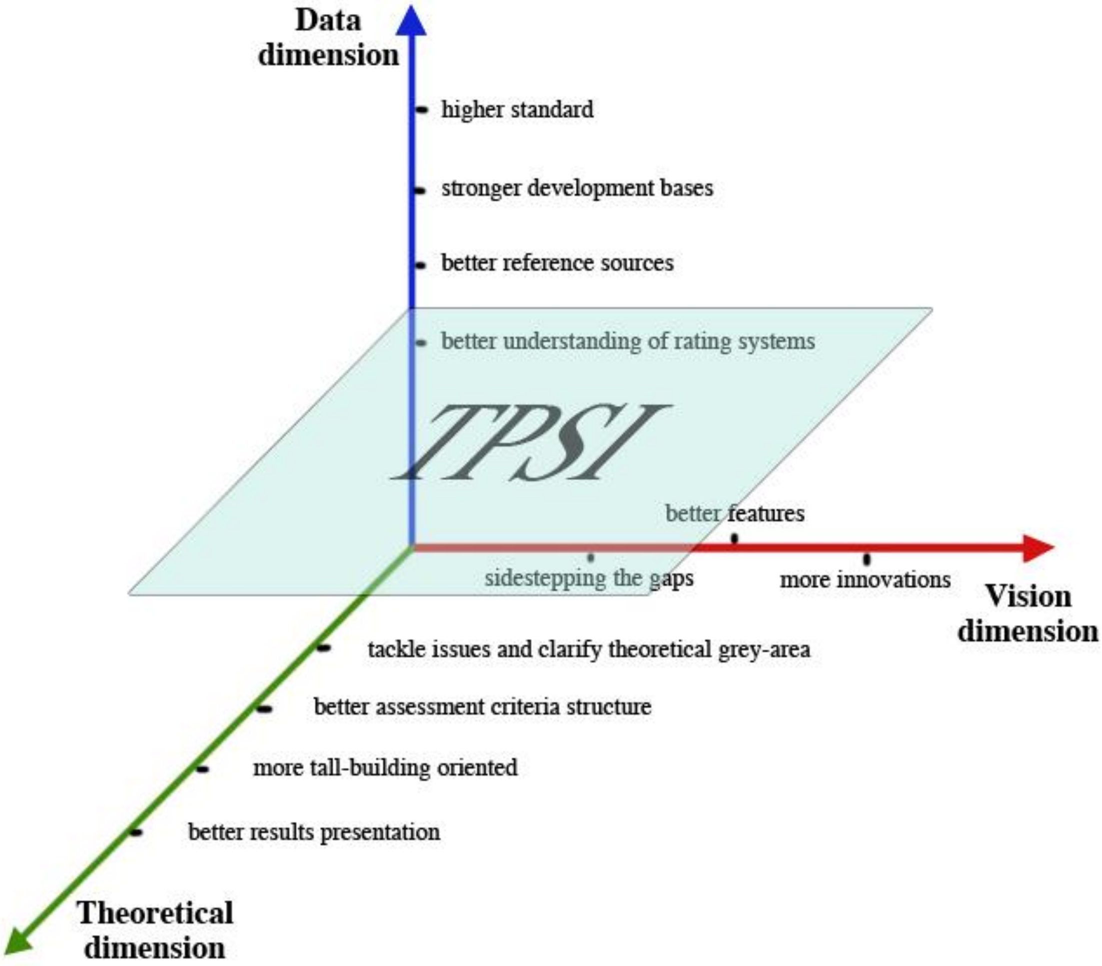

Figure 2.2: The three dimensions of TPSI development 2

The three-dimension concept introduced in this chapter represents a *method to build a better rating tool*. A basic sustainability rating system, principally, is made of 'criteria' and 'features.' 'Criteria' being the basis of an assessment, and 'features' being the means that users use to *carry out* this assessment. The Vision dimension represents the effort to come up with better and more innovative features, while as the Theoretical dimension represents the efforts to develop better assessment criteria structure. (Please note that 'better assessment criteria' in Theoretical dimension has a different meaning than the technical quality of standards, which is covered in the Data dimension). Rating systems must strive to be 'larger' on the plane created by the Vision dimension and the Theoretical dimension in order to get 'better.' The Data dimension represents more in-depth efforts to achieve a broader understanding of existing systems, which leads to more informed selections of development bases. This dimension affects the quality of a rating system on a holistic level. It also offers the opportunities to raise the bar on sustainable standards, or 'technical quality' of assessment criteria.

2.4.2. Research Methodology Mapping

Based on the three dimensions mentioned in Section 2.4.1, the methodology of TPSI's development was designed, which is described in Figure 2.3.

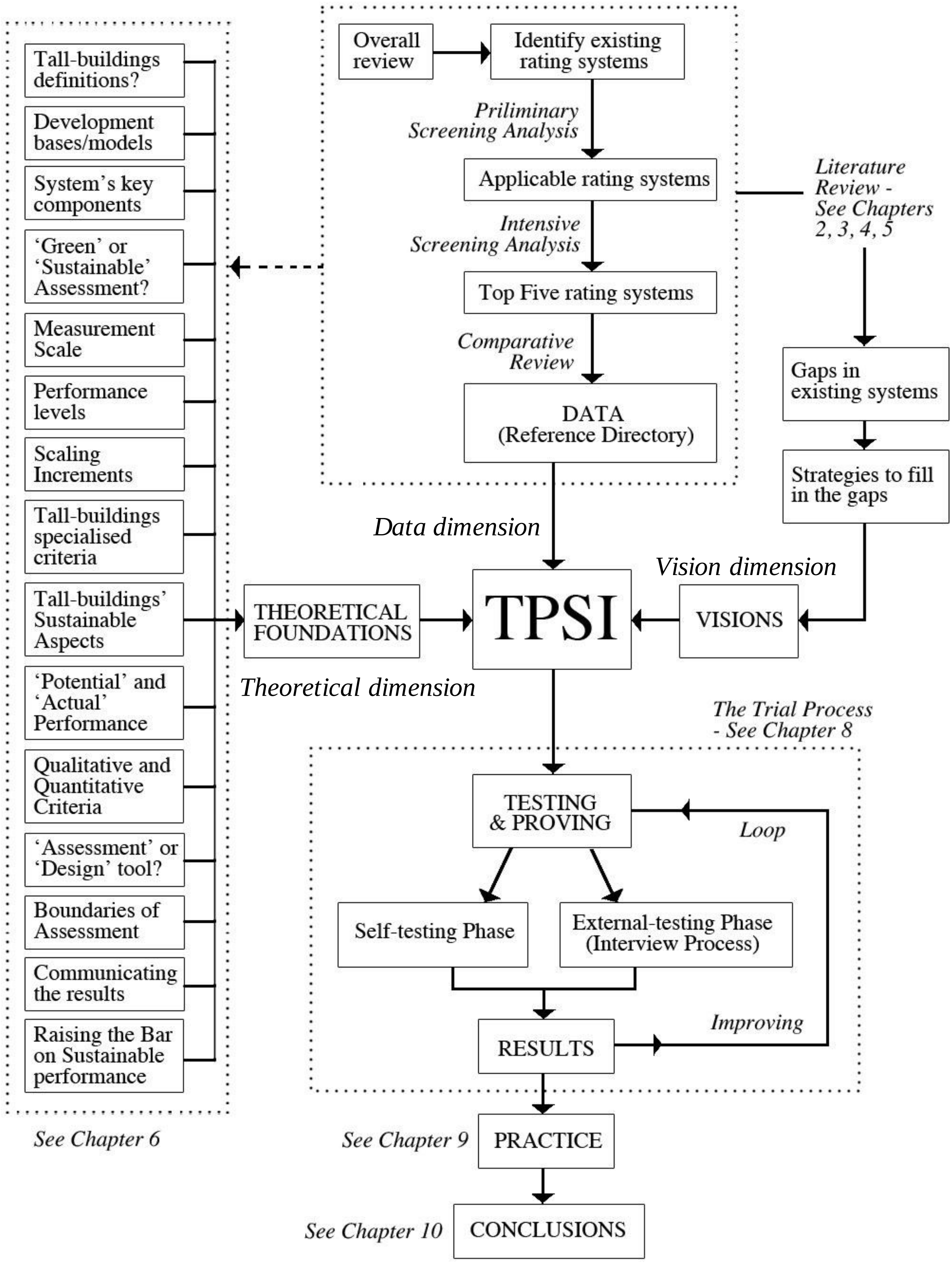

Figure 2.3: Research methodology mapping

2.4.3. The Data Dimension

The Data dimension represents the whole literature review process. This dimension identifies all notable existing rating system across the World. It undertakes an international comparison of global sustainability tools and examines their characteristics and differences. Most importantly, it focuses on which tools from different countries can be directly compared with each other (e.g. is a five-star building with one rating system directly comparable with a four-star rating of another rating system?). The results are designed to provide some clarifications of the assessment tools for sustainable tall-buildings, which in turn will assist investors, developers, tenants, and government bodies in making informed decisions about sustainable tall-buildings. In addition, it is envisaged that removing some of the uncertainty associated with sustainable tall-buildings will increase transparency for stakeholders and facilitate their acceptance.

The essence of this dimension is the Screening Analysis Procedure (see Chapter 4). The ultimate goals of this process are:

- Identify applicable sustainability rating systems for tall-buildings;
- Narrow and filter to the most suitable rating systems for assessing tall-buildings' sustainability and comparatively review them;
- Build up a reference system for further steps of the research.

The literature review and ultimately TPSI's quality rely heavily on the results of this Screening Analysis Procedure. The Screening Analysis Procedure will affect virtually every aspects of TPSI's development. It will decide the main development models; indicate the strengths and weaknesses of each system; help determining what features should be built and what mistakes should be avoided; and specify exactly where to look for reference sources.

It is therefore very important that a systematic approach is adopted during the Screening Analysis Procedure. The goal is to ensure existing rating systems are identified and judged in a *resourceful* and *critical* manner. Figure 2.4 conceptually describe the Screening Analysis Model. The middle column shows the main stages of the Screening Analysis Procedure, which are based on the criteria listed in the left column. The right column shows the resources used to make the selections or elimination or judgements.

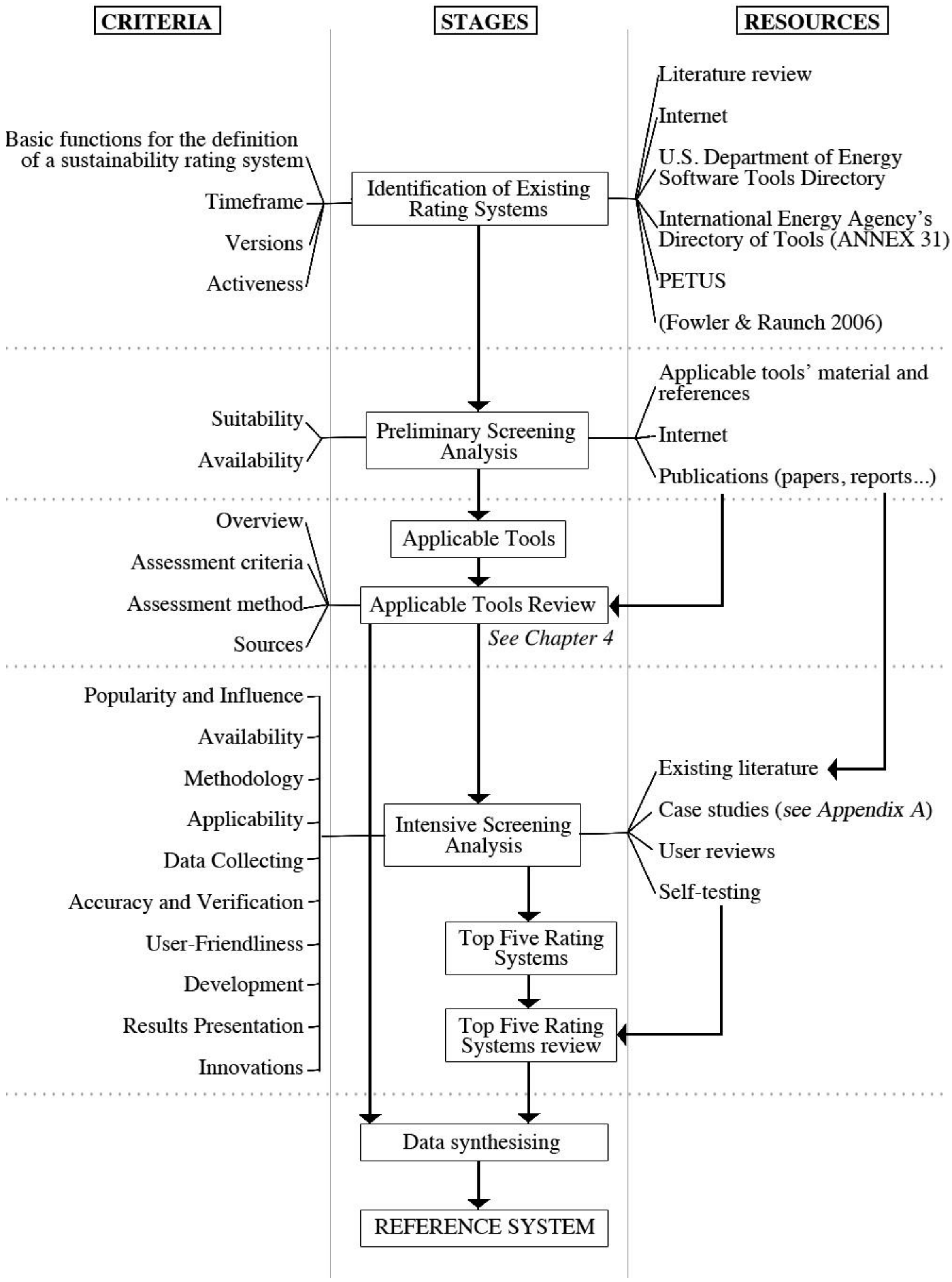

Figure 2.4: The Screening Analysis Model

Remarkably, the Screening Analysis Process introduces a system of evaluating and marking was created with 10 criteria. These 10 criteria were developed to serve the purposes of rating tools development, and can be roughly categorised into three areas:

- *Reference*: assessing the contributions of the tool in term of providing reference sources; having positive effects to sustainability, to other tools and to the field; providing development bases to the research and other existing systems.
- *Technical and Literature Contributions*: assessing the possible contributions of the tool in term of assessment criteria contents, assessment mechanisms, criteria structure, and all other materials that help building up the contents of TPSI.
- *Tool Functions:* assessing the contributions of the tool in term of providing bases/models for the development of TPSI's components/modules (see Section 6.4 for discussions about key components of an environmental rating system).

Figure 2.5 explains the structure of this system. This criteria system is used throughout the research, from the reviewing and comparison of existing tools, to the development of TPSI, to the testing of TPSI in reality and the validating of TPSI's advantages over other systems. This is very important in order to maintain the consistency throughout the stages of this research. See Section 4.5 for more discussions on this criteria system. The Screening Analysis Procedure is described in more details across Chapter 4.

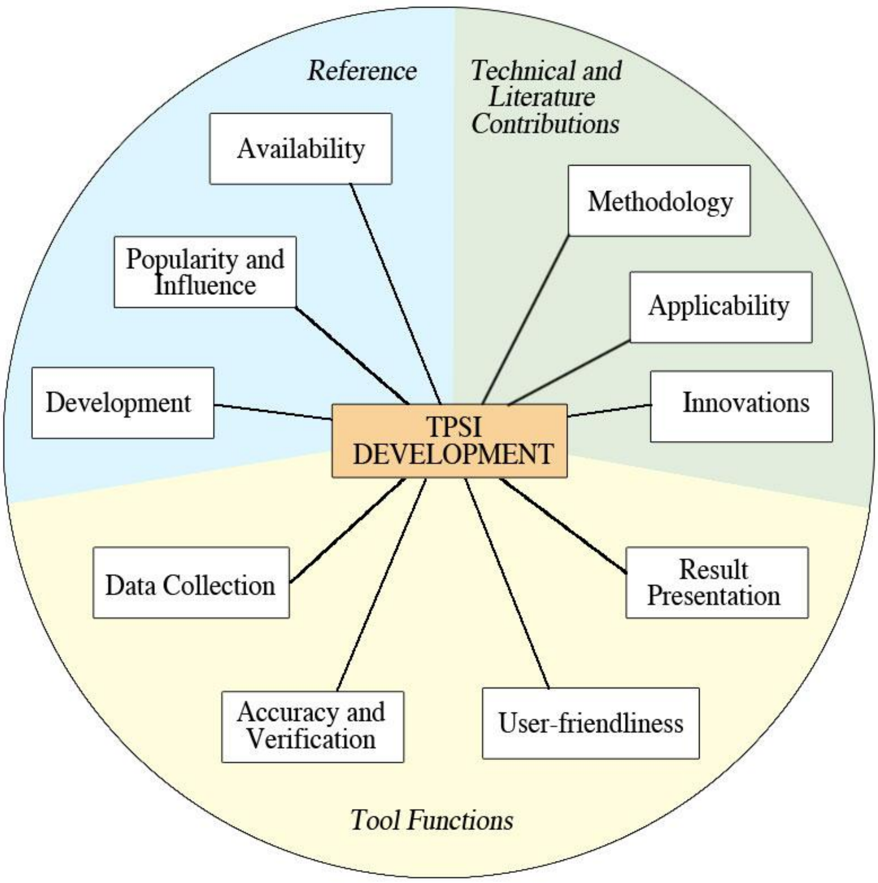

Figure 2.5: The Intensive Screening Analysis criteria structure

This Screening Analysis criteria structure was developed upon the following sources:

- 'Sustainable building rating system summary' (Fowler & Raunch, 2006) - a research by the U.S. Department of Energy, which proposed a range of criteria in an attemp to compare popular rating systems such as BREEAM and LEED.
- 'Directory of Tools' (Lützkendorf, Tanz & Moffatt, 2004) – a research by the International Energy Agency's (IEA) One of the main outcomes of this research is the identification of active rating systems and their summarised features, which were presented in a systematic strucutre (see Section 4.3.1).
- The review process of 29 applicable tools (see Appendix A) and the Vision dimension (see Section 2.4.4).

2.4.4. The Vision Dimension

This dimension takes root from the Data dimension. Based on the literature review, this dimension's aim is to identify the gaps in existing rating systems and plan to fill in those gaps in further research. This is conceptually described in Figure 2.6 and is discussed further in Section 5.4.

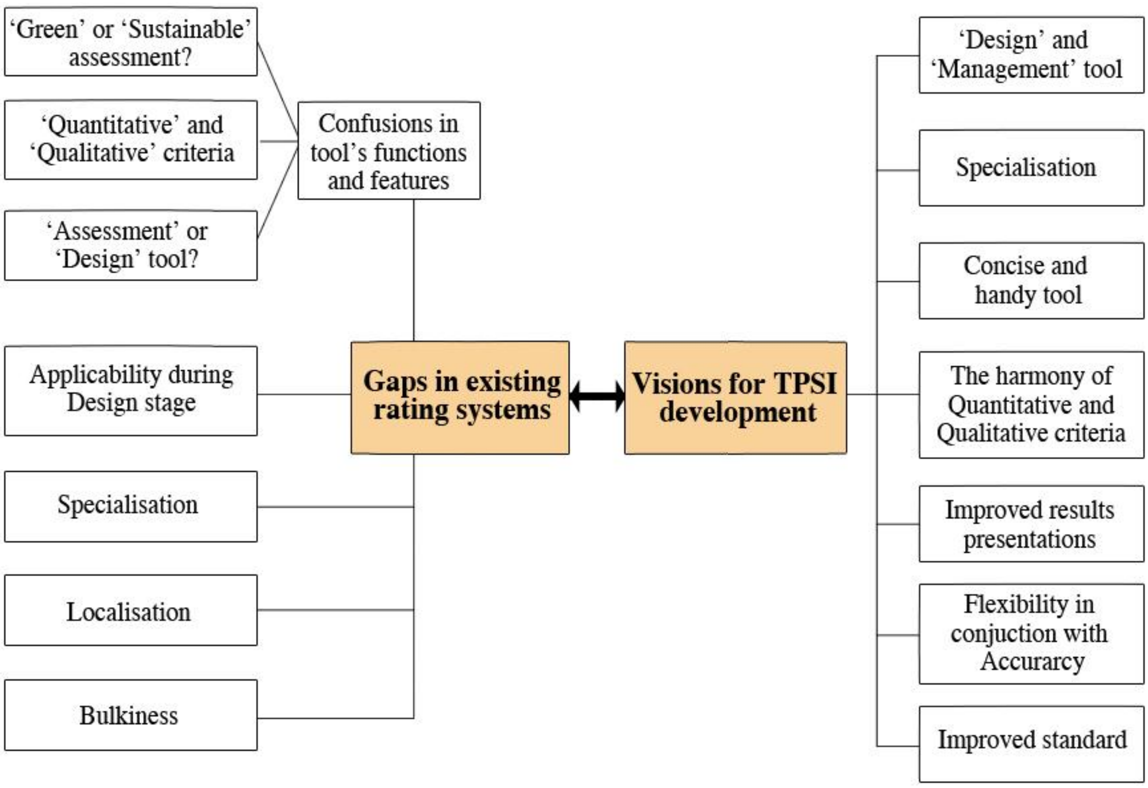

Figure 2.6: Gaps in existing rating system and the visions for TPSI development

The vision dimension ensures that TPSI's development follow the right course and that TPSI will have certain advantages over existing tools in tall-building aspects as well as overall sustainability assessment aspects. This dimension also has connections with the Theoretical dimension: it helps defining the foundations and theoretical issues when developing TPSI. For an example, the 'Localisation' issues in existing rating systems (see Figure 2.6) leads to the arguments regarding the weighting of assessment criteria (see Section 6.16.6), which in turn leads to the introduction of TPSI's Dynamic Weighting System (see Section 7.8.4). Another example is, as an attempt to increase the system's applicability during early stages of a project, charts and graphs and TPSI Factor (adopted from CASBEE's BEE Factor idea) were introduced to enhance the results communicating ability (see Section 6.16).

2.4.5. The Theoretical Dimension

The Theoretical dimension is affected by both the Data dimension and the Vision dimension. After studying existing systems, identifying the gaps and establishing the visions for TPSI development, it is recognised that tool development aspects can be divided into four main areas – or 'quarters,' representing four main loads of work when developing a rating system. These four quarters can be divided further into smaller issues and aspects - they are the theoretical foundations for the development of TPSI. This issues structure is conceptually described in Figure 2.7. The individual aspects are discussed in Chapter 6.

The Theoretical dimension directly determines all aspects of TPSI development:

- *Basic Foundations Quarter*: defining the assessment objects and selecting the best development bases to develop TPSI upon. The issues within this quarter also help deciding the best format to adopt for TPSI rating system, which in turn establishes the components structure (see Section 6.2, 6.3, and 6.4).
- *Assessment Methodology Quarter*: clearing up any confusion in tool functions and theoretical grey-areas, identifying the core assessment mechanism, developing the core functions of the system (see Sections 6.5, 6.6 and 6.7).
- *Assessment Criteria Quarter*: identifying important aspects of tall-building sustainability, which leads to the introduction of tall-building specialised

assessment criteria. Designing the structure of assessment criteria system, translating and modifying the adopted standards into synchronised criteria, introducing new criteria, balancing the quantitative and qualitative criteria, strategies to set higher standards (see Section 6.8, 6.9, 6.10, and 6.11).

- *Results Presentation Quarter*: translating the evaluations into actual results and ratings, identifying boundaries of assessment and target performance levels, improving the utilisations of assessment results (see Sections 6.12, 6.13, 6.14, and 6.15).

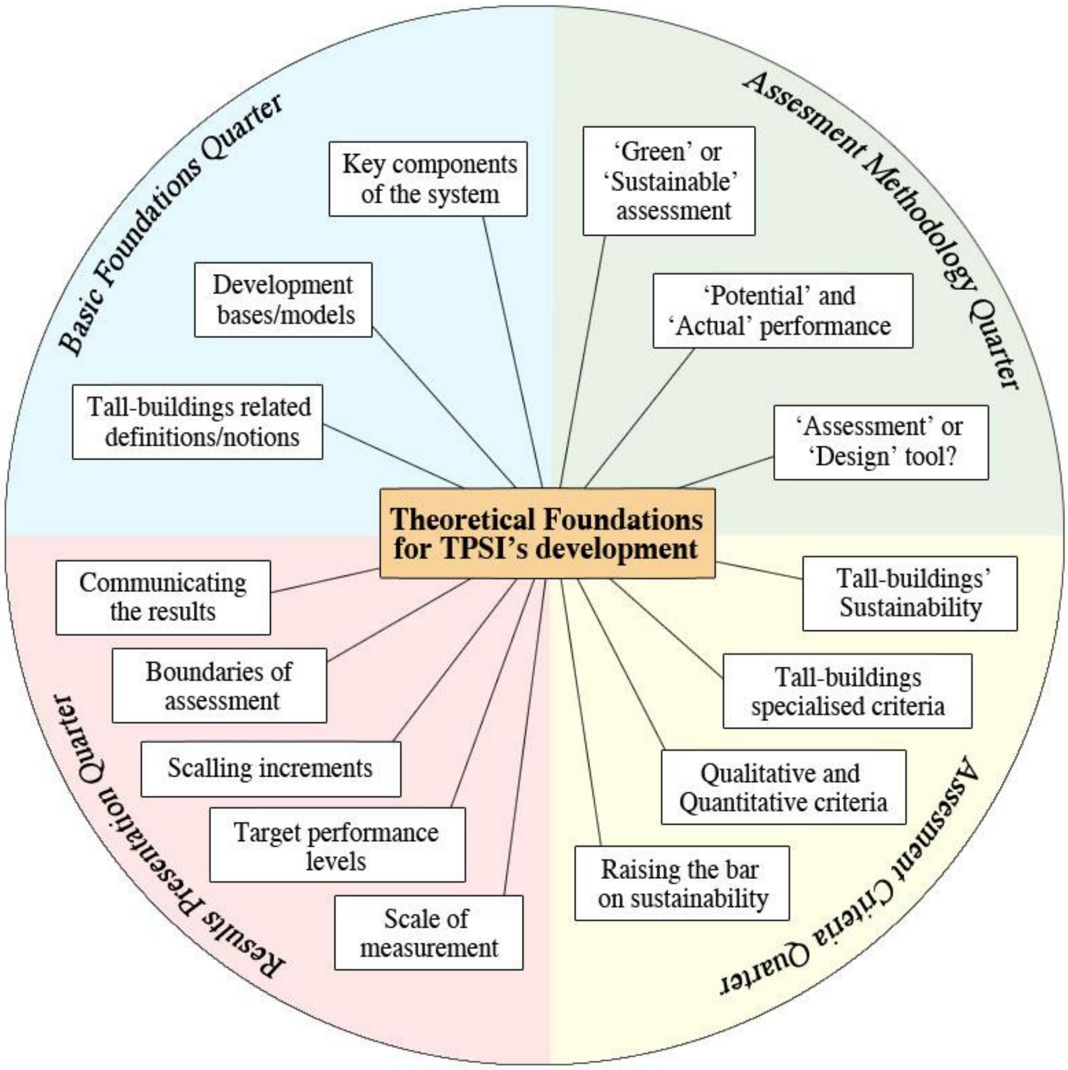

Figure 2.7: Theoretical foundations for TPSI's development

Developing a sustainability rating scheme/system has never been the topic of a PhD research. For security, Intellectual Property and other reasons, the major organisations that own popular rating systems never publish the development process and methodology of their systems. The issues structure of the Theoretical dimension is an original proposal of the candidate, which was developed upon the following sources:

- 'Preliminary Assessment of the GBC Assessment Process' - A joined research by Cole and Larsson (1998), in which they identified the main obstacles and tasks during the development of GBTool (see Appendix A.23).
- 'International comparison of sustainable rating tools' (Reed *et al.*, 2009) – a research that undertakes an international comparison of global sustainability tools and examines their characteristics and differences.
- 'Tall buildings and Sustainability' (Pank, Girardet, & Cox, 2002) - a thorough research by the Corporation of London, which tried to identify the main sustainable issues of tall-buildings projects.

2.5. RESEARCH FRAMEWORK

Basically, the research is divided into three main parts/stages (see Figure 2.8) - according to three main research questions and the research methodology mapped in Figure 2.3.

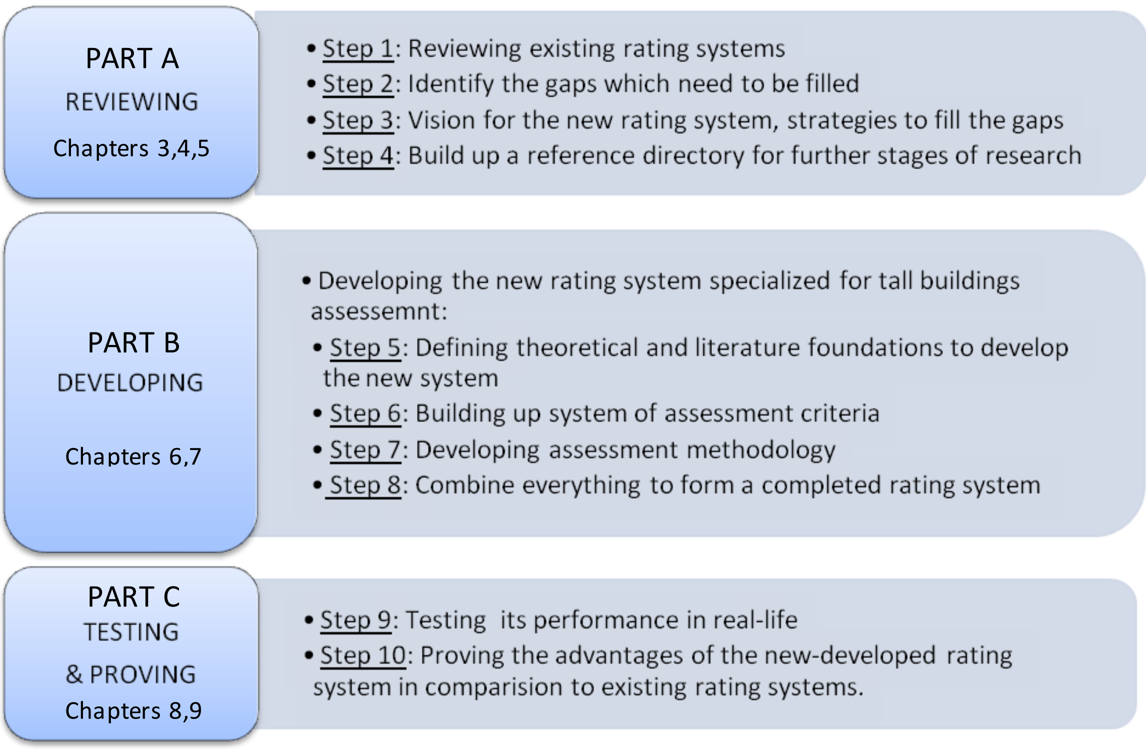

Figure 2.8: The research's framework

'Part A - Reviewing' – Chapters 3, 4, 5.

- An extensive and thorough literature review process is carried out to identify a large number of existing sustainable and environmental tools from a number of verified sources and the Internet. Verification mechanisms are applied to edge out inappropriate tools and to make sure no suitable tool is left out. A reasonable number of 29 suitable tools (or applicable tools) are selected to review further.
- A screening procedure is designed with two phases to carefully and systematically review all the suitable tools. During this process, all the features and related literature of 29 applicable tools are collected and summarised. A referencing system is built, ready to use in the next research stages.
- A system of evaluating and marking was created with 10 intensive criteria. The 29 applicable tools are put through this process to test their appropriateness in term of assessing the sustainability of tall-buildings. The five systems that score the highest during this process will be the basis for the development of TPSI.
- The five selected rating systems are studied in details. Case studies of tall-buildings assessed by these systems are also identified and studied. The advantages and disadvantages of these systems are recognised.
- The visions for the new rating system are established with specific features.

'Part B - Developing' – Chapters 6, 7.

- Based on the visions established in the 'Reviewing' stage, the keys development foundations are identified. A development model for the new rating system is built. This model adopts the advantageous features of different existing rating systems and fills in all the recognised gaps. The development model is built with strict considerations of tall-building projects' characteristics.
- All the sustainable features of tall-building projects are systemised. The assessment criteria system of TPSI is built to appropriately assess all

these features. Many methods are applied to different criteria to ensure that they are measurable, effective, and easy to implement.

- An input mechanism (or 'Input Module') is designed to realise and award the fulfilment of each assessment criterion. This input mechanism will then convert these fulfilments into quantifiable values i.e. 'credits.'
- An assessment methodology (or 'Assessment Module') is designed to evaluate and weigh up the input values. This assessment module is built based on several models and will have special features, which assure accurate evaluation of different types of tall-buildings in different contexts.
- An 'Output Module' is designed to synthesise the outcome produced by the assessment module into actual results. This output module is able to generate overall scores, rankings, graphs, charts and other materials. Strict requirements are in place to ensure that the final results are usable and comparable between multiple parties, as well as other features.
- All modules are assembled to construct the Excel tool (the 'TPSI Calculator'). Multiple resources are utilised to solve the technical issues when coding the Excel tool. The 'TPSI Technical Manual' is also produced to form the complete TPSI system.

'Part C - Testing and Proving' – Chapter 8, 9.

- The Trial Period begins. TPSI is used to assess some local tall-buildings in Sheffield first before being tested with various tall-buildings across the UK.
- A trial version of TPSI is provided to many parties and organisations to study its functions and advantages over existing rating systems. Different types of organisations are deliberately chosen across the Built Environment to fully test TPSI's operation when using by different types of users. Individuals and organisations with experiences using sustainability rating systems are targeted. There are over 50 individuals and organisations make commitments to take part in the trial period (results of only 40 cases are chosen to analyse).
- A tall-building project is assigned to each case. The phases of these case-study projects are intentionally varied to test the entire capability of

TPSI. The individual/organisation is asked to use two or three different rating systems on the case-study project (one of them is TPSI).

- A questionnaire is designed which will collect the participants' opinions on various aspects of the rating systems they used. A marking system is used to compare various aspects of TPSI and other rating systems. The disadvantages of TPSI are clearly identified; its advantages over other rating systems are also verified.
- Based on the feedback, TPSI is put through a revival process, during which the flaws and disadvantages are fixed or improved until a certain level of participants' satisfaction is achieved.
- The verification phase reaches a higher stage with the involvement of the University of Sheffield and major firms in the Built Environment. Realising the economical and social potentials of TPSI, the University of Sheffield has released a fund to develop TPSI into an online rating system. A social network is also developed for people and organisations working in the Built Environment. The online TPSI rating tool (under a new name: 'GreenLight') is distributed on this network to attract more users. TPSI keeps being perfected throughout the development of this project (called TPSI Project) (see Figure 2.9 and Section 9.2).
- From the connections of the research's supervisor: Dr. Hasim Altan, some major UK firms in the Built Environment have shown interest in TPSI system, including Mott MacDonald and Hilson Moran. Some major firms and the government in Vietnam also express their attention. Arrangements are being made, according to which TPSI will be used in many major high-rise projects across the UK and worldwide. This will be a highly important verification and authentication of TPSI's advantages, values and success; as well as the research's contributions.

Figure 2.9: TPSI 2012 Version and TPSI Project

2.6. CHAPTER CONCLUSIONS

This chapter conceptually presents the whole process of developing a completed rating system, from the initiation to the final trial/testing. This framework is original and is an important outcome of the research, apart from the TPSI system itself. The essence of this methodology is to develop TPSI based on five main development models (five successful systems namely BREEAM, LEED, CASBEE, HK-BEAM and Green Star). Most existing rating systems are developed based on one or several rating systems bases for some internal reasons. This research's approach took it a step further by analysing potential development bases first before choosing them. In other words, the research based the selection of development foundations on systematic and thorough study. This strategy offers good insurances of TPSI's stability and reliability since it is developed upon well-established standards that have been around for decades. TPSI adopts the best features of these tools, while filling in their gaps and possess original features that are suitable for tall-building assessment. This methodology also provides the chances to build a new rating system that would be an improvement from existing tools, especially in the area of tall-buildings assessment; as well as sidestepping the mistakes made by existing systems.

CHAPTER 3: REVIEW OF SUSTAINABILITY RATING SYSTEMS

3

3.1. CHAPTER INTRODUCTION

'Part A – Reviewing' is the initial stage of the research, which aims to develop a new sustainability assessment system specialised for tall-building projects (see Figure 2.8, Section 2.5 for the research framework). The results and findings of Part A are presented across Chapter 2, Chapter 3, Chapter 4 and Chapter 5. Part A executively reflexes the whole literature review process. This chapter gives a holistic review of sustainability rating tools and systems and the historical development of sustainability rating systems. An insight into rating systems that are being used in tall-building projects is also presented.

3.2. REVIEW APPROACH

In order to achieve the above goals, the following review approach was used throughout Part A of the research (see Figure 2.4, Section 2.4.3 for the review process model):

- Identification of available sustainability rating tools;
- Preliminary Screening Analysis to limit review to applicable systems;
- Data collection on applicable systems for intensive review;
- Intensive Screening Analysis/review to find out the most suitable rating systems (the Top Five rating systems);
- Comparative review of Top Five rating systems;
- Identify the gaps in existing sustainability rating systems;
- Develop the visions for the new assessment system (i.e. TPSI).

The five rating systems that score highest in the Intensive Screening Analysis are the most suitable ones for assessing tall-buildings' sustainability. They will be the main reference sources during the research and the new tool will be developed mainly based on these systems. Nevertheless, this does not mean that other systems will be totally neglected. The detailed steps and results are presented in Chapter 4, Chapter 5 and Appendix A.

3.3. WHAT ARE SUSTAINABILITY RATING SYSTEMS?

3.3.1. Public Concerns

Leaders in both the public and private sectors now have recognised that our society's current approach to economic development is not sustainable, and that its accompanying problems and issues are becoming very important in the mind of the public. Accordingly, these leaders are responding in many ways, most notably in the building or refurbishing of facilities and infrastructure that make more efficient use of natural and financial resources, protect ecological systems and account for community needs (Wallace, 2010). Yet as these projects are initiated, designed and delivered, questions are beginning to surface regarding the extent to which these projects actually contribute to achieving conditions of sustainability, how is that contribution measured, and what benchmarks are being used to judge the level of contribution. It is clearly important and even admirable to sponsor and deliver projects that reduce pollution, and reduce energy and water usage beyond what is normally expected or required. However, according to Wallace (2010), it is more important that those projects, in aggregate, bring resource consumption and pollution rates down to levels that are sustainable, that is, within the regenerative and ecological carrying capacity of the planet. Moreover, the delivery of such projects must happen at a rate adequate with the urgencies of the problems at hand.

Today, there are strong and undeniable evidences that our society is falling well short of achieving sustainable development. Current resource consumption and pollution emission rates are extremely high, pushing the limits of resource supplies and carrying capacity. The consequences of these excesses are now turning up throughout the World in various forms. Spiking energy prices, extended droughts, extreme weather events, unprecedented flood damage, urban sprawl, expanding dead zones in the World's oceans, and loss of fisheries resources, are just a sample of the trends and events that are appearing in increasing frequency and intensity.

3.3.2. Building Environmental Assessment Methods

The public's concern and knowledge on environmental issues, which is maturing and strengthening, will naturally translate into an expectation for greater environmental responsibility. As with other sectors, the building industry will be increasingly scrutinised and required to develop approaches and practices that address immediate environmental concerns and adhere to the emerging principles and dictates of sustainability. Building environmental assessment methods have emerged as a legitimate means to evaluate the performance of buildings across a broader range of environmental considerations. The increase in development and application of such methods has provided considerable theoretical and practical experience on their potential contribution in furthering environmentally responsible building practices. Their most significant contribution to date has clearly been to acknowledge and institutionalise the importance of assessing building across a broad range of considerations beyond established single performance criteria such as energy.

An important indirect benefit is that the broad range of issues incorporated in environmental assessments requires greater communication and interaction between members of the design team and various sectors with the building industry, hence encourage greater dialogue and teamwork. Furthermore, since assessment methods are implicitly a synthesis of current environmental knowledge related to buildings, they can play a significant role in focussing a broad range of research through a common filter (Cole & Larsson, 1998). Hui (2009) has summarised the principal roles and involvements of building environmental assessment methods in the Built Environment as in Figure 3.1.

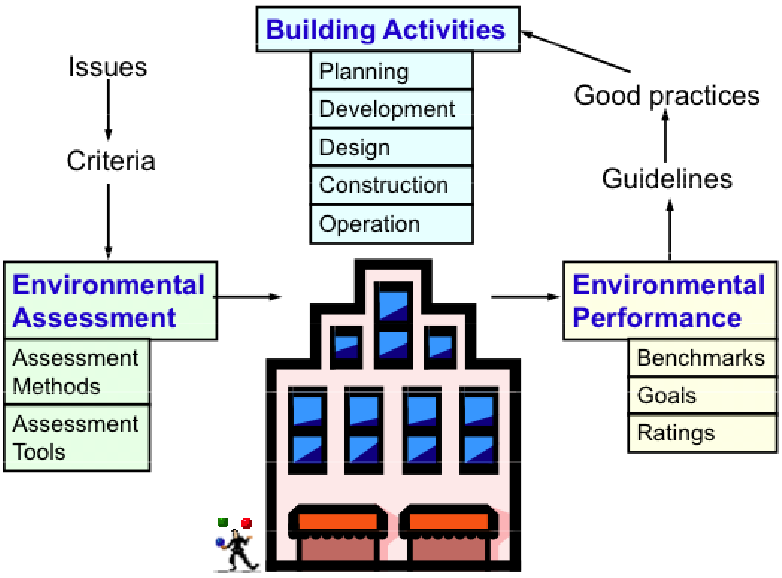

Figure 3.1: Principal roles and involvements of environmental assessment methods in the Built Environment

Source: (Hui, 2009)

3.3.3. Sustainability Rating Tools/Systems

It is important to understand that, 'Assessment Methods' and 'Assessment Tools/Systems' (i.e. 'Rating Tools/Systems') are not the same thing, although in reality these two notions are often mixed up. They are both expressions of Environmental Assessment activities, as shown in Figure 3.1. *Building environmental assessment methods are represented by sustainability rating tools/systems*. When a rating system is being developed, the developers can choose to adopt an existing assessment method or to create an original one. Thus, during the expansion of environmental assessment activities, there could be many assessment tools/systems sharing the same or similar assessment method.

Principally, sustainability rating systems are key tools to evaluate and compare sustainable buildings/projects. They provide systematic frameworks for specifying performance criteria, thereby enabling actors in the building industry to be more measured and accurate about the movement towards more sustainable forms of designing, constructing and operating buildings (EC Consulting & IH Consulting, 2006). The key and ultimate advantage of sustainability rating systems is that they are a tool that provides credible frameworks for specifying and achieving high performance buildings.

3.4. WHY USE SUSTAINABILITY RATING SYSTEMS?

3.4.1. General Benefits

Building sustainability rating systems fulfil a number of important roles. While they essentially provide a standard for what systems, materials and strategies can help making a building green; they are also key tools for using the market to increase demand for high performance buildings (EC Consulting & IH Consulting, 2006). They provide a mean for a building owner or tenant to ask for a green building, and to compare the greenness or sustainability of their building design proposals.

At another level, organisations working to effect market transformation (see Section 3.4.2) can use building sustainability rating systems as a tool for specifying minimum performance levels, and to create an industry standard that is above and beyond what is required by code. They help to increase a broader understanding of the impact buildings have on our society, and provide a means for disseminating information on how to reduce these impacts. For those who are in charged of operating the movement towards high performance buildings, sustainability rating systems help to structure the thought process, and to keep issues at the top of the priority list that might not have been given serious consideration otherwise. They can serve to offer structured advice, including goals, strategies, and actions that are suitable for improving performance. Finally, sustainability rating systems have created a market in part by virtue of the standardised recognition they permit; thereby enabling owners, developers and professionals to gain credit, awards, and other marketing outputs (EC Consulting & IH Consulting, 2006).

3.4.2. How Sustainability Rating Systems Support Market Transformation

One definition of market transformation is *"the reduction of barriers to cause lasting changes in the structure of a market, or the behaviour of market participants, resulting in accelerated market adoption"* of the desired product (EC Consulting & IH Consulting, 2006). In other words, market transformation is the process of intervening to change customers' behaviour. In the case of the building industry, the desired end state is to ensure that the market demands buildings that are high performance, or green.

The intent of a market transformation initiative is to accelerate the natural growth of the technology or approach, and to increase the overall market demand for it. Over time, the typical market transformation objectives and intervention tools evolve. Markets can be considered as moving towards technologies that provide a net increase in social welfare. But occasionally, market dynamics are not sufficient to reach a desired objective that is considered to be in the greater social interest – much like how the Built Environment is struggling to achieve sustainable development worldwide. In these cases, barriers and/or failures prevent the markets from achieving that societal objective.

Sustainability rating systems for assessing the performance of buildings can therefore be considered as a 'technology' that can help to transform the building industry towards higher performance buildings that minimise impacts on the environment, optimise economic, and ensure achievement of social goals and quality of life. They are an important market-based tool for transforming the building industry, raising consumers' awareness, and stimulating competition and dialogue. Market aspects are very important in tools development, beside the academic and technical contributions that new developed tools/systems must bring.

3.4.3. Actors within the Building Industry

Understanding the potential role of rating tools within this sector is closely linked to understanding the nature of the people who would be using the tools, and what their needs are. Table 3.1 outlines the range of target audiences for rating tools, and emphasises what needs are associated with each of these actors.

Table 3.1. Needs of end users of rating systems

Actor	Design resource	Best practice guide	Audit tool	Monitor	Market transformation
Property manager		■	■	■	
Property owner			■	■	
Design professional	■	■			
Operations staff			■	■	
Supplier		■			
Program Administrator		■			■
Tenant	■	■		■	

Data source: (EC Consulting & IH Consulting, 2006)

Evidently, the use of rating systems as a mechanism for providing best practices is a need shared by many of the actors in the existing building industry. Design professionals and tenants require tools to use as a design resource, and often as a mechanism for monitoring performance. It is the owners and property managers that rely on building rating tools to facilitate auditing and monitoring, as these functions feed into roles related to on-going operations. At the level of consciously effecting market transformation, it is the program administrators who rely on the rating tools to play a direct role in changing behaviour.

What becomes clear is that, within the existing building industry, there is a range of phases of building/operations, and there is a range of actors. Because of this diversity, it is inappropriate to consider that one tool alone would satisfy all the needs sufficiently. For this reason, multiple tools are necessary (see Section 3.4.4).

3.4.4. Benefits of Supporting Multiple Tools

A range of benefits has been identified by Campbell (2006), which supports the endorsement of multiple rating tools:

- A range of tools is already in use in the market place. These tools are complementary, and, if suitably positioned, may transform the market more successfully than reliance on a single tool.
- The market is not likely to be confused by the presence of multiple tools.
- Building certification is only one of the potential values and benefits of rating tools.
- No one tool or system should be expected to meet the full range of needs of the building community.
- The range of groups, budget, knowledge and interest is addressed by the presence of multiple tools.

The ultimate system is likely to be a harmonised set of tools with horizontal integration to meet the requirements of a range of different building types (e.g. different tools to serve different purposes), as well as vertical integration to meet the requirements of different client groups, budgets, knowledge and interest levels (e.g. different versions of the same tool). This calls for the development of specialised tools such as TPSI, but at the same time, creates an extremely complex system of tools with obvious problems (see Section 3.5).

3.5. HISTORICAL DEVELOPMENT OF SUSTAINABILITY RATING SYSTEMS

The idea of assessing the sustainability of a building/project has been around for several decades – with the emergence of green and sustainable architecture. However, not until the 1990s was the assessment of sustainable buildings officially generalised and standardised. It is commonly accepted that the current era of rating tools commenced in 1990 with the introduction of the BRE's Environmental Assessment Method (BREEAM)[7] (Reed *et al.*, 2009). The development of sustainability rating systems is a

[7] The **Building Research Establishment (BRE)** is a former UK government establishment (but now a private organisation) that carries out research, consultancy and testing for the construction and built

complex and inheritable process. This is most important when judging the originality of a rating system. The main motivation of the multiplication of rating tools is the differences between environmental conditions, policies and standards of countries in term of sustainable development. This is the main reason why each country has to develop its own rating systems. In the case of some countries namely the U.S., the UK, Canada, Japan, France, Hong Kong, each region even has its own standard and thus its specialised tool. This makes sustainability rating tools constantly evolve with a rapid pace. Figure 3.2 shows the timeline of main rating systems' development since the 1990's.

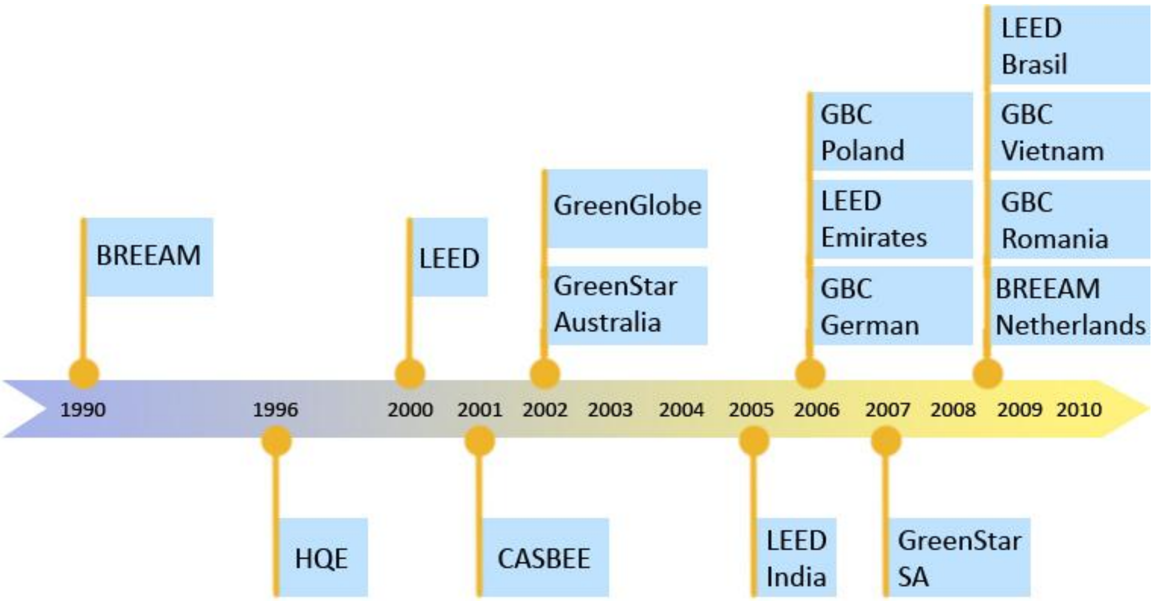

Figure 3.2: Timeline of the development of rating systems in different countries

The emergence of BREEAM was followed shortly by the French system HQE[8] and the U.S.'s system LEED[9] in 2000. Up to March 2010, there were 191 official sustainability

environment sectors in the United Kingdom. BRE's main rating scheme is **BREEAM (Building Research Establishment's Environmental Assessment Method)**. <http://www.bre.co.uk/>.

[8] The **Haute Qualité Environnementale** or **HQE** (High Quality Environmental standard) is a standard for green building *in* France which is controlled by the Paris based *Association pour la Haute Qualité Environnementale (ASSOHQE)*. <http://assohqe.org/hqe/>.

[9] **Leadership in Energy and Environmental Design (LEED)** is an internationally recognised green building certification system, providing third-party verification that a building or community was designed and built using strategies intended to improve performance in metrics such as energy savings, water efficiency, CO_2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts. It was developed by the **U.S. Green Building Council (USGBC)** in 1998. <http://www.usgbc.org/>.

rating tools identified, the actual number (including unofficial tools and developing tools which related to sustainability assessment) is approximately over 600 tools (Reed *et al.*, 2009). Regardless the vast number, there are not many systems that have been recognised worldwide and have set a standard/development model for other systems. Noticeable milestones in the 20-year development of sustainability rating tools include: HQE (1996), LEED (2000), CASBEE (2001),[10] GreenGlobe[11] and Green Star (2002),[12] and the Green Building Challenge (2006).[13]

Although there is a call for multiple rating systems as established in Section 3.4.4, the fact that each country and region has its own rating system also raises some serious concerns. The main issue is that many tools equals many standards and it can be very confusing when it comes to choosing a tool for a certain building/project. This becomes especially puzzling in countries such as the UK or the U.S., where there are too many tools and standards available. Figure 3.3 shows the complex system of popular international rating tools.

Another problem is that it is nearly impossible to compare the sustainability of different buildings that are assessed by different rating systems. For example, the highest BREEAM standard (or 'rating') (Excellent) is not necessarily equals to the highest Green Star standard (Six Stars). Building an internationally accepted rating tool is a

[10] **CASBEE (Comprehensive Assessment System for Building Environmental Efficiency)** was developed in Japan, beginning in 2001. CASBEE is one of the raising rating schemes with extremely complicated assessment method. <http://www.ibec.or.jp/CASBEE/english/>.

[11] The **Green Globes** system is a revolutionary building environmental design and management tool. It delivers an online assessment protocol, rating system and guidance for green building design, operation and management. Green Globe is based upon the Agenda 21 Plan that was originally endorsed by 182 heads of state at the Rio Earth Summit of 1992 and provided a set of principles for local, state, national and international action on sustainable development. This resulted in *Agenda 21 for the Travel and Tourism Industry: Towards Environmentally Sustainable Development*, which listed an action plan for a number of overall objectives for the industry. <http://www.un.org/esa/dsd/agenda21/>.

[12] **Green Star** is a voluntary environmental rating system for buildings developed by the Green Building Council of Australia. Although only a national tool, Green Star is wildly known worldwide for its performance and features. Since it launching Green Star has positively and greatly transformed Australia's property and construction market. <http://www.gbca.org.au>.

[13] The **Green Building Challenge** is an international collaborative effort to develop a building environmental assessment tool that exposes and addresses controversial aspects of building performance and from which the participating countries can selectively draw ideas to either incorporate into or modify their own tools. Although not active anymore, this movement had left important inheritance to the Built Environment including the **GBTool**. <http://www.iisbe.org/gbc2k/gbc-start.htm>.

really hard work as the environmental conditions and sustainable development policies of each country are too different.

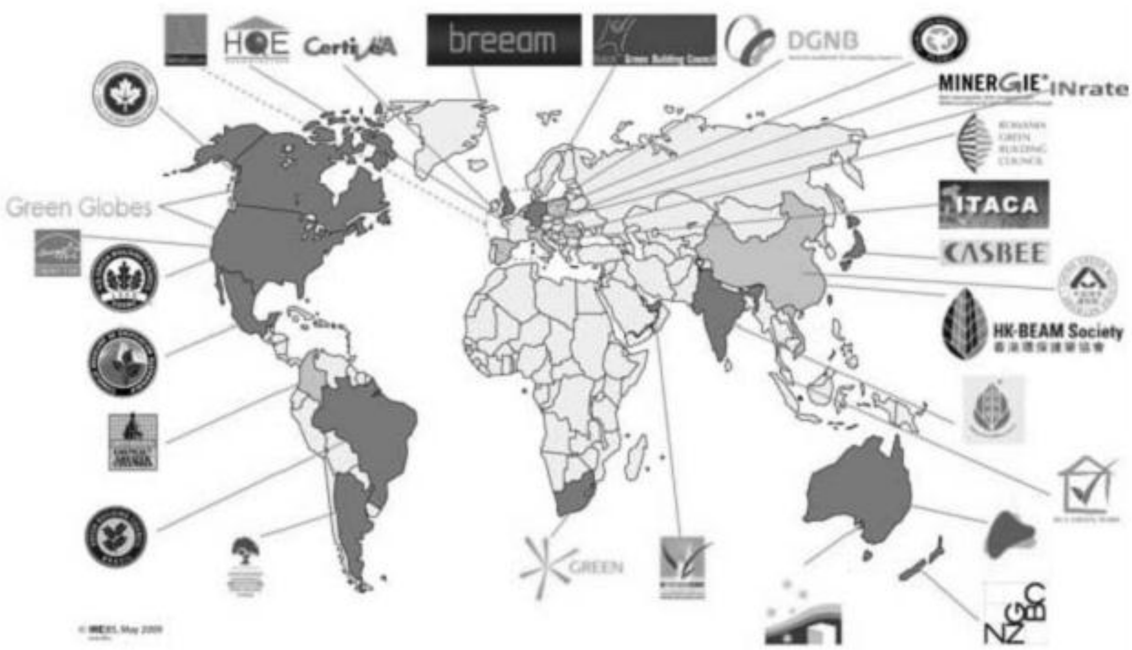

Figure 3.3: The complex system of popular international sustainability rating tools

Source: (Reed *et al*., 2009)

However, there are recent signs of changes and compromises. For example, it is reported that three of the most common rating tools, namely BREEAM, LEED, and Green Star, are seeking to develop common metrics that will help international stakeholders compare buildings in different cities using an ‘international language’ (Kennett, 2009).

It is obvious that the countries that have prestigious and well-known rating systems also have developed economies and special interests to environmental issues. These countries also have the most active Green Building Councils. This fact is shown clearly in the map of existing and emerging green building councils around the World (see Figure 3.4). The UK has always been the leading country in term of sustainable development strategies and sustainable development standard. Following up are the U.S., Canada, Japan, Australia, Hong Kong, and France.

Figure 3.4: Green Building Councils around the World

Source: <http://www.worldgbc.org>.

Normally, a rating system is modified and adopted from earlier models that were originally developed in other countries. For example, it is possible to trace many systems back to LEED and BREEAM. Even LEED was largely inspired by and based on BREEAM (Green Building Magazine, 2010). Tracing back to the root of this evolvement, it is possible to say all systems are based on the Triple Bottom Line (see Section 1.1.2). The aspects that make the difference between systems are their assessment criteria and their assessment method, which will be discussed further and summarised in Chapter 5.

3.6. SUSTAINABILITY RATING SYSTEMS FOR TALL-BUILDINGS

In most of the cases, existing sustainability rating systems divide up buildings/projects by their *functions* in order to give more detailed assessments and comparisons. For example, BREEAM divides up buildings/projects into ‘categories,’ including: Courts, Homes, Healthcare, Industrial, Multi-residential, Prison, Offices, Retail, Education, Communities, Domestic Refurbishment, and Other Buildings. There is a specialised version for each category. There is no BREEAM tool or version that is specially intended for high-rise constructions. This becomes problematic when it comes to, for instance, assessing a mixed-use tall-building. There are serious issues such as: under what BREEAM scheme should a refurbished office-residential high-rise building be assessed, BREEAM Offices or BREEAM Multi-residential or BREEAM Refurbishment or BREEAM Other Buildings?

Although their specialisation, some tools are still largely used to assess tall-buildings and are commonly acknowledged positively. LEED, BREEAM, HKBEAM, CASBEE, GBTool, and CEEQUAL,[14] have been used for many tall-buildings. Especially, LEED is unofficially considered the standard for sustainable tall-buildings in the U.S. LEED's Core and Shell version has come close to be a dedicated tool for tall-buildings. However, there still are many issues in this version. The gaps of existing sustainable rating methods for tall-buildings will be identified in Chapter 5, as well as proposed plan to fill in those gaps in further research.

3.7. CHAPTER CONCLUSIONS

There are many reasons to believe that, among the booming of sustainability assessment methods and activities nowadays, there are still essentially neglected areas. Major firms such as BRE and USGBC dominate the field with special connections and supports from the governments and financial advantages. Their assessment schemes therefore are accepted worldwide and are even used for tall-building projects despite the flaws that need to be fixed. They are technical, methodical, and systematic flaws; which will be discussed further in Chapter 5.

[14] **CEEQUAL** is an assessment and awards scheme for improving sustainability in civil engineering and public realm projects, based in the United Kingdom. It is promoted by the Institution of Civil Engineers (ICE) and a group of civil engineering organisations including CIRIA, CECA and ACE. <http://www.ceequal.co.uk>.

CHAPTER 4: SCREENING ANALYSIS OF SUSTAINABILITY RATING SYSTEMS

4

4.1. CHAPTER INTRODUCTION

As established in Chapter 3, the development of new sustainability rating systems is an inheritable process, during which the new tools are built based on the obsolete ones. They absorb the good features and advantages of existing systems and gradually build up better sets of standards. In order to develop a new rating tool for tall-building projects, initially, development bases have to be built. In other words, all existing tools that are being used have to be identified and analysed to find out the most suitable ones for tall-buildings assessment. This chapter summarises the following steps:

- Identification of existing sustainability rating systems;
- Systems screening process to find out applicable systems for tall-building projects;
- Identification of development bases for the new system;
- Building up the reference system for further stages of the research.

4.2. THE SCREENING ANALYSIS PROCEDURE

4.2.2. Summarised Procedure

The Screening Analysis Procedure is the essence of the Data dimension (see Section 2.4.3 and Figure 2.3). It was designed based on the Screening Analysis Model presented in Figure 2.4. The summarised screening procedure, step-by-step, is as follow:

- First of all, an extensive and thorough literature review process is carried out to identify a large number of existing sustainable and environmental tools from a number of trusted sources. 202 tools/systems in total were selected to enter the next round.
- To eliminate inappropriate tools for the research (i.e. for the development of TPSI) and narrow down the number of tools needed to be reviewed; these 202 tools were put through a *Preliminary Screening Analysis*.
- During the Preliminary Screening process, inappropriate tools are crossed out because of their *'Availability'* and/or *'Suitability'.*
- There were 29 tools stood through the Preliminary Screening Analysis (referred to as 'applicable tools'). They are the main reference sources during the

research. Literature about these tools were systematically reviewed and summarised in Appendix A.

- An *Intensive Screening Analysis* is created, which employs a system of evaluating and marking with 10 criteria.
- These 29 applicable tools were put through the Intensive Screening Analysis to evaluate their appropriateness in term of assessing the sustainability of tall-buildings.
- The five systems that have the highest overall score will then be the basis for the development of TPSI.
- Data (assessment criteria, assessment mechanisms, and all other features) of 29 applicable tools and particularly the Top Five rating systems are processed and synthesised to build a Reference System for further stages of the research.

Details of these steps are discussed in the Sections 4.3, Sections 4.4 and Section 4.5. The final result is presented in Section 4.6.

4.2.3. The Importance of the Screening Analysis Model

The Screening Analysis Model (see Figure 2.4) is enhanced and developed based on the following main theoretical foundations/studies:

- ‘Sustainable Building Rating Systems Summary’ – A study carried out by Fowler and Rauch (2006), which proposed a set of criteria to examine and compare rating systems (see Section 4.3.1);
- ‘The Philosophy of Sustainable Design’ – a book by McLennan (2004), which conceptually mapped the aspects of sustainability in architecture;
- ‘Planning and Design Strategies for Sustainability and Profit’ – a book by Pitts (2004), which identifies the drivers for sustainable development practices;

The Screening Analysis Model is designed to aim for long-term benefits, which are not only applied for the development of TPSI but also for all related research. In term of this research, the structure of this model allows systematic and thorough review of existing tool, and easy extraction of useful data to include into the reference system. It is notable that information of rating systems changes frequently (release of new tools and versions, modification of assessment criteria and evaluation mechanisms, etc.).

Therefore the Screening Model has to be stable enough to process all mixed information and literature into categorised data. Another key point is that the Preliminary Screening and Intensive Screening have to be an endless loop to allow continuous data input. The criteria used to examine the rating systems become more and more strict as the Screening Analysis Model runs: from the basic function requirements at the identification stage to the rigorous ten-fold set of criteria at the Intensive Screening stage. This also serves the purpose of allowing circling data input and improving the data processing speed.

At the Intensive Screening Analysis stage, key aspects of sustainability rating tools/systems are covered by ten categories, which then are divided further into smaller issues (see Section 4.5). This set of criteria's structure also represents the structure of the Reference System. More importantly, this set of criteria will be used to structure the Testing and Proving Stage of the research. For example, the questionnaire used in the Trial Process (see Chapter 8) is designed based on these criteria, so the users' opinions and other results can be processed in a similar way, and can be compared to the results of the Screening Analysis Procedure (presented in Section 4.6).

It is significant that, although designed to serve the development of TPSI – a tall-building rating system, this Screening Analysis Model can be applied to similar research/review. This is one of the initial purposes when creating this model, which is reflected in the fact that none of the criteria categories are tall-building specialised. It is the contents of these categories that are dedicated to tall-building assessment, and they can be easily modified to serve different review subjects.

4.3. IDENTIFICATION OF EXISTING SUSTAINABILITY RATING SYSTEMS

4.3.1. Resources for the Identification of Existing Rating Systems

Worldwide, there is hundreds of building evaluation tools that focus on different areas of sustainable development and are designed for different types of projects. These tools include life cycle assessment, life cycle costing, energy systems design, performance evaluation, productivity analysis, indoor environmental quality assessments, operations and maintenance optimisation, whole building design and operations tools, and more.

1. The U.S. Department of Energy's Building Energy Software Tools Directory[15] is one of the truth worthy sources to start with. This directory is sponsored by the U.S. Department of Energy (DOE). DOE developed this directory because many Office of Building Technology, State and Community Program (BTS) programs develop software tools to help researchers, designers, architects, engineers, builders, code officials, and others involved in the building life cycle to evaluate and rank potential energy efficiency technologies and renewable energy strategies in new or existing buildings. It has long outgrown the border of the U.S. and has been keeping track of environmental tools worldwide.

2. International Energy Agency's Directory of Tools (Annex 31 project)[16] is another main source to identify rating tools. Annex 31 is a project established under the auspices of the International Energy Agency's (IEA) Agreement on Energy Conservation in Buildings and Community Systems. The mandate for the Annex 31 working group is to provide information on how to improve the Energy-related Environmental Impact of Buildings. More specifically, Annex 31 has focused on how tools and assessment methods might improve the energy-related impact of buildings on interior, local and global environments. The ultimate objective is to promote energy efficiency by increasing the use of appropriate tools by practitioners. Tools stimulate communication, make energy and environmental efficiency quantifiable and ultimately make it possible to set goals and monitor performance. One of Annex 31 main outcomes is the identification of active rating systems and their summarised features, which were presented in a very systematic manner.

3. PETUS - Practical Evaluation Tools for Urban Sustainability[17] is one of the main Internet sources used during the identification stage. PETUS has been developed to help people who are involved with, or affected by, building and infrastructure to consider impacts on the environment, society and the economy.

[15] **U.S. Department of Energy's Building Energy Software Tools Directory**: <http://apps1.eere.energy.gov/buildings/tools_directory/subjects_sub.cfm>.

[16] **Annex 31 Project:** <http://www.greenbuilding.ca/annex31/index.html>.

[17] **PETUS**: <http://www.petus.eu.com>.

It includes information that can be used to analyse and improve the sustainability of urban infrastructure, whatever the size or type. Although specialised for European systems, PETUS also has information on sustainability tools worldwide. The information on the PETUS website includes:

- Case study projects that illustrate where sustainability has been considered;
- Methods that can be used to guide and analyse consideration of sustainability in a practical way;
- Legislation that has to be followed in particular countries.

More importantly, PETUS offers a systematic and automatic reference system, the layout of which is described in Figure 4.1. Users can easily switch between different parts of a tool's data to fully explore its features, which were put in the context of case studies as well as its background information. PETUS's layout is designed to support the decision making of users and it works really well. PETUS has proved to be a valuable source during the Literature Review of the research. It also provides a development model to build up the Reference System.

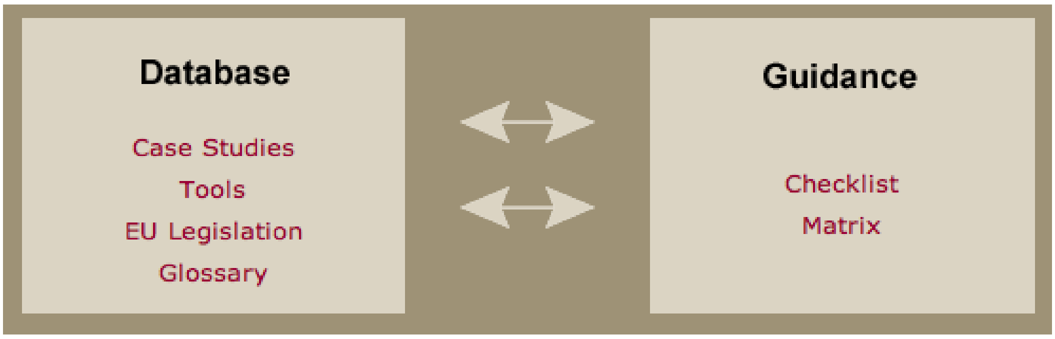

Figure 4.1: PETUS decision support system site map

Source: <http://www.petus.eu.com/>.

Apart from the above, many other resources also contributed to the identification of sustainability rating systems, such as Internet search, reports and other publications employed during the literature review.

4.3.2. Criteria for the Identification of Existing Rating Systems

According to the U.S. Department of Energy's Building Energy Software Tools Directory, by April 2011, there are 382 registered building software tools for evaluating energy efficiency, renewable energy, and buildings' sustainability. The actual number could be much greater because there are many unregistered tools; and more importantly, due to the fact that 'environmental tools/systems' is a very large notion. Not all of these tools can have actual contribution to the research and it is therefore important to set a definition of 'sustainability building rating systems.'

For the purposes of this review, 'sustainability building rating systems' are defined as tools that examine the performance or expected performance of a 'whole building' and translate that examination into an overall assessment that allows for comparison against other buildings. This definition was developed based on one of the findings of a research by the U.S. Department of Energy - 'Sustainable Building Rating Systems Summary' (Fowler & Rauch, 2006). Furthermore, for a rating system to add value to the sustainable design and/or operation of a building, it must offer a credible, consistent basis for comparison, evaluate relevant technical aspects of sustainable design, and not be over-burdensome to implement and communicate. These are also taken into account.

Rating system documentation that was identified and publicly available during the time period of December 2009 through April 2011 has been used for this review. As an illustration of the necessity to create time boundaries, during the review time period, 21 of the systems made significant changes to their primary webpages and many features were identified as under development. It is recognised that there are planned updates to various rating systems, however for the purpose of this review only the active attributes were considered. Another notable point is: there are rating tools with many versions for different types of projects, building functions; or for different countries. Depending on how far those versions have parted from each other, they can be merged or detached accordingly. For example, the UK and Canada versions of BREEAM are quite different so they are assessed separately; while as all LEED versions for US, Canada, India, and Mexico are merge as one rating tool. On the other hand, some special versions of existing tools are not so different from the original systems and therefore are not considered as independent tools.

4.3.3. List of Existing Rating Systems Pre-screened

Initially, there are *202 rating tools in total* that were identified for this review from the mentioned resources. The list of all tools and their country of origin (if known) is shown in Table 4.1.

Table 4.1: List of all sustainability rating systems (Pre-Screened)

Tools	Tools
Green Building Advisor (U.S.)	EcoInstall (Netherlands)
Environmental Profiles of construction materials, components and buildings (UK)	Energy Certification for Buildings (Finland)
Energy Star (U.S.)	HK BEAM (Hong Kong)
HQE (France)	Global Reporting Initiative
BM Bau Building Passport (Germany)	BEAT 2000 (Denmark)
BSEA 1.0 (Finland)	EcoPro (Germany)
The Movement for Innovation (M4i)	EcoQuantum (Netherlands)
NEN 2916/5128, NPR 2917/5129 (Netherland)	Environmental Classification of Properties
EcoProP (International)	SBTool/GBTool (International)
SIMBAD (Finland)	FirstRate (Australia)
Costing Reference Model (n/a)	G/Rated (Portland, U.S.)
iDP (Integrated Design Process) (Canada)	BRI LCA (Japan)
AccuRaate (Australia)	EcoIndicator (Netherlands)
Papoose (Finland)	LCA- House (Finland)
Alameda County (U.S.)	HERS (U.S.)
Envest 2 (UK)	BREEAM (UK)
BASIX Building Sustainability Index (Australia)	Build a better Clark (Clark County, Washington, U.S.)
EcoEffect (Sweden)	Green Rating Initiative (Ethiopia)
EEWH (Taiwan)	EnerGuide House Program (Canada)
ISO 14001 (International)	Ecohomes (UK)
MRPI Netherlands (Netherlands)	Green Seal Certification (U.S.)
Build A Better Kitsap Home Builder Program (Kitsap, Washington, U.S.)	TERI Green Rating For Integrated Habitat Assessment (India)
Cities for Climate Protection Software (n/a)	EarthCraft House (U.S.)
GOBAS (Green Olympic Building Assessment System) (International)	Built GreenTM (MBA of King and Snohomish Counties, Washington, U.S.)
Built Green Alberta (Canada)	Green Globes (U.S., Canada, UK)
ECDG (Japan)	Green Rating Program (Africa)
Green Building Program (Austin, U.S.)	City of Boulder Green Points (Boulder, U.S.)
Built Green Colorado (HBA of Metro Denver, U.S.)	National Packages Sustainable Building (Netherlands)
California Green Builder Program (U.S.)	CEEQUAL (UK)
NYC High Performance Building Guidelines (U.S.)	Chula Vista GreenStar Building Incentive Program (U.S.)
Seattle Sustainable Building Action Plan and Built Smart (Seattle, U.S.)	City of Frisco Green Building Program (U.S.)
Tokyo Metro Green Building Program (Japan)	Earth Advantage Home (U.S.)
SBAT (Sustainable Building Assessment Tool) (Africa)	Coalition for Environmentally Responsible Economies (CERES) Green Hotel Initiative (U.S.)
NAHB Green Home Building Guidelines	International Green Construction Code

EarthCraft House (Greater Atlanta, U.S.)	Earth Advantage (Commercial) (U.S.)
Energy Rated Homes of Colorado (U.S.)	Energy Star (Canada)
Sustainable Ecotourism Rating (Costa Rica)	Vermont Green Hotels in the Green Mountain State (U.S.)
Evergreen Building Guide (Issaquah, Washington, U.S.)	Sustainable Project Appraisal Routine (SPeAR) (UK)
Green Building Program, Austin Energy (U.S.)	Green Built Program (HBA of Greater Grand Rapids, MI, U.S.)
Legoe (Germany)	LCAiT (Sweden)
Green Built Home (Wisconsin Environmental Initiative, U.S.)	MSBG (The State of Minnesota Sustainable Building Guidelines, U.S.)
BOMA Best (Canada)	TEAM (Finland)
Green Points Building Program (Boulder, U.S.)	NABERS (National Australian Built Environment Rating System) (Australia)
OGIP (Switzerland)	REGENERS (Finland)
KCL-ECO (International)	TAKE-LCA (Finland)
Home Builder Association of Greater Kansas City (U.S.)	Hudson Valley HBA Green Building Program (U.S.)
Promis E (n/a)	Athena Model (Canada)
Novoclimat (Canada)	R-2000 (Canada)
Multifamily Green Building Guidelines (Alameda County, U.S.)	New Mexico Building America Partner Program (HBA of Central New Mexico, U.S.)
SeaGreen (Seattle, U.S.)	CEPAS (Hong Kong)
Eko Profile (Norway)	NatHERS (Australia)
Schenectady HBA Green Building Program (U.S.)	Southern Arizona Green Building Alliance (U.S.)
Green Building Certification System (Korea)	Super E House Program (Canada)
Solution Spaces (Canada)	Solution Spaces (Canada)
The BREEAM Green Leaf for Multi-Residential Buildings (Canada)	Super Good Cents and Natural Choice Homes (n/a)
Scottsdale's Green Building Program (Commercial Buildings) (U.S.)	Environmental Choice Program (Canada)
The Green Builder Program (International)	NMG (Netherlands)
SIA 493 (Switzerland)	Vermont Built Green (U.S.)
Western North Carolina Green Building Council (U.S.)	LEED (U.S.)
CASBEE (Japan)	GaBi 4 (International)
'Green' Hotel Association (U.S.)	'Quality of Life Counts' Indicator (UK)
Green Star (Australia)	Quest (International)
Green Rating of Indian Industry (India)	BERS (Australia)
HVS International ECOTEL Certification	LISA (Australia)
City of Santa Monica Green Building and Construction Guidelines (U.S.)	Green Home Designation (Florida Green Building Coalition, U.S.)
E-Scale (International)	Umberto (International)
GEM (Global Environmental Management) (International)	Green Leaf Eco-Rating Program (U.S., Canada)
Super E House Program (Canada)	EDIP (Denmark)
Labs21 (UK)	Home Run (Canada)
ITACA Protocol (Italia)	BEES (U.S.)
Health House Advantage Certification (U.S.)	County of Santa Barbara Innovative Building Review Program (U.S.)
Enquer (France)	TQ Building Assessment System (n/a)
National Association of Home Buildings (NAHB) Green guidelines (UK)	SPiRiT (Sustainable Project Rating Tool) (International)

Best Value and Sustainability Checklist (SOLACE, I&DeA, Local Government Association, U.S.)	Action Toward Local Sustainability (ATLAS) sustainability management toolkit (International)
Eco Balance Model (International)	Eco-Indicator 99 (EU)
Ecological Footprint (International)	EiEolienne planning-map (International)
Green Plot Ratio (International)	Health Impact Assessment (HIA) (n/a)
NHS Environmental Assessment Tool (UK)	Impact Monitoring and Assessment (IMA)
Institutional Sustainability Indicators	Key Performance Indicators (KPIs)
Land use Evolution and Impact Assessment Model (LEAM) (International)	Multi-criteria analysis (Brown, Vence and Associates, Inc.) (International)
Housing Quality Indicators (HQI)	Partnering (International)
Quality of Life (International)	RST Grid (France)
Seascape Assessment (International)	Social Impact Assessment (International)
Sustainable Diagnosis (France)	Toolbox for Regional Policy Analysis (n/a)
Dispute Resolution Ladder (n/a)	Green Energy Compass (International)
Contract Evaluation (Contractor Selection Matrix) (n/a)	Welsh Assembly Government Integration Tool
BERDE (Building for Ecologically Responsive Design Excellent) (Philippine)	DQI (Design Quality Indicator) (UK)
U.S. Environment Protection Authority's Energy Star Portfolio Manager	SE Checklist (UK)
PASSIVHAUS Standard (Germany)	MINERGIE (Switzerland)
Building Energy Quotient (International)	Green Plot Ratio (International)
Green Mark (Singapore)	LCA/LCC Tool (Hong Kong)
Green Building Index (Malaysia)	BEPAC (Canada)
Green Communities Program (International)	Building Greenhouse Rating (Australia)
Minnesota GreenStar (U.S.)	Living Building Challenge (LBC) (U.S.)
GBAS (China)	The code for Sustainable Homes (UK)
Environmental Impact Assessment (EIA) & Environmental statement (ES) (International)	GBCC Multi-Unit Residential Building (Korea)
Building Performance Compass (International)	ECO-BAT (International)
EQUER (France)	1D-HAM (n/a)
Building Advice (International)	DGNB (Germany)
CHPS National (U.S.)	EPIC (n/a)
SUBET (UK)	Lotus (Vietnam)

4.4. PRELIMINARY SCREENING ANALYSIS

4.4.1. The Preliminary Screening Analysis Criteria

Although the vast number, most of the detected rating systems are not suitable to assess tall-buildings' sustainability or to be used as a reference source for the research. There are two main reasons for this inappropriateness (Figure 4.2 describes more clearly the elimination mechanism used during the Preliminary Screening Analysis):

- **Availability**: Rating system's data cannot be retrieved or used because of different reasons;
- **Suitability**: Rating system cannot be used because of its inappropriateness.

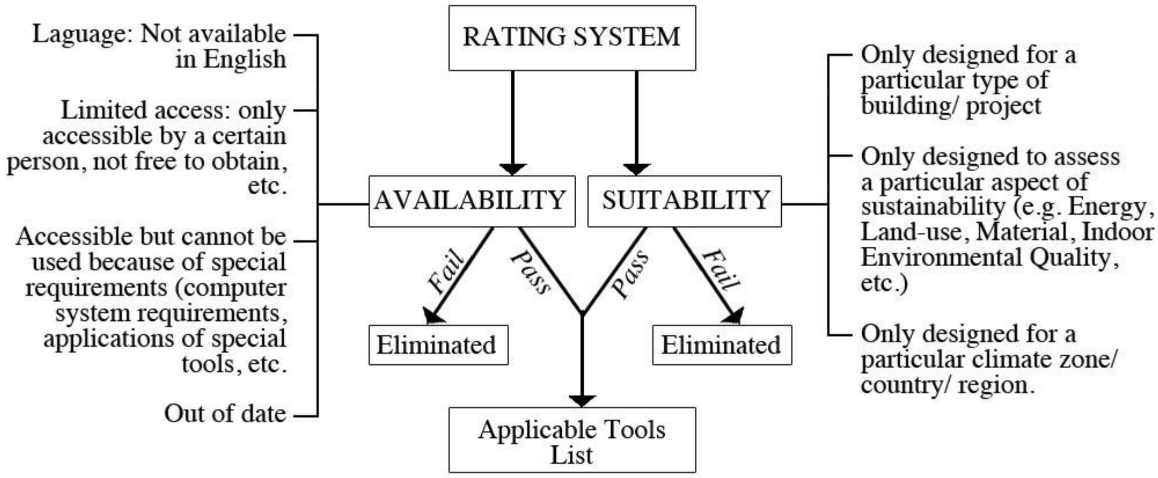

Figure 4.2: The Preliminary Screening Analysis criteria

4.4.2. Preliminary Screening Analysis Procedure

To eliminate inappropriate tools and narrow down the number of tools required for the next review stage, initial 202 tools are put through the *Preliminary Screening Analysis*. It is important that a rating system must fulfil the criteria in *both* Availability and Suitability category in order to pass through the Preliminary Screening procedure. However, there are some exceptional systems that did not fulfil all of the criteria but still passed through to the next round. Below are some sample cases during the Preliminary Screening Analysis process.

a. BEAT 2000[18] is a typical example of a rating tool being eliminated because of its availability. BEAT 2000 is a Life Cycle Assessments (LCA) tool developed at the Danish Building and Urban Research (By og Byg) for performing environmental assessment of products, building elements and buildings. The tool, a relational database built with Microsoft Access 97, consists of a database containing environmental data and a user interface with an integrated inventory and assessment tool. The database contains environmental data for unit processes, based on these data the inventory tool can calculate the environmental impacts, i.e. the total energy consumption (and its distribution on energy sources), the total consumption of raw materials (including fuels) and the total emissions (to air, water and soil) related to:

[18] **BEAT 2000**: <http://www.sbi.dk/english/publishing/software/beat2000/prices.htm>.

- Production of a building material;
- Construction, maintenance and demolition of a building element; and
- Construction, operation, maintenance and demolition of a building.

Technically, judging by its features, BEAT 2000 is exactly what is being sought for in order to back the development of TPSI. However, most of the related information about this system is in Danish. It looks like the creators stopped supporting the tool and it is virtually impossible to gain access to the system. The materials acquired are also rather out of date. Similar examples include: BSEA 1.0 (Finland), BM Building Passport (Germany), EcoProP (Finland), SIMBAD (Finland), BRI LCA (Japan), and Enquer (France).

b. Another case of unachievable system is PromisE[19] - an Environmental Assessment and Classification System for Residential, Office and Retail Buildings in Finland. PromisE includes two systems: an assessment and classification system for existing buildings and for new buildings. The PromisE system includes four main categories: Health of users, consumption of natural resources, environmental loadings and environmental risks. The system includes a five-stepped classification. The indicators and categories have been weighted in such a way that the final result can be expressed in terms of one class (A, B, C, D or E). The selection of weighting values for different categories and indicators took place in working seminars in cooperation with different actors of building sector. All in all, it seems like a right reference source.

However, PromisE was finally eliminated because of its uncertainty. At first, the system was developed in cooperation with VTT, practitioners, representatives of standardisation and building authorities. It was then adopted by many Finnish governmental and private organisations. The literature acquired on this system show serious inconsistency and within a short period of 4 months, there were many updates released that came without a coherent structure of technical contents. Similar examples include: ITACA Protocol (Italia), Eco Balance Model, Ecological Footprint, Sustainable Diagnosis (France), Home Builder Association of Greater Kansan City, and Eko Profile (Norway).

[19] **PromisE**: <http://www.motiva.fi/files/471/PromiseEsiteEng.pdf>.

c. Austin Energy Green Building (AEGR) Program is a typical example of a tool being eliminated because of its unsuitability. Started out in 1991, this program is even the U.S's first green building program, which just celebrated its 20-year-annivesary last year. AEGB has used its rating tools to save over 53.6 million kilowatt hours of electricity, 65.8 million gallons of water and diverted 120,690 tons of construction waste from the landfill (AEGB, 2012). AEGB's rating system is one of the most prestigious systems in the U.S. However, because it was developed specially for Austin area, its assessment criteria structure and contents are not very helpful for reference purposes. There are many assessment mechanisms and codes that cannot be used outside of this area. There are many similar systems that were eliminated because of the same reason. Examples include: G/RATE (Portland, OR), Green Rating Initiative (Ethiopia), EnerGuide House Program (Canada), MRPI Netherland, Energy Star (U.S.), EcoEffect (Sweeden), Built GreenTM (MBA of King and Snohomish Counties, WA), Build Green Alberta (Canada), and many more.

d. Green Seal[20] is another type of examples in term of unsuitability. Green Seal is a non-profit organisation that uses science-based programs to empower consumers, purchasers and companies to create a more sustainable World. Green Seal develops life cycle-based sustainability standards for products, services and companies and offer third-party certification for those that meet the criteria in the standard. It has been actively identifying and promoting sustainability in the marketplace, and helping organisations be greener in a real and effective way since 1989. Green Seal offers a range of sustainability standards that was highly intricate and thorough. However the objects of these standards do not related to the purpose of TPSI (i.e. tall-building assessment). It was therefore eliminated. Similar examples can be named: Energy Star (U.S), Environmental Classification of Properties, LCA-House (Finland), HERS (U.S), ECDG (Japan), GOBAS (Green Olympic Building Assessment System), Sustainable Ecotourism Rating (Costa Rica), R-2000 (Canada), 'Green' Hotel Association (U.S.), RST Grid (France), and Coalition for Environmentally Responsible Economies (CERES) Green Hotel Initiative (U.S.).

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[20] **Green Seal**: <http://www.greenseal.org>.

e. There are tools/systems that are eliminated because of both Availability and Suitability features. OGIP[21] (Switzerland) is one of the examples. OGIP stands for Optimisation of Global demands in terms of costs, energy and environment within an Integrated Planning process. OGIP is a tool that enables architects and engineers to optimise resources (costs, energy, environmental impact). It offers a standardised procedure for determining the environmental impact of the construction process and the building's operation and calculates the costs and energy used in operation.

OGIP, however, is based on the construction element method developed by CRB (Centre Suisse d'études pour la rationalisation de la construction). This method allows an early estimate of construction cost based on structural elements (such as external walls, floor slabs, windows) and is more accurate than an estimate based on costs per m^3. The structural elements are linked to the cost calculations of the CRB and the building associations and to the life cycle inventories (EcoInvent '96) produced by the Swiss Federal Institute of Technology (ETH). A separate interface allows the energy consumption during the building's operation to be calculated (according to SIA 380/1). Although innovative, the system's assessment mechanisms are not appropriate to the essence of TPSI's development. OGIP is also available in German and French only. Similar examples include: Seattle Sustainable Building Action Plan and Built Smart, Green Points Building Program, SeaGreen, NMG (Neatherland), New Mexico Building America Partner Program (HBA of Central new Mexico), Best Value and Sustainability Checklist (SOLACE, I&DeaA, Local Government Association).

f. There are, however, special cases where a rating system does not fulfil all the criteria but still has great potential contributions to the research. HQE (France) is one of the examples. The *Haute Qualité Environnementale* or HQE (High Quality Environmental standard) is a standard for green building in France which is controlled by the *Paris based Association pour la Haute Qualité Environnementale (ASSOHQE)*. Although the system is in French, it is still considered a significant development base. HQE has an important place in the

[21] **OGIP**: <www.ogip.ch>.

historical development of sustainability rating systems (see Section 3.5). It was the second major rating system after BREEAM and was even developed before LEED. HQE proposes a distinctive assessment criteria system of two areas (Environmental Preservation and User's Health), which are divided further into four categories (Eco Construction, Eco Management, Comfort and Health – see Appendix A.16). Another original feature of the HQE process is it not compulsory to have the best performance for the 14 targets. Users are asked to choose the main important targets on which special attention and efforts will be carried out. The uniqueness of HQE and how it parted from the developing directions of other major systems are invaluable to the development of TPSI.

Similarly, there are also other privilege national and regional rating systems that were passed the Preliminary Screening Analysis, namely: Green Building Certification System (Korea), Green Leaf Eco-Rating Program (U.S., Canada), SBAT (Africa), Scottsdale's Green Building Program (Commercial version – U.S.), and TERI GRIHA (India).

4.4.3. Preliminary Screening Analysis Result

The result of the Preliminary Screening Analysis is shown in Table 4.2. The applicable rating systems are marked with a '✓' symbol. Inappropriate systems are marked with an 'A' or a 'S' or both (meaning they are eliminated from the review process because of their Availability or Suitability, or both).

Table 4.2: Result of the Preliminary Screening Analysis

Tools		Tools	
Green Building Advisor (U.S.)	*A*	EcoInstall (Netherlands)	*S*
Environmental Profiles of construction materials, components and buildings (UK)	*A, S*	Energy Certification for Buildings (Finland)	*S*
Energy Star (U.S.)	*S*	HK BEAM (Hong Kong)	✓
HQE (France)	✓	Global Reporting Initiative	*A,S*
BM Building Passport (Germany)	*A*	BEAT 2000 (Denmark)	*A*
BSEA 1.0 (Finland)	*A*	EcoPro (Germany)	*S*
The Movement for Innovation (M4i)	✓	EcoQuantum (Netherlands)	*S*
NEN 2916/5128, NPR 2917/5129 (Netherland)	*S*	Environmental Classification of Properties (International)	*S*
EcoProP (Finland)	*A*	SBTool/GBTool (International)	✓
SIMBAD (Finland)	*A*	FirstRate (Australia)	*S*

Costing Reference Model (n/a)	*S*	G/Rated (Portland, U.S.)	*S*
iDP (Integrated Design Process) (Canada)	*S*	BRI LCA (Japan)	*A*
AccuRaate (Australia)	*S*	EcoIndicator (Netherlands)	*S*
Papoose (Finland)	*S*	LCA- House (Finland)	*S*
Alameda County (U.S.)	*S*	HERS (U.S.)	*S*
Envest 2 (UK)	✓	BREEAM (UK)	✓
BASIX Building Sustainability Index (Australia)	*S*	Build a better Clark (Clark County, Washington, U.S.)	*A,S*
EcoEffect (Sweden)	*S*	Green Rating Initiative (Ethiopia)	*S*
EEWH (Taiwan)	✓	EnerGuide House Program (Canada)	*S*
ISO 14001 (International)	*S*	Ecohomes (UK)	*S*
MRPI Netherlands (Netherlands)	*S*	Green Seal Certification (U.S.)	*S*
Build A Better Kitsap Home Builder Program (Kitsap, Washington, U.S.)	*S*	TERI Green Rating For Integrated Habitat Assessment (India)	✓
Cities for Climate Protection Software (n/a)	*A,S*	EarthCraft House (U.S.)	*S*
GOBAS (Green Olympic Building Assessment System) (International)	*A,S*	Built GreenTM (MBA of King and Snohomish Counties, WA, U.S.)	*A,S*
Built Green Alberta (Canada)	*A,S*	Green Globes (U.S., Canada, UK)	✓
ECDG (Japan)	*S*	Green Rating Program (Africa)	*S*
Green Building Program (Austin, U.S.)	*A,S*	City of Boulder Green Points (Boulder, U.S.)	*S*
Built Green Colorado (HBA of Metro Denver, U.S.)	*S*	National Packages Sustainable Building (Netherlands)	*A,S*
California Green Builder Program (U.S.)	*S*	CEEQUAL (UK)	✓
NYC High Performance Building Guidelines (U.S.)	*S*	Chula Vista GreenStar Building Incentive Program (U.S.)	*S*
Seattle Sustainable Building Action Plan and Built Smart (Seattle, U.S.)	*A,S*	City of Frisco Green Building Program (U.S.)	*A,S*
Tokyo Metro Green Building Program	*S*	Earth Advantage Home (U.S.)	*S*
SBAT (Sustainable Building Assessment Tool) (Africa)	✓	Coalition for Environmentally Responsible Economies (CERES) Green Hotel Initiative (U.S.)	*S*
NAHB Green Home Building Guidelines (U.S.)	*S*	International Green Construction Code	*S*
EarthCraft House (Greater Atlanta, GA, U.S.)	*A,S*	Earth Advantage (Commercial Buildings) (U.S.)	✓
Energy Rated Homes of Colorado (U.S.)	*S*	Energy Star (Canada)	*S*
Sustainable Ecotourism Rating (Costa Rica)	*A,S*	Vermont Green Hotels in the Green Mountain State (U.S.)	*A,S*
Evergreen Building Guide (Issaquah, Washington, U.S.)	*S*	Sustainable Project Appraisal Routine (SPeAR) (UK)	✓
Green Building Program, Austin Energy (U.S.)	*A*	Green Built Program (HBA of Greater Grand Rapids, MI, U.S.)	*S*
Legoe (Germany)	*S*	LCAiT (Sweden)	*S*
Green Built Home (Wisconsin Environmental Initiative, U.S.)	*S*	MSBG (The State of Minnesota Sustainable Building Guidelines, U.S.)	✓
BOMA Best (Canada)	*A,S*	TEAM (Finland)	*S*
Green Points Building Program (Boulder, U.S.)	*A,S*	NABERS (National Australian Built Environment Rating System) (Australia)	✓

OGIP (Switzerland)	*A,S*	REGENERS (Finland)	*S*
KCL-ECO (International)	*S*	TAKE-LCA (Finland)	*S*
Home Builder Association of Greater Kansas City (U.S.)	*A*	Hudson Valley HBA Green Building Program (U.S.)	*A,S*
Promis E (n/a)	*A*	Athena Model (Canada)	*S*
Novoclimat (Canada)	*S*	R-2000 (Canada)	*S*
Multifamily Green Building Guidelines (Alameda County, U.S.)	*S*	New Mexico Building America Partner Program (HBA of Central New Mexico, U.S.)	*A,S*
SeaGreen (Seattle, U.S.)	*A,S*	CEPAS (Hong Kong)	✓
Eko Profile (Norway)	*A*	NatHERS (Australia)	*S*
Schenectady HBA Green Building Program (U.S.)	*A*	Southern Arizona Green Building Alliance (U.S.)	*A,S*
Green Building Certification System (Korea)	✓	Super E House Program (Canada)	*S*
Solution Spaces (Canada)	*S*	Solution Spaces (Canada)	*S*
The BREEAM Green Leaf for Multi-Residential Buildings (Canada)	*S*	Super Good Cents and Natural Choice Homes (n/a)	*S*
Scottsdale's Green Building Program (Commercial Buildings) (U.S.)	✓	Environmental Choice Program (Canada)	*S*
The Green Builder Program (International)	*S*	NMG (Netherlands)	*A,S*
SIA 493 (Switzerland)	*S*	Vermont Built Green (U.S.)	*S*
Western North Carolina Green Building Council (U.S.)	*S*	LEED (US)	✓
CASBEE (Japan)	✓	GaBi 4 (International)	*S*
'Green' Hotel Association (U.S.)	*S*	'Quality of Life Counts' Indicator (UK)	✓
Green Star (Australia)	✓	Quest (International)	*S*
Green Rating of Indian Industry (India)	*A,S*	BERS (Australia)	*A,S*
HVS International ECOTEL Certification (International)	*S*	LISA (Australia)	*S*
City of Santa Monica Green Building and Construction Guidelines (U.S.)	*S*	Green Home Designation (Florida Green Building Coalition, U.S.)	*S*
E-Scale (International)	*A,S*	Umberto (International)	*S*
GEM (Global Environmental Management) (International)	*S*	Green Leaf Eco-Rating Program (U.S., Canada)	✓
Super E House Program (Canada)	*S*	EDIP (Denmark)	*S*
Labs21 (UK)	*S*	Home Run (Canada)	*S*
ITACA Protocol (Italia)	*A*	BEES (U.S.)	✓
Health House Advantage Certification (U.S.)	*S*	County of Santa Barbara Innovative Building Review Program (U.S.)	*S*
Enquer (France)	*A*	TQ Building Assessment System (n/a)	*A*
National Association of Home Buildings (NAHB) Green guidelines	*A*	SPiRiT (Sustainable Project Rating Tool) (International)	✓
Best Value and Sustainability Checklist (SOLACE, I&DeA, Local Government Association, U.S.)	*A, S*	Action Toward Local Sustainability (ATLAS) sustainability management toolkit (International)	*A,S*
Eco Balance Model (International)	*A*	Eco-Indicator 99 (EU)	*A*
Ecological Footprint (International)	*A*	EiEolienne planning-map (International)	*A*
Green Plot Ratio (International)	*S*	Health Impact Assessment (HIA) (n/a)	*S*
NHS Environmental Assessment Tool (NEAT) (UK)	*A*	Impact Monitoring and Assessment (IMA)	*S*

Institutional Sustainability Indicators	*A*	Key Performance Indicators (KPIs)	*A*
Land use Evolution and Impact Assessment Model (LEAM)	*S*	Multi-criteria analysis (Brown, Vence and Associates, Inc.) (International)	*S*
Housing Quality Indicators (HQI)	*S*	Partnering (International)	*A*
Quality of Life (International)	*A*	RST Grid (France)	*A*
Seascape Assessment (International)	*S*	Social Impact Assessment (International)	*S*
Sustainable Diagnosis (France)	*A*	Toolbox for Regional Policy Analysis	*S*
Dispute Resolution Ladder (n/a)	*S*	Green Energy Compass	*A*
Contract Evaluation (Contractor Selection Matrix)	*A,S*	Welsh Assembly Government Integration Tool	*A,S*
BERDE (Building for Ecologically Responsive Design Excellent) (Philippine)	*A,S*	DQI (Design Quality Indicator) (UK)	✓
U.S. Environment Protection Authority's Energy Star Portfolio Manager	*S*	SE Checklist (UK)	✓
PASSIVHAUS Standard (Germany)	*S*	MINERGIE (Switzerland)	*S*
Building Energy Quotient (International)	*S*	Green Plot Ratio (International)	*A,S*
Green Mark (Singapore)	✓	LCA/LCC Tool (Hong Kong)	*S*
Green Building Index (Malaysia)	*A,S*	BEPAC (Canada)	*A*
Green Communities Program (International)	*S*	Building Greenhouse Rating (Australia)	*S*
Minnesota GreenStar (U.S.)	*S*	Living Building Challenge (LBC) (U.S.)	✓
GBAS (China)	*A*	The code for Sustainable Homes (UK)	*S*
Environmental Impact Assessment (EIA) & Environmental statement (ES)	*A*	GBCC Multi-Unit Residential Building (Korea)	*S*
Building Performance Compass	*S*	ECO-BAT (International)	*A,S*
EQUER (France)	*A,S*	1D-HAM (n/a)	*S*
Building Advice (International)	*A*	DGNB (Germany)	*A*
CHPS National (U.S.)	*S*	EPIC (n/a)	*A,S*
SUBET (UK)	*A,S*	Lotus (Vietnam)	*S*

4.5. INTENSIVE SCREENING ANALYSIS

4.5.1. List of Applicable Rating Systems

There are 29 rating systems that stood through the Preliminary Screening Analysis, which means they are applicable to assess tall-buildings' sustainability. As stated in Chapter 3, the development of sustainability rating systems is an inheritable process, where later systems are built based on one or a number of existing systems. BREEAM and LEED with their long-lasting prestige are the two tools that were used the most as development bases. The systems' origin is an important factor when studying the methodology to develop a new rating system. It also helps to systemise and speed up the review process. Table 4.3 shows the alphabetical list of 29 applicable tools and their development basis. There are five systems of which the sources could not be identified.

Table 4.3: List of Applicable Rating Systems

No.	Tools	Development Basis
1	BEES (US)	ISO 14040 series of standards, ASTM standard
2	BREEAM (UK)	Original
3	CASBEE (Japan)	Original
4	CEEQUAL (UK)	Original
5	CEPAS (Hong Kong)	LEED, BREEAM, HK-BEAM
6	DQI (Design Quality Indicator) (UK)	Undisclosed
7	Earth Advantage (Commercial Buildings) (US)	Undisclosed
8	EEWH (Taiwan)	LEED
9	Envest 2 (UK)	Original
10	Green Building Certification System (Korea)	BREEAM, LEED, BEPAC
11	Green Globes (US, Canada, UK)	BREEAM
12	Green Leaf Eco-Rating Program (US, Canada)	Original
13	Green Mark (Singapore)	BREEAM, LEED
14	Green Star (Australia)	BREEAM, LEED
15	HK BEAM (Hong Kong)	BREEAM
16	HQE (France)	Undisclosed
17	LEED (US)	Original
18	Living Building Challenge (US)	LEED
19	M4i (UK)	Original
20	MSBG (US)	LEED, Green Building Challenge '98, BREEAM
21	NABERS (Australia)	Undisclosed
22	'Quality of Life Counts' Indicator (UK)	Original
23	SBTool/GBTool (International)	Original
24	SBAT (Africa)	Original
25	SE Checklist (UK)	Original
26	SPeAR (UK)	Original
27	SPiRiT (Sustainable Project Rating Tool) (US)	LEED
28	Scottsdale's Green Building Program (Commercial) (US)	LEED
29	TERI GRIHA (India)	Original

4.5.2. Applicable Rating Systems Review Process

These 29 applicable rating systems will be the main reference sources throughout the research and the new specialised tool for tall-buildings will be developed based on these sources. Literature about these 29 tools has been carefully reviewed and summarised in Appendix A.

Basically, there are two main aspects that make the differences between sustainability rating systems:

- What does the tool assess in a project/building? Or what are the *assessment criteria?*
- How does the tool assess a project/building? Or what is the *methodology of the assessment process?*

The summarised contents of each rating system therefore will consist of four parts:

- Overview: Overall review of the tool.
- Assessment criteria: The aspects that are assessed in a project/building.
- Assessment method: Evaluation process and result presentation.
- Source: Where to find the tool?

4.5.3. The Intensive Screening Analysis Criteria

The 29 applicable rating systems were put through an Intensive Screening Analysis to evaluate their appropriateness in term of assessing the sustainability of tall-buildings. A system of evaluating and marking was created with 10 criteria (see Table 2.5, Section 2.4.3) to thoroughly study these 29 rating systems.

Each criterion contributed a number of points due to their importance (100 points in total). For example, the most important feature which decides a rating system is suitable for tall-buildings assessing or not is its 'Applicability' – meaning its assessment criteria are appropriate and adequate enough to examine all aspects of a tall-building's sustainability. 'Applicability' therefore contributes the largest share (20 points) out of 100 points. Meanwhile other factors such as 'User-Friendliness' or 'Results Presentation' (the way a rating system presents evaluations and classification of buildings after its assessment process) are not as important. They therefore could only contribute five points at maximum. The Intensive Screening Analysis criteria are shown in Table 4.4.

Table 4.4: Intensive Screening Analysis criteria

Screening criteria	Points (100)
Popularity and Influence Well-known: Is the system well-known among the built environment community? Importance: Does the system play a significant part in the development of sustainable built environment in the World? Number of countries involved, Number of Buildings/Projects involved Versatility: Number of systems that use it as its basis for development or comparison	**10**
Availability Availability of the system itself: Is it easy to access the system? The system's format? How much information is available publicly? Cost of system, Certification fee? Availability of references: On-line Information? How to obtain Information that is not On-line? Availability of Case Studies, Users' review. System's Openness.	**10**
Methodology Methodology Summary, Weightings and Rating Levels Standardisation: Established collection procedures exist Quantitative criteria: Does the system use prescriptive-based criteria? Qualitative criteria: Does the system use performance-based criteria? Whole Life cycle Assessment Complexity and Efficiency	**15**
Applicability Target building groups Stages of building life cycle influenced Technical contents: How appropriate does the tool's assessment criteria of the criteria in order to assess tall-buildings' sustainability?	**20**
Data Collecting Data Gatherer: Identify the party which in charge of data inputting process Data Collecting Method: Identify the method used to input data Documentation: What type of documents needed for the assessment? At what stage of the project? Is it easy to gather those documents? Measurability: Does the tool use measurable method to collect data? Convenience: Is it easy and quick to gather data? Is it possible to finish data inputting process without the need of excessive technical knowledge?	**10**
Accuracy and Verification Accuracy of Data Inputting Stage, Data Processing Stage and Data Outputting Stage Verification: Define the system for verifying assessment results, Assessor Qualification, Level of Detail of Check, Third-party Assessment	**10**
User-Friendliness Ease of use and Product support	**5**
Development Country of Origin, Development Basis and Developer System Management, System's Maturity and System's Stability Update: How is the tool constantly improved? Development approach Future development	**10**
Results Presentation Presentation method: End products of assessment process, ratings, result product Clarity: Well-defined, easily communicated, and clearly understood among parties? Comparability: Amenable to normalisation for comparisons over varying building types, locations, years, or different sustainable design characteristics Result usability	**5**
Innovations Innovative features which would be good contributions to the new tool's development	**5**

Each one of 29 applicable rating systems will be examined and marked in every criterion. The five systems that have the highest overall score will be intensively and comparatively reviewed (see Chapter 5). They will be the main development basis of the new specialised rating system for tall-buildings. The screening criteria system would also be a great help throughout the research when it comes to referencing. For example, the systems that scored highest in the 'Accuracy' criteria will be the most suitable reference sources for improving the precision of the developing system.

4.6. SCREENING ANALYSIS RESULTS

The Intensive Screening Analysis is an intricate process that utilised various analysing and synthesising methods/techniques. During this process, all aspects of sustainability assessment systems are scrutinised and evaluated using a tailored set of criteria. This section presents the final results of the Intensive Screening Analysis:

- The result of the Intensive Screening Analysis is shown in Table 4.5.
- The list of rating systems according to their scores and the chosen Top Five systems are shown in Table 4.6.
- Intensive review results of the Top Five rating systems are presented in more details in Chapter 5.

Table 4.5: Intensive Screening Analysis - Result 1

TOOLS	Popularity and Influence (10 pts)	Availability (10 pts)	Methodology (15 pts)	Applicability (20 pts)	Data Collecting (10 pts)	Accuracy and Verification (10 pts)	User Friendliness (5 pts)	Development (10 pts)	Results Presentation (5 pts)	Innovation (5 points)	**Total (100 pts)**
BEES (US)	5	5	11	11	5	6	3	6	3	2	**57**
BREEAM	10	7	11	14	7	8	4	8	3	4	**76**
CASBEE	6	7	13	10.5	6	9	3	7	4	5	**70.5**
CEEQUAL	6	6	10	13	6	6	3	6	2	2	**60**
CEPAS	5	6	10	12	6	5	3	6	3	2	**58**
Design Quality Indicator	5	5	8	14	6	5	2	7	3	2	**57**
Earth Advantage	5	5	5	6	6	3	4	4	2	2	**42**
EEWH	6	6	8	12	9	4	3	6	3	3	**60**
Envest 2	6	6	7	8	7	3	4	4	2	3	**50**
GBCS	5	4	7	8	6	3	4	4	2	2	**45**
Green Globes	7	6	11	14	6	6	3	6	3	2	**64**
Green Leaf Eco-Rating	6	5	10	12	6	5	3	7	3	2	**59**
Green Mark	6	6	10	13	6	5	3	7	3	2	**61**
Green Star	5	7	9	11	9	5	4	8	3	4	**65**
HK BEAM	5	8	11	11	8	5	4	8	4	2	**66**
HQE	4	3	8	10	5	4	3	5	2	2	**46**
LEED	10	7	10	15	7	7	5	8	3	3	**75**
Living	6	6	11	11	5	6	3	6	3	2	**59**
M4i	4	3	10	9	5	4	2	5	2	2	**46**
MSBG	5	6	10	12	6	5	3	7	3	2	**59**
NABERS	6	6	10	14	6	6	3	6	2	2	**61**
Quality of Life Counts	4	4	7	8	6	3	4	4	2	2	**44**
SBTool/GBTool	7	7	11	14	6	6	3	6	2	2	**64**
SBAT	5	7	10	14	6	6	3	7	3	2	**63**
SE Checklist	5	5	9	14	5	5	3	5	3	2	**56**
SPeAR	6	7	10	11	7	4	4	7	4	3	**63**
SPiRiT	5	5	11	11	5	6	3	6	3	2	**57**
Scottsdale's Green Building Program	4	5	7	8	6	3	4	4	2	2	**45**
TERI GRIHA	4	5	9	14	5	5	3	5	3	2	**55**

Table 4.6: Intensive Screening Analysis - Result 2

No.	TOOLS	Total (/100 points)
1	BREEAM (UK)	**76**
2	LEED (US)	**75**
3	CASBEE (Japan)	**70.5**
4	HK BEAM (Hong Kong)	**66**
5	Green Star (Australia)	**65**
6	SBTool/GBTool (International)	**64**
7	Green Globes(US, Canada, UK)	**64**
8	SBAT (Africa)	**63**
9	SPeAR (UK)	**63**
10	Green Mark (Singapore)	**61**
11	NABERS (Australia)	**61**
12	CEEQUAL (UK)	**60**
13	EEWH (Taiwan)	**60**
14	Green Leaf Eco-Rating Program (US, Canada)	**59**
15	Living Building Challenge (US)	**59**
16	MSBG (US)	**59**
17	CEPAS (Hong Kong)	**58**
18	Design Quality Indicator (UK)	**57**
19	BEES (US)	**57**
20	SPiRiT (US)	**57**
21	SE Checklist (UK)	**56**
22	TERI GRIHA (India)	**55**
23	Envest 2 (UK)	**50**
24	HQE (France)	**46**
25	M4i (UK)	**46**
26	Green Building Certification System (GBCS) (Korea)	**45**
27	Scottsdale's Green Building Program (Commercial) (US)	**45**
28	'Quality of Life Counts' Indicator (UK)	**44**
29	Earth Advantage (Commercial Buildings) (US)	**42**

As the final screening analysis result, BREEAM and LEED topped the list with only one point different from each other. This is somewhat anticipated because of the huge success of these two systems. BREEAM and LEED scored very well in the criteria under the 'Reference' category (i.e. 'Popularity and Influence,' 'Availability,' and 'Development' criteria). This is natural due to the fact that they are among the oldest systems on the market and have been developing a strong user base. BREEAM and LEED also scored high under 'Applicability' criterion (14/20 and 15/20 points respectively), as well as 'Methodology' and 'Innovations' criteria - which ensure its technical and literature contributions to TPSI development. All in all, there is no rating system that should be developed without paying tribute to BREEAM and LEED.

On the other hand, the fact that CASBEE, HK-BEAM and Green Star are among the Top Five was an interesting outcome. CASBEE in particular did outstandingly during the Screening Analysis. CASBEE scored highest under 'Methodology' criterion (13/15 points) with its highly intricate assessment method, which logically leads to the highest level of accuracy (9/10 points under 'Accuracy' and 'Verification' criterion). CASBEE's pre-assessment software is state-of-the-art Excel tool, which offers useful, graphical, intuitive results presentation. Along with SPeAR, CASBEE scored highest under 'Results Presentation' criterion.

CASBEE, however, did not score well under 'Applicability' criterion because it was designed for Japanese projects only and the technical contents do not contribute much to tall-building sustainability. Users sometimes are intimidated by its intricacy thus CASBEE performed poorly under 'User-friendliness' and 'Data-Collecting' criteria. But overall, CASBEE has more than enough reasons to be one of the key contributors to the development of TPSI.

HK-BEAM found its way into Top Five mainly because of its high scores under the 'Methodology' and 'Applicability' criterion. Developed based on BREEAM, HK-BEAM's assessment criteria system has a good level of credibility. And more importantly, being the official rating system of Hong Kong – one of the countries with the highest density of high-rise structures, HK-BEAM has been used to assess a lot of tall-building projects. This makes HK-BEAM highly appropriate for TPSI's development. HK-BEAM is also well supported by an online directory of case studies.

Green Star is one of the systems with good innovative features. The central one being the adoption of a weighting system that can be changed to better reflect the importance of each sustainable aspects in different contexts – the inspiration of TPSI's *dynamic weighting system* (see Section 7.8.4) – although this system is not incorporated in the tool (users have to find out and apply the weighting them manually). Green Star scored 4/5 points under 'Innovations' criterion. Green Star also possesses an online case studies database, which is managed and updated regularly. Green Star has a similar format as BREEAM and LEED.

4.7. CHAPTER CONCLUSIONS

Among hundreds of sustainability rating tools/systems worldwide, the 29 applicable systems that are suitable for tall-buildings projects were identified. They were pushed through an intensive review process with an intricate system of criteria, at the end of which five systems that scored highest were chosen to be the bases for the development of TPSI. These five rating systems are:

- BREEAM (UK);
- LEED (US);
- CASBEE (Japan);
- HK-BEAM (Hong Kong);
- Green Star (Australia).

It is essential to understand that, also finding the Top Five rating system is the ultimate goal; the result is not the only important outcome. It is during the review process that the features and issues of existing rating systems are scrutinised, which in turn helped developing the theoretical foundations and literature bases for the development of TPSI (see Chapter 2). The whole Screening Analysis process also provides a model and a framework, on which similar studies and reviews can base on. Although playing an important role in the research, the Screening Analysis can be considered a stand-alone research by itself.

CHAPTER 5: TOP FIVE SUSTAINABILITY RATING SYSTEMS FOR TALL-BUILDING ASSESSMENT

5

5.1. CHAPTER INTRODUCTION

This chapter presents in details the comparative review process of the Top Five rating systems identified in Chapter 4 (the result of this process was previously shown in Table 4.5 and Table 4.6.). These five systems are evaluated based on the same assessment criteria system proposed in Table 4.4. The Top Five rating systems are:

- BREEAM (Building Research Establishment's Environmental Assessment Method) – UK and International;
- LEED (Leadership in Energy and Environmental Design) – U.S. and International;
- CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) – Japan;
- Green Star – Australia;
- HK-BEAM (Hong Kong Building Environmental Assessment Method).

5.2. SUMMARIES OF TOP FIVE RATING SYSTEMS

Top Five rating systems' reviews are summarised into five headings (similar to the headings used to review 29 applicable rating systems in Appendix A):

- Overview;
- Assessment criteria;
- Assessment method;
- Case studies;
- Note (where applicable).

5.2.1. BREEAM

Overview:

BREEAM (Building Research Establishment's Environmental Assessment Method) is the leading and most widely used environmental assessment method for buildings. It was developed in the UK in 1990 and is the building environmental assessment method with the longest track record (AACSB, 2010). Since its inception BREEAM has always been an important measurement method and the main development basis for many rating systems including LEED, HK-BEAM and Green Star. BREEAM covers a range of building types including: Courts, Homes, Healthcare Units, Industrial Units, Multi-residential Units, Prisons, Offices, Retail Units, Education Units, Communities, and Domestic Developments.[22] Other building types can be assessed using Bespoke BREEAM (‘bespoke’ is another word for ‘custom-made’). The BREEAM standard is now being exported by a BRE division called BREEAM International. It is set to be used in regions such as the Gulf and Europe. BRE is now working toward a common assessment method throughout the European Union (Fowler & Rauch, 2006).

Assessment criteria:

BREEAM’s assessment criteria are divided into 10 categories as in Table 5.1.

Table 5.1: Summary of BREEAM’s system of assessment criteria

Management Commissioning Construction site impacts Security	**Waste** Construction waste Recycled aggregates Recycling facilities
Health and Well-being Daylight Occupant thermal comfort Acoustics Indoor air and water quality Lighting	**Pollution** Refrigerant use and leakage Flood risk NOx emissions Watercourse pollution External light and noise pollution
Energy CO2 emissions Low or zero carbon technologies Energy sub metering Energy efficient building systems	**Land Use and Ecology** Site selection Protection of ecological features Mitigation/enhancement of ecological value
Transport Public transport network connectivity Pedestrian and Cyclist facilities Access to amenities Travel plans and information	**Materials** Embodied life cycle impact of materials Materials re-use Responsible sourcing Robustness
Water Water consumption Leak detection Water re-use and recycling	**Innovation** Exemplary performance levels Use of BREEAM Accredited Professionals New technologies and building processes

Data source: (BREEAM, 2008)

[22] According to BREEAM Website, viewed 25 September 2011, <http://www.breeam.org/>.

Assessment method:

Points are awarded for each criterion and the points are added for a total score. The overall building performance is awarded a 'Pass', 'Good', 'Very Good' or 'Excellent' rating based on the score. Figure 5.1 shows sample BREEAM reporting and certification pages found online for a BREEAM example.

BREEAM Offices 2005 - Design & Procurement Assessment tool

Design Stage Assessment Results

BREEAM Rating: Example 1	Good

Core & Design & Procurement Credit Allocation Table

Overall Credit Allocation	Env Weighting	Available	Achieved	Percentage section credits achieved	Overall Weighted Percentage
Management	15%	10	5	50.00%	7.50%
Health & Wellbeing	15%	15	8	53.33%	8.00%
Energy		17	9	52.94%	
Transport		14	7	50.00%	
Energy & Transport	25%	31	16	51.61%	12.90%
Water	5%	6	4	66.67%	3.33%
Materials	10%	12	4	33.33%	3.33%
Land Use & Ecology	15%	11	6	54.55%	8.18%
Pollution	15%	12	6	50.00%	7.50%
				Totals	50.75%

BRE BREEAM

BREEAM Offices 2005 - Design & Procurement Assessment tool

Design Stage Assessment Results

BREEAM Rating: Example 1	Good

BREEAM Rating	% Benchmark
Unclassified	<25
Pass	≥25 - <40
Good	≥40 - <55
Very Good	≥55 - <70
Excellent	≥70

Figure 5.1: Sample BREEAM score sheet

Source: Google Images

Case studies – Tall-buildings assessed by BREEAM:

- Hero Tower, London, UK.
- 25 Ropemaker Place, London, UK.

Note:

The tools, documents and more information can be found at: <http://www.breeam.org>.

5.2.2. LEED

Overview:

The Leadership in Energy and Environmental Design (LEED) Green Building Rating System, developed by the U.S. Green Building Council (USGBC), provides a suite of standards for environmentally sustainable construction. Since its inception in 1998, LEED has grown to encompass more than 14,000 projects in the U.S. and 30 countries covering 1.062 billion ft^2 (99 km²) of development area (Fowler & Rauch, 2006); and now is still growing fast. LEED is an open and transparent process where the technical criteria proposed are publicly reviewed by more than 10,000 membership organisations that currently constitute the USGBC.[23] Figure 5.2 shows different versions of LEED.

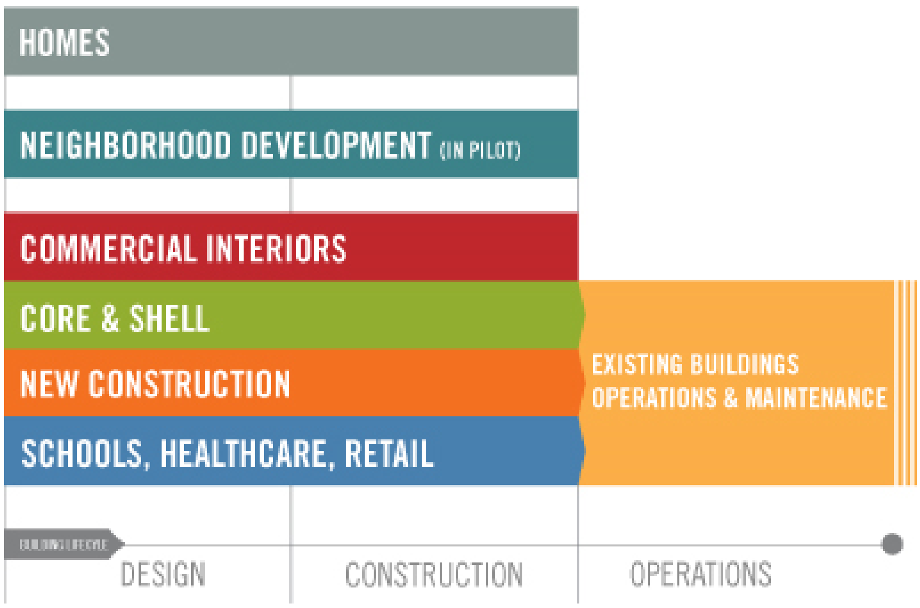

Figure 5.2: LEED's versions

As of April 2011. Source: < http://www.usgbc.org/>

[23] According to USGBC Website, viewed 25 April 2011, < http://www.usgbc.org/>.

Assessment criteria:

LEED's system of assessment criteria consists of seven categories as shown in Table 5.2.

Table 5.2: Summary of LEED's system of assessment criteria

Sustainable Sites	Construction Activity Pollution Prevention Site Selection Development Density and Community Connectivity Brownfield Redevelopment Alternative Transportation Site Development Storm-water Design Heat Island Effect Light Pollution Reduction Tenant Design and Construction Guidelines
Water Efficiency	Water Use Reduction Water Efficient Landscaping Innovative Wastewater Technologies Water Use reduction
Energy and Atmosphere	Fundamental Commissioning of Building Energy Systems Minimum Energy Performance Fundamental Refrigerant Management Optimise Energy Performance On-site Renewable Energy Enhanced Commissioning Enhanced Refrigerant Management Measurement and Verification: Base Building, Tenant Sub-metering Green power
Materials and Resources	Storage and Collection of recyclables Building reuse Construction Waste Management Materials Reuse Recycled Content Regional materials Certified Wood
Indoor Environmental Quality (IAQ)	Minimum IAQ performance Environmental Tobacco Smoke Control Outdoor Air Delivery Monitoring Increased Ventilation Construction IAQ Management Plan Low-Emitting materials Indoor Chemical and Pollutant Source Control Controllability of Systems Thermal Comfort Daylight and views
Innovation in Design	
Regional Priority	

Data source: (LEED, 2009a; 2009b)

Assessment method:

In LEED 2009 there is 100 possible base points plus an additional six points for Innovation in Design and four points for Regional Priority. Buildings can qualify for four levels of certification: Certified (40-49 points), Silver (50-59 points), Gold (60-79 points), Platinum (≥ 80 points). Figure 5.3 shows an example of LEED 2009 report documentation.

SSA Child Care Center, LEED Project # 0265
LEED Version 2.0 Certification Level: CERTIFIED
Feb. 27, 2003

28 Points Achieved — Possible Points: 69

Certified 26 to 32 points   Silver 33 to 38 points   Gold 39 to 51 points   Platinum 52 or more points

Y		6 Sustainable Sites	Possible Points: 14
Y	Prereq 1	**Erosion & Sedimentation Control**	
1	Credit 1	**Site Selection**	1
	Credit 2	**Urban Redevelopment**	1
	Credit 3	**Brownfield Redevelopment**	1
1	Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
	Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
	Credit 4.3	**Alternative Transportation**, Alternative Fuel Refueling Stations	1
	Credit 4.4	**Alternative Transportation**, Parking Capacity	1
1	Credit 5.1	**Reduced Site Disturbance**, Protect or Restore Open Space	1
1	Credit 5.2	**Reduced Site Disturbance**, Development Footprint	1
1	Credit 6.1	**Stormwater Management**, Rate and Quantity	1
	Credit 6.2	**Stormwater Management**, Treatment	1
	Credit 7.1	**Landscape & Exterior Design to Reduce Heat Islands**, Non-Roof	1
	Credit 7.2	**Landscape & Exterior Design to Reduce Heat Islands**, Roof	1
1	Credit 8	**Light Pollution Reduction**	1

Y		2 Water Efficiency	Possible Points: 5
1	Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
1	Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
	Credit 2	**Innovative Wastewater Technologies**	1
	Credit 3.1	**Water Use Reduction**, 20% Reduction	1
	Credit 3.2	**Water Use Reduction**, 30% Reduction	1

Y		5 Energy & Atmosphere	Possible Points: 17
Y	Prereq 1	**Fundamental Building Systems Commissioning**	
Y	Prereq 2	**Minimum Energy Performance**	
Y	Prereq 3	**CFC Reduction in HVAC&R Equipment**	
2	Credit 1.1	**Optimize Energy Performance**, 20% New / 10% Existing	2
2	Credit 1.2	**Optimize Energy Performance**, 30% New / 20% Existing	2
1	Credit 1.3	**Optimize Energy Performance**, 40% New / 30% Existing	2
	Credit 1.4	**Optimize Energy Performance**, 50% New / 40% Existing	2
	Credit 1.5	**Optimize Energy Performance**, 60% New / 50% Existing	2
	Credit 2.1	**Renewable Energy**, 5%	1
	Credit 2.2	**Renewable Energy**, 10%	1
	Credit 2.3	**Renewable Energy**, 20%	1
	Credit 3	**Additional Commissioning**	1
	Credit 4	**Ozone Depletion**	1
	Credit 5	**Measurement & Verification**	1
	Credit 6	**Green Power**	1

Y		6 Materials & Resources	Possible Points: 13
Y	Prereq 1	**Storage & Collection of Recyclables**	
	Credit 1.1	**Building Reuse**, Maintain 75% of Existing Shell	1
	Credit 1.2	**Building Reuse**, Maintain 100% of Existing Shell	1
	Credit 1.3	**Building Reuse**, Maintain 100% Shell & 50% Non-Shell	1
1	Credit 2.1	**Construction Waste Management**, Divert 50%	1
1	Credit 2.2	**Construction Waste Management**, Divert 75%	1
	Credit 3.1	**Resource Reuse**, Specify 5%	1
	Credit 3.2	**Resource Reuse**, Specify 10%	1
1	Credit 4.1	**Recycled Content**, Specify 25%	1
1	Credit 4.2	**Recycled Content**, Specify 50%	1
1	Credit 5.1	**Local/Regional Materials**, 20% Manufactured Locally	1
1	Credit 5.2	**Local/Regional Materials**, of 20% Above, 50% Harvested Locally	1
	Credit 6	**Rapidly Renewable Materials**	1
	Credit 7	**Certified Wood**	1

Y		7 Indoor Environmental Quality	Possible Points: 15
Y	Prereq 1	**Minimum IAQ Performance**	
Y	Prereq 2	**Environmental Tobacco Smoke (ETS) Control**	
	Credit 1	**Carbon Dioxide (CO_2) Monitoring**	1
	Credit 2	**Increase Ventilation Effectiveness**	1
	Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
1	Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
1	Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
	Credit 4.2	**Low-Emitting Materials**, Paints	1
1	Credit 4.3	**Low-Emitting Materials**, Carpet	1
	Credit 4.4	**Low-Emitting Materials**, Composite Wood	1
1	Credit 5	**Indoor Chemical & Pollutant Source Control**	1
	Credit 6.1	**Controllability of Systems**, Perimeter	1
	Credit 6.2	**Controllability of Systems**, Non-Perimeter	1
1	Credit 7.1	**Thermal Comfort**, Comply with ASHRAE 55-1992	1
1	Credit 7.2	**Thermal Comfort**, Permanent Monitoring System	1
	Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
1	Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

Y		2 Innovation & Design Process	Possible Points: 5
1	Credit 1.1	**Innovation in Design:** Exemplary Performance 38% Local Materials	1
	Credit 1.2	**Innovation in Design:**	1
	Credit 1.3	**Innovation in Design:**	1
	Credit 1.4	**Innovation in Design:**	1
1	Credit 2	**LEED™ Accredited Professional**	1

Figure 5.3: Sample LEED score sheet

Source: Google Images

Case studies – Tall-buildings assessed by LEED:

- Hearst Tower, New York, U.S.
- Comcast Centre, Philadelphia, U.S.

Note:

The tools and related materials can be found at: <http://www.usgbc.org/>.

5.2.3. CASBEE

Overview:

CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) was developed in Japan, beginning in 2001. CASBEE can be applied to both private and public buildings, which are broadly divided into residential and non-residential and further into other building types. There are four basic versions of CASBEE which correspond to the individual stages of the building's life cycle, namely: CASBEE for pre-design (CASBEE-PD), CASBEE for new construction (CASBEE-NC), CASBEE for existing buildings (CASBEE-EB) and CASBEE for renovation (CASBEE-RN).[24] The CASBEE tool does not take into consideration aesthetic design parameters or economic parameters, namely assessment of cost and profitability. Also, it should be mentioned that it does not account for any social parameters.

CASBEE is developed based on three major concepts. Firstly, it is designed for the assessment of buildings, which corresponds to their life cycle. Secondly, it is based on a concept that early distinguishes environmental load (LR) and quality of building performance (Q) as the major assessment targets. Thirdly, it introduces a new indicator - BEE (Building Environmental Efficiency) - based on the eco-efficiency concept (Reed *et al.*, 2009).

Assessment criteria:

CASBEE's assessment criteria system consists of six categories, which are divided further into two main Groups (see Table 5.3):

- *Q Group*: Building Environmental Quality and Performance; and
- *LR Group*: Reduction of Building Environmental Loadings.

[24] According to CASBEE Website, viewed 30 April 2011, <http://www.ibec.or.jp/CASBEE/english/>.

Table 5.3: Summary of CASBEE's system of assessment criteria

Q- Building Environmental Quality and Performance	LR- Reduction of Building Environmental Loadings
Q1: Indoor environment - Sonic Environment: Noise, Sound Insulation, Sound Absorption. - Thermal Comfort: Room Temperature Control, Humidity Control, Type of Air Conditioning System. - Lighting and Illumination: Day-lighting, Anti-glare Measures, Illuminance Level, Lighting Controllability. - Air Quality: Source Control, Ventilation, Operation Plan.	**L1: Energy** - Building Thermal Load. - Natural Energy Utilisation: Direct Use of Natural Energy, Converted Use of Renewable Energy. - Efficiency in Building Service System: HVAC System, Ventilation System, Lighting System, Hot Water Supply System, Elevators, Equipment for Improving Energy Efficiency. - Efficiency Operation: Monitoring, Operation and Management System.
Q2: Quality of Services - Service Ability: Functionality and Usability, Amenity, Maintenance Management. - Durability and Reliability: Earthquake Resistance, Service Life of Components, Reliability. - Flexibility and Adaptability: Spatial Margin, Floor Load Margin, Adaptability of Facilities.	**L2: Resources and materials** - Water Resources: Water Saving, Rainwater and Grey Water. - Reducing Usage of Non-renewable Resources: Reducing Usage of Materials, Continuing Use of Existing Structural Skeletons etc., Use of Recycled Materials as Structural Frame Materials, Use of Recycled Materials as Non-structural Materials, Timber from Sustainable Forestry, Efforts to Enhance the Reusability of Components and Materials. - Avoiding the Use of Materials with Pollutant Content: Use of Materials without Harmful Substances, Avoidance of CFCs and Halons.
Q3: Outdoor environment on site - Preservation and Creation of Biotope. - Townscape and Landscape. - Local Characteristics and Outdoor Amenity: Attention to Local Character and Improvement of Comfort, Improvement of the Thermal Environment on Site.	**L3: Off-site environment** - Consideration of Global Warming. - Consideration of Local Environment: Air Pollution, Heat Island Effect, Load on Local Infrastructure. - Consideration of Surrounding Environment: Noise, Vibration and Odour, Wind Damage and Sunlight Obstruction, Light Pollution.

Data source: (JSBC, 2010a)

Assessment method:

Each criterion is scored from level 1 to level 5, with level 1 defined as meeting minimum requirements, level 3 defined as meeting typical technical and social levels at the time of the assessment, and level 5 representing a high level of achievement. A Technical Manual is available which presents detailed definitions of each level for each criterion and includes reference material and calculation tools where needed.

Each assessment item, such as Q1, Q2 and Q3, is weighted so that all the weighting coefficients within the assessment category Q sum up to 1.0. The scores for each assessment item are multiplied by the weighting coefficient, and aggregated into *SQ: total scores for Q Group* and *LR: total scores for LR Group,* respectively.

CASBEE results are presented as a measure of eco-efficiency or BEE (Building Environmental Efficiency). BEE is defined as Q/LR to indicate the overall result of environmental assessment of buildings.

Aggregated results are plotted on a graph, with L (L = 100% - LR) on the X axis and Q on the Y axis. The higher the Q value and the lower the L value, the steeper the gradient and the more sustainable the building is (Smith, 2010). The best buildings will fall in the section representing lowest environmental load and highest quality. CASBEE introduces a labelling classification of five areas, according to BEE value (JSBC, 2010a) (see Table 5.4).

Table 5.4: CASBEE labelling classification

Rank	Assessment	BEE Value	Expression
S	Excellent	BEE=3.0 or more, Q=50 or more	★★★★★
A	Very Good	BEE=1.5~3.0	★★★★
B+	Good	BEE=1.0~1.5	★★★
B-	Fairy Poor	BEE=0.5~1.0	★★
C	Poor	BEE=less than 0.5	★

Data source: (JSBC, 2010a)

Figure 5.4 is an example of CASBEE reporting documentation.

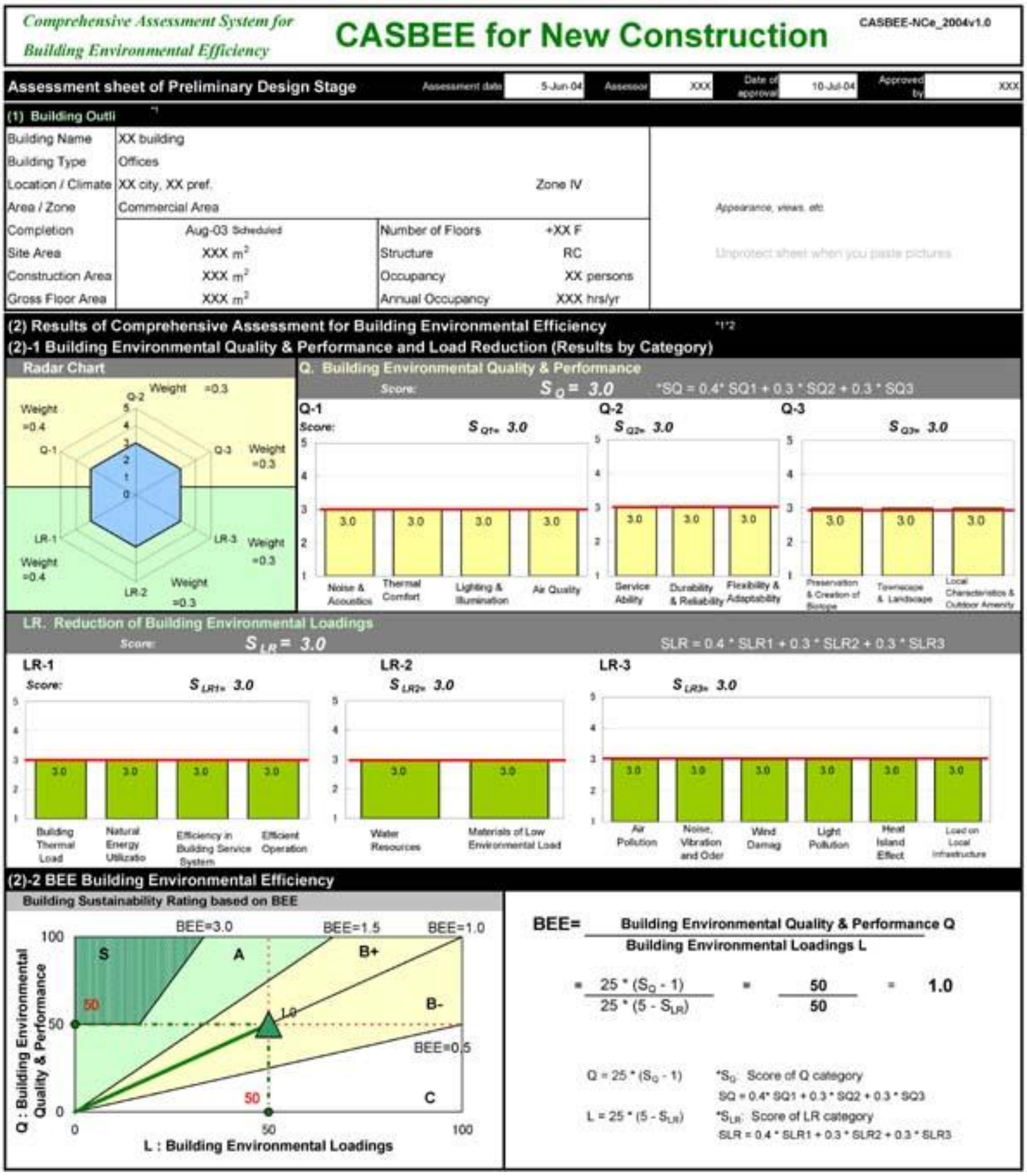

Figure 5.4: Sample CASBEE score sheet

Source: Google Images

Case studies - Tall-buildings assessed by CASBEE:

- Kansai Electric Power Building, Osaka, Japan.
- Dentsu Head Office Building, Tokyo, Japan.

Notes:

The CASBEE tools and manuals are available at:

<http://www.ibec.or.jp/CASBEE/english/>

5.2.4. GREEN STAR

Overview:

Green Star is a voluntary environmental rating system for buildings in Australia. It was launched in 2003 by the Green Building Council of Australia. The system considers a broad range of practices for reducing the environmental impact of buildings and to showcase innovation in sustainable building practices, while also considering occupant health and productivity, and cost savings (Smith, 2010). With more than 4 million square metres of Green Star-certified space around Australia, and a further 8 million square metres of Green Star-registered space, Green Star has positively transformed Australia's property and construction market.

Green Star was developed for the property industry in order to:

- Establish a common language;
- Set a standard of measurement for green buildings;
- Promote integrated, whole-building design;
- Recognise environmental leadership;
- Identify building life cycle impacts; and
- Raise awareness of green building benefits.

Latest Green Star tools are listed in Table 5.5.

Table 5.5: Green Star versions

Certified Tools*	Pilot Tools*
Green Star - Education v1	Green Star - Industrial PILOT
Green Star - Healthcare v1	Green Star - Mixed Use PILOT
Green Star - Multi Unit Residential v1	Green Star - Office Existing Building EXTENDED PILOT
Green Star - Office v3	
Green Star - Office Interiors v1.1	Green Star - Convention Centre Design PILOT
Green Star - Retail Centre v1	
Green Star - Office Design v2	
Green Star - Office as Built v2	

*: As of April 2011. Data source: (GBCA, 2011b)

Assessment criteria:

Green Star's assessment criteria system consists of eight main categories as demonstrated in Table 5.6.

Table 5.6: Summary of Green Star's system of assessment criteria

IEQ - Ventilation Rates - Air Change Effectiveness - CO_2 Monitoring and Control - Daylight and Glare Control - High Frequency Ballast - Electric Lighting Levels - External Views - Thermal Comfort - Individual Comfort Control - Hazardous Materials - Internal Noise Levels - Volatile Organic Compounds - Formaldehyde Minimisation - Mold Prevention - Tenant Exhaust Riser	**Materials** - Recycling Waste Storage - Building Reuse - Reused Materials - Shell and Core /Integrated Fit out - Concrete - Steel - PVC Minimisation - Sustainable Timber - Design for Disassembly - Dematerialisation **Land Use and Ecology** - Conditional Requirement - Topsoil - Reuse of Land - Contaminated Land - Change of Ecological Value	**Management** - Green Star Accredited Professional - Commissioning Clauses - Building Tuning - Independent Commissioning Agent - Building Users' Guide - Environmental Management **Water** - Occupant Amenity Water - Water Meters - Landscape Irrigation - Heat Rejection Water - Fire System Consumption
Emissions - Refrigerant ODP - Refrigerant GWP - Refrigerant Leaks - Insulant ODP - Watercourse Pollution - Discharge to Sewer - Light pollution - Legionella	**Energy** - Conditional Requirement - Greenhouse Gas Emissions - Energy Sub-metering - Lighting Power Density - Lighting Zoning - Peak Energy Demand Reduction	**Transport** - Provision of Car Parking - Fuel-Efficient Transport - Cyclist Facilities - Commuting Mass Transport **Innovation** - Innovative Strategies and Technologies - Exceeding Benchmarks

Data source: (GBCA, 2010)

Assessment method:

Green Star awards points for achievement of specific credits in each rating category. Each category score will be calculated and multiplied with that category's environmental weighting. All weighted category score are combined together plus innovation points to make up buildings' overall score. The Green Star rating is determined by comparing the overall score with the rating scale shown below (GBCA, 2009):

One Star: 10 - 19 pts	Two Star: 20 - 29 pts	Three Star: 30 - 44 pts
Four Star: 45 - 59 pts (Best Practice)	Five Star: 60 - 74 pts (Australian Excellence)	Six Star: 75+ pts (World Leader)

Figure 5.5 shows a sample Green Star result documentation.

Green Star - Office Design v3 & Office As Built v3

Credit Summary for:

Category	Title	Credit No.	Points Availabl	Points Achieve	Points to be Confirmed
Management					
	Green Star Accredited Professional	Man-1	2	0	0
	Commissioning Clauses	Man-2	2	0	0
	Building Tuning	Man-3	2	0	0
	Independent Commissioning Agent	Man-4	1	0	0
	Building Users' Guide	Man-5	1	0	0
	Environmental Management	Man-6	2	0	0
	Waste Management	Man-7	2	0	0
		TOTAL	12	0	0
Indoor Environment Quality					
	Ventilation Rates	IEQ - 1	3	0	0
	Air Change Effectiveness	IEQ - 2	2	0	0
	Carbon Dioxide Monitoring and Control	IEQ - 3	1	0	0
	Daylight	IEQ - 4	3	0	0
	Daylight Glare Control	IEQ - 5	1	0	0
	High Frequency Ballasts	IEQ - 6	1	0	0
	Electric Lighting Levels	IEQ - 7	1	0	0
	External Views	IEQ - 8	2	0	0
	Thermal Comfort	IEQ - 9	2	0	0
	Individual Comfort Control	IEQ - 10	2	0	0
	Hazardous Materials	IEQ - 11	1	0	0
	Internal Noise Levels	IEQ - 12	2	0	0
	Volatile Organic Compounds	IEQ - 13	3	0	0
	Formaldehyde Minimisation	IEQ - 14	1	0	0
	Mould Prevention	IEQ - 15	1	0	0
	Tenant Exhaust Riser	IEQ - 16	1	0	0
		TOTAL	27	0	0
Energy					
	Conditional Requirement	Ene -	-	-	0
	Greenhouse Gas Emissions	Ene - 1	20	0	0
	Energy Sub-metering	Ene - 2	2	0	0
	Lighting Power Density	Ene - 3	3	0	0
	Lighting Zoning	Ene - 4	2	0	0
	Peak Energy Demand Reduction	Ene - 5	2	0	0
		TOTAL	29	0	0
Transport					
	Provision of Car Parking	Tra - 1	2	0	0

Figure 5.5: Sample Green Star score sheet

Source: Google Images

Case studies - Tall-buildings assessed by Green Star:

- National Australia Bank Headquarters, Melbourne.
- Santos Place, Brisbane.

Note:
The tool and more information can be found at: <http://www.gbca.org.au/>.

5.2.5. HK-BEAM

Overview:

HK-BEAM has been adopted in Hong Kong since 1996, aiming at promoting voluntary initiatives to measure, improve and label the environmental performance of buildings on environmental sustainability. It is run by a non-profit and self-financing Hong Kong based organisation named the BEAM Society.

The latest HK-BEAM standards (BEAM Plus 1.1 for Existing and New buildings) covers all building types, including Office, Residential, Mall, Hotel, School, Hospital, Institutional and Mixed Complexes – Air-conditioned, Naturally Ventilated or Mixed Mode (Smith, 2010).

HK-BEAM assessment embraces a range of good practices into a pool of criteria using a life cycle approach. The comprehensive assessment framework encompasses exemplary environmental practices in planning, design, construction, commissioning, operation, maintenance, and management (BEAM Society, 2011a).

Assessment criteria:

HK-BEAM's assessment criteria system consists of six main categories as demonstrated in Table 5.7.

Table 5.7: Summary of HK-BEAM's assessment criteria

Site Aspects (SA) - Site Location: Land Use, Contaminated Land, Local Transport, Neighbourhood Amenities. - Site Planning and Design: Site Design, Appraisal, Ecological Impact, Cultural Heritage, Landscaping and Planters, Microclimate Around Building, Overshadowing and Views, Vehicular Access, Demolition/Construction Management Plan. - Emissions from the site: Air and Noise Pollution During Construction, Water Discharges During Construction, Emission from Cooling Towers, Noise from Building Equipment, Light Pollution.	**Materials Aspects (MA)** - Efficient Use of Materials: Building Reuse, Modular and Standardised Design, Off-site Fabrication, Adaptability and Deconstruction, Envelope Durability. - Selection of Materials: Rapidly Renewable Materials, Sustainable Forest Products, Recycled Materials, Ozone Depleting Substances. - Waste Management: Demolition Waste, Construction Waste, Waste Disposal and Recycling Facilities.
Energy Use (EU) - Annual Energy Use. - Energy Efficient Systems: Embodied Energy in Building Structural Elements, Ventilation Systems in mechanically Ventilated Buildings, Lighting Systems in Mechanically Ventilated Buildings, Hot Water Supply Systems, Lift and Escalator Systems, Electrical Systems, Renewable Energy Systems. - Energy Efficient Equipment: Air-Conditioning Units, Clothes Drying Facilities, Energy Efficient Lighting in Public Areas, Heat-Reclaim, Mechanical Ventilation, Energy Efficient Appliances. - Facilities for Energy Management: Testing and Commissioning, Operation and Maintenance, Metering and Monitoring.	**Indoor Environmental Quality (IEQ)** - Safety: Fire Safety, Electromagnetic Compatibility, Security. - Hygiene: Plumbing and Drainage Systems, Biological Contamination, Waste Facilities. - Indoor Air Quality: Construction IAQ Management, Outdoor Sources of Pollution. - IAQ in Car Parks. - IAQ in Public Transport Interchanges. - Ventilation: Ventilation in Air-Conditioned Interchanges, Background Ventilation, Uncontrolled Ventilation, Localised Ventilation, Ventilation in Common Areas. - Thermal Comfort. - Lighting Quality. - Acoustic and Noise: Room Acoustics, Noise Isolation, Background Noise, Vibration. - Building Amenities: Access for Persons with Disability, Amenities, IT Provisions.
Water Use (WU) - Water Quality. - Water Conservation: Annual Use, Monitoring and Control, Water Use for Irrigation, Water Recycling, Water Efficient Facilities and Appliances. - Effluent Discharge to Foul Sewers.	**Innovations and Additions (IA)** - Innovative Techniques. - Performance Enhancements.

Data source: (BEAM Society, 2010a)

Assessment Method:

HK-BEAM adopts a simple assessment method. Credits are given for evidences of fulfilments of sustainable features. The number of credits and weight of each category are shown in Table 5.8. The Overall Assessment Grade is based on the percentage (%)

of credits gained. Given the importance of SA, EU and IQE it is compulsory to obtain a minimum percentage (%) of credits for the three categories in order to qualify for the overall grade. In addition, a minimum number of credits have to be earned under the category of IA (Innovations and Additions). The classifications are shown in Table 5.9.

Table 5.8: HK-BEAM categories' credits and weight

Categories	Credits	Weight
Site Aspects	22 (+3 Bonus)	25%
Materials Aspects	22 (+1 Bonus)	8%
Energy Use	42 (+2 Bonus)	35%
Water Use	9 (+ 1 Bonus)	12%
Indoor Environmental Quality	32 (+ 3 Bonus)	20%
Innovation and Additions	5 Bonus +1	

Data source: (BEAM, 2010b)

Table 5.9: HK-BEAM award classification

Award Classifications	Overall	SA	EU	IEQ	IA	Assessment
Platinum	75%	70%	70%	70%	3 credits	Excellent
Gold	65%	60%	60%	60%	2 credits	Very Good
Silver	55%	50%	50%	50%	1 credits	Good
Bronze	40%	40%	40%	40%	-	Above average

Data source: (BEAM, 2009)

Case studies - Tall-buildings assessed by HK-BEAM:

- 1 Peking Road, Hong Kong, China.
- Bank of China, Hong Kong, China.

Notes:

The tool, documents and more information can be found at:

<http://www.hk-beam.org.hk>.

5.3. COMPARATIVE REVIEW OF TOP FIVE RATING SYSTEMS

This section presents in details the comparative review process of Top Five rating systems. The summarised result of this process (for all 29 applicable rating systems) is previously shown in Chapter 4 (see Table 4.4, Table 4.5 and Table 4.6). See Section 4.5.3 for the system of criteria used during this comparative review.

Table 5.10 explains the keys used during the review process.

Table 5.10: Keys used in the Comparative Review process

Keys	
✓	Meet criterion
●	Under development
✓/-	Meet criterion with exceptions
-	Does not meet criterion
(blank)	Information Unknown
n/a	Not applicable

5.3.1. Popularity and Influence

The following issues were considered under 'Popularity and Influence' criterion:

- Well-known: Is the system well-known among the built environment community? (2 points).
- Importance: Does the system play a significant part in the development of sustainable built environment in the World? (2 points).
- Number of countries involved: Number of countries that have buildings registered, assessed and certified under the system (2 points).
- Number of Buildings/Projects involved: (2 points).
- Versatility: Number of systems that use it as its basis for development or comparison (2 points).

Table 5.11 summarises the data gathered and the score achieved (maximum 10 points) of each rating system for the 'Popularity and Influence' review criterion.

Table 5.11: Popularity and Influence

Criteria		BREEAM	LEED	CASBEE	Green Star	HK-BEAM
Well-known		✓ (2/2)	✓ (2/2)	✓ (2/2)	✓/- (2/2)	✓/- (2/2)
Importance		✓ (2/2)	✓ (2/2)	● (1/2)	● (1/2)	● (1/2)
Number of countries involved*		+21 (Across Europe and U.S.A) (2/2)	+ 100 worldwide (2/2)	1 (1/2)	1 (1/2)	1 (1/2)
Number of Buildings/ Projects involved *	Registered	+ 500,000	27,000		404	
	Certified	+ 110,000	4,400	80	237	247
	Development Area		+ 5.6 billion ft^2			+ 10.7 million ft^2
	Score	2/2	2/2	1/2	1/2	1/2
Versatility**		12 (2/2)	10 (2/2)	1 (1/2)	0 (0/2)	0 (0/2)
Total score		**10/10**	**10/10**	**6/10**	**5/10**	**5/10**

*: As of April 2010 – Data source: (Fowler & Rauch, 2006).
**: Only major and official systems are counted, the actual number can be higher.

5.3.2. Availability

The following issues were considered under 'Availability' criterion:

- Availability of the system itself: (5 points)
  - Easy to Access: Is it convenient to have full-possession of the system? (1 point).
  - System's Format: In what format and language is the system available? (1 point).
  - How much information is available publicly? (1 point).
  - Cost of System: (1 point).
  - Certification fee: (1 point).
- Availability of references: (5 points)
  - Availability of On-line Information: (1 point).
  - Availability of Information that is not On-line (How to obtain?): (1 point).
  - Availability of Case Studies: (1 point).
  - Availability of Users' review: (1 point).
  - System's Openness: Ability to gather information on the rating system membership and represented organisations. (1 point).

Table 5.12 summarises the data gathered and the score achieved (maximum 10 points) of each rating system for the 'Availability' review criterion.

Table 5.12: Availability

Criteria		**BREEAM**	**LEED**	**CASBEE**	**Green Star**	**HK-BEAM**
Availability of the system itself*	Easy to Access	✓/- (0/1)	✓ (1/1)	✓/- (0/1)	✓ (1/1)	✓ (1/1)
	System's Format	Checklists and Excel Pre Assessment Estimators (1/1)	PDF Rating Checklists and Excel Checklists (1/1)	Assessment Software and Technical Manual (1/1)	Excel Tools and Technical Manual (1/1)	Standards, Checklists, Manual and On-line Pre Assessment Tools (1/1)
	How much information is available publicly?	Assessment prediction Checklists and Pre Assessment Estimator (1/1)	PDF rating systems, Excel Checklists, Credit Interpretation, Guides (1/1)	Assessment Software and Technical Manual (Partly Japanese) (0/1)	Excel Tools and Technical Manual (1/1)	Standards, Checklists, Manual and On-line Pre Assessment Tools (1/1)
	Cost of System	Free (1/1)	Free (1/1)	Free (1/1)	Free Excel Tools, £200 for Technical Manual (0/1)	Free (1/1)
	Certification Fee ***	£740-£1500 (1/1)	£1133-£11331 (0/1)	£1100-£1500 (1/1)	£2550–£7185 (1/1)	£6680-£12525 (0/1)
	Score	4/5	4/5	3/5	4/5	4/5
Availability of references**	On-line Information	✓ (1/1)	✓ (1/1)	✓ (1/1)	✓ (1/1)	✓ (1/1)
	Information that is not On-line (How to obtain?)	E-mail address (1/1)	E-mail help desk and local USGBC Chapters (1/1)	E-mail help desk (1/1)	E-mail help desk (1/1)	E-mail address (1/1)
	Case Studies	● (0/1)	- (0/1)	✓(1/1)	✓(1/1)	✓(1/1)
	Users' Review	✓(1/1)	✓(1/1)	✓(1/1)	✓(1/1)	✓(1/1)
	Systems' Openness	✓/- (0/1)	✓/- (0/1)	- (0/1)	- (0/1)	- (0/1)
	Score	3/5	3/5	4/5	4/5	4/5
Total score		**7/10**	**7/10**	**7/10**	**7/10**	**8/10**

*, **: Data sources: (Fowler & Rauch, 2006); (Lützkendorf, Tanz & Moffatt, 2004); (Smith, 2010); (Fenner & Ryce, 2009).
***: As of April 2010.

5.3.3. Methodology

The following issues were considered under 'Methodology' criterion (not all of them are marked):

- Methodology summary: Identify the method used to process the inputs to produce final results/ grades/ assessments (not marked).
- Weightings: Identify the system applied to weigh the issue categories (not marked).
- Rating Levels: (2 points).
- Standardisation: Established collection procedures exist (2 points).
- Quantitative criteria: Does the system use prescriptive-based criteria? (1 point).
- Qualitative criteria: Does the system use performance-based criteria? (1 point).
- Whole Life cycle assessment: (2 points).
- Complexity: The level of sophistication of assessment method (Sophisticated: 2 points – Average: 1 point – Basic: 0 point).
- Efficiency: The level of efficiency of assessment method (Very high: 5 points - High: 4 points – Average: 3 points – Low: 2 points – Very Low: 1).

Table 5.13 summarises the data gathered and the score achieved (maximum 15 points) of each rating system for the 'Methodology' review criterion.

Table 5.13: Methodology

Criteria	BREEAM	LEED	CASBEE	Green Star	HK-BEAM
Methodology summary	Scores are given to fulfilled sustainable issues. Building's performance is rated based on overall score.	Scores are given to fulfilled sustainable issues. Building's performance is rated based on overall score.	Score-based system. Building is rated based on the balance between environmental performance and loadings.	Score-based system. Building's performance is rated based on overall score.	Score-based system. Building's performance is rated based on overall score and categories' score.
Weightings	Applied to each issue category (consensus based on scientific/ open consultation)	All credits equally weighted, the number of credits related to each issue is a de facto weighting.	Highly complex weighting system applied to every category and at every level.	Applied to each issue category (industry survey based).	Applied to each issue category (industry survey based).
Rating levels	5 levels (1/2)	4 levels (1/2)	5 levels (1/2)	6 levels (2/2)	4 levels (1/2)
Standardisation	✓(2/2)	✓ (2/2)	✓(2/2)	✓(2/2)	✓(2/2)
Quantitative criteria	✓(1/1)	✓(1/1)	✓(1/1)	✓(1/1)	✓(1/1)
Qualitative criteria	✓(1/1)	✓(1/1)	✓(1/1)	- (0/1)	✓(1/1)
Whole Life cycle assessment	✓ (2/2)	● (1/2)	✓/- (1/2)	✓- (1/2)	✓ (2/2)
Complexity (Sophisticated/ Average/Basic)	Average (1/2)	Basic (0/2)	Sophisticate (2/2)	Basic (0/2)	Average (1/2)
Efficiency (Very High/High/ Average/Low/ Very Low)	Average (3/5)	High (4/5)	Very high (5/5)	Average (3/5)	Average (3/5)
Total score	**11/15**	**10/15**	**13/15**	**9/15**	**11/15**

Data sources: (Fowler & Rauch, 2006); (Colwell, 2009); (Reed *et al.*, 2009); (Fenner & Ryce, 2008a; 2008b); (Hui, 2009); (EC Consulting & IH Consulting, 2006); (Air Quality Sciences, 2009).

5.3.4. Applicability

Target building groups

Table 5.14 listed each rating system's target building groups and the number of tall-buildings that have been assessed and certified by that system. The coloured versions are the ones that often used to assess tall-buildings.

Table 5.14: Target building groups and number of tall-building certified

	BREEAM	LEED	CASBEE	Green Star	HK-BEAM
	Courts	Commercial Interiors	New Construction	Education	New Buildings
	Healthcare	Core and Shell (433 projects)	Existing Building	Healthcare	Existing Buildings
	Multi-residential	Homes	Renovation	Office Interior (28 projects)	
	Sustainable Homes	New Construction (2561 project)	Heat Island	Office Design (164 buildings)	
Target building groups	Eco-homes	School, Healthcare, Retail	Urban Development	Office as Built (28 projects)	
	Domestic Refurbishment	Existing Building Operations and Maintenance (491 projects)	Urban Area + Building	Commercial (Retail, Shopping centre Design)	
	Offices	Neighbourhood development	Property Appraisal	Multi-unit Residential (4 projects)	
	Retails		Home	Industrial	
	Education			Convention Centre	
	Industrial			Mixed Use (0 project)	
	Communities				
	Other Buildings				
	Prisons				
Number of Tall-building certified	More than 2000*	More than 1000*	8 buildings**	140-170 buildings***	107 buildings ****
Score	**4/5**	**5/5**	**2/5**	**3/5**	**3/5**

*: As of April 2010. Figure estimated based on the following sources: (Fowler & Rauch, 2006); (USGBC, 2011a).
**: As of August 2009. Data source: (JSBC, 2011a).
***: As of May 2010. Data source: (GBCA, 2011a).
****: As of May 2010. Data source: (BEAM Society, 2011b).

LEED scored highest in this section despite there are fewer tall-buildings certified by LEED than BREEAM. This mostly because of LEED's Core and Shell version has come very close to a specialised rating system for tall-buildings with many dedicated assessment criteria for Core and Shell structures (which is the dominated type of structure for tall-buildings). HK-BEAM has been used to assess 107 buildings only, but this number is actually very impressive as there are only 247 buildings certified by this system so far (see Table 5.11). Meanwhile, the number of tall-buildings assessed by BREEAM is quite low compared to the huge number of projects involved with this system. This is actually reasonable because the tall-building density in UK and Europe is quite low compared to the U.S. and especially Hong Kong.

Stages of building life cycle influenced

Table 5.15 indicates the score achieved by each system according to the stages of building life cycle they influence (6 stages: 5 points - 5 stages: 4 points – 4 stages: 3 points – 3 stages: 2 points - 1, 2 stages: 1 point).

Table 5.15: Stages of building life cycle influenced

Stages of building life cycle	BREEAM	LEED	CASBEE	Green Star	HK-BEAM
Pre-Design/ Planning/ Site Selection	-	-	✓	-	-
Design/ Procurement/	✓	✓	✓	✓	✓
Construction/Post Construction Review	✓	✓	-	✓	-
Existing Building Management/ Operations/ Maintenance	✓	✓	✓	●	✓
Tenant Fit-Out/ Refurbishment	✓	✓	✓	✓	-
Demolition	-	-	-	-	-
Total score	**3/5**	**3/5**	**3/5**	**2/5**	**1/5**

Technical Contents

In order to calculate a single score from the diverse range of environmental issues that each of the methodologies covers, each system attributes a different weighting to the issues covered. The way that different systems set these weightings varies. In some cases, weighting factors are built into the value of each criterion (i.e. LEED), in the others these are built into the value of the environmental issue category (i.e. BREEAM, Green Star, HK-BEAM).

The weightings used are summarised in Table 5.16. For the purposes of the comparison, the weightings have all been compared to the BREEAM sustainable issues categories (see Table 5.1). Figure 5.6 and Table 5.17 compare technical contents of the systems from a different point of view, which is more tall-building oriented. Total score of 'Applicability' criterion (combined score of 'Target building groups,' 'Stage of building life cycle' and 'Technical contents' criteria) is also showed in Table 5.17.

Table 5.16: Issue value/weighting comparison - Summary 1

	BREEAM	LEED	CASBEE	Green Star *	HK-BEAM
Management	15	8	It is not possible to calculate the value of each issues category for CASSBEE, as the value is dependent on the final score.	10	- (Included in 'Site Aspects' Category).
Energy	25	25		25	35
Transport				10	
Health and Well-being	15	13		20	20
Water	5	5		10	12
Materials	10	19		10	8
Land-use and Ecology	15	5		10	25 (All included in 'Site Aspects' Category).
Pollution	15	11		5	
Sustainable Sites	-	16		-	

*: Green Star's weighting factors slightly vary across Australia's states and territories.
Data sources: (BEAM Society, 2010b); (Sandler, 2008).

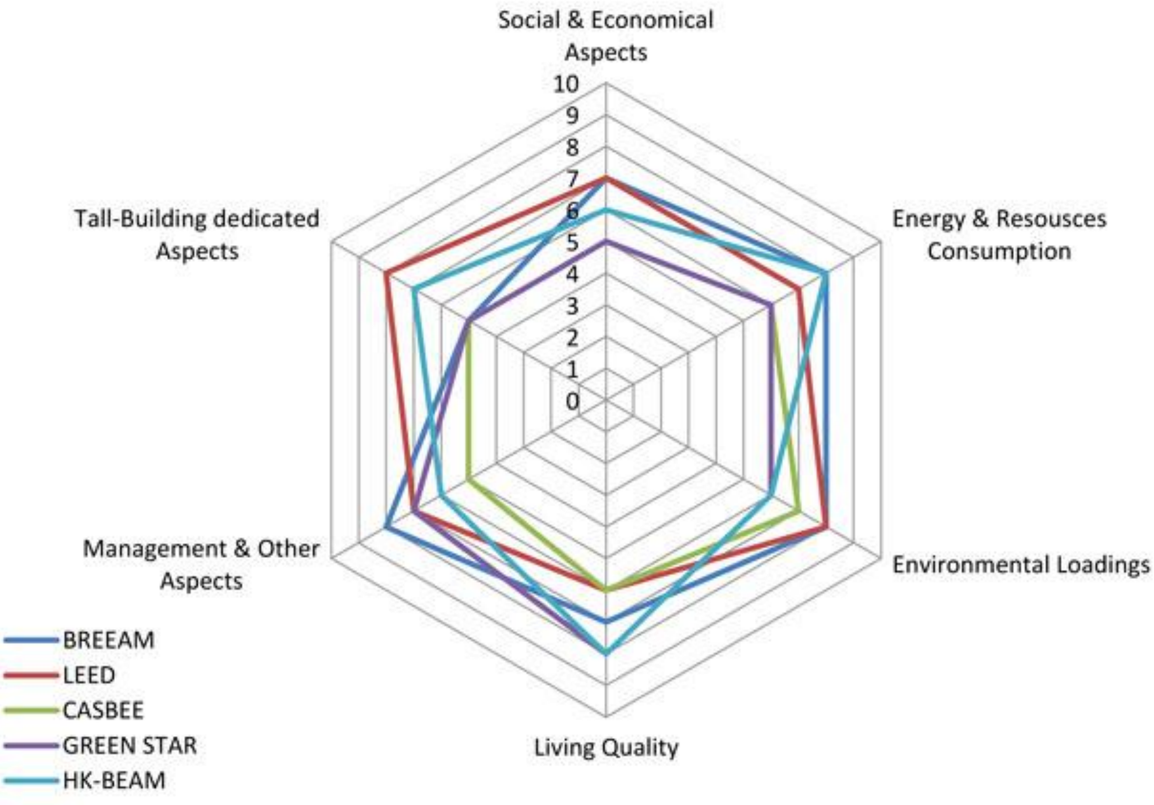

Figure 5.6: Issue value/weighting comparison - Summary 2

Table 5.17: Issue value/weighting comparison - Summary 3

	BREEAM	LEED	CASBEE	Green Star	HK-BEAM
Social and Economical Aspects	7	7	5	5	6
Energy and Resources Consumption	8	7	6	6	8
Environmental Loadings	8	8	7	6	6
Living Quality	7	6	6	8	8
Management and Other Aspects	8	7	5	7	6
Tall-Building dedicated Aspects	5	8	5	5	7
'Technical Contents' criterion score	7	7	5.5	6	7
'Applicability' criterion total score	**14/20**	**15/20**	**10.5/20**	**11/20**	**11/20**

5.3.5. Data Collecting

The following issues were considered under 'Data Collecting' criterion:

- Data Gatherer: Identify the party that in charge of data inputting process (2 points).
- Data Collecting Method: Identify the method used to input data (2 points).
- Documentation: What type of documents needed for the assessment? At what stage of the project? Is it easy to gather those documents? (2 points).
- Measurability: Does the tool use measurable method to collect data? (2 points).
- Convenience: Is it easy and quick to gather data? Is it possible to finish data inputting process without the need of excessive technical knowledge? (2 points).

Table 5.18 summarises the data gathered and the score achieved (maximum 10 points) of each rating system for the 'Data Collecting' review criterion.

Table 5.18: Data Collecting

Criteria		BREEAM	LEED	CASBEE	Green Star	HK-BEAM
Data Gatherer		Design/ management team or assessor. (2/2)	Design/ Management team or Accredited Professional. (2/2)	Design/ management team. (1/2)	Design team. (1/2)	Design/ management team or professional assessor. (2/2)
Data Collection Method		Checklists or Online-spread sheet. (2/2)	Checklist or Excel spread sheet. (2/2)	Excel-spread sheet. (2/2)	Excel-spread sheet. (2/2)	Checklist or Online Tool spread sheet. (2/2)
Documentation	Type	Online and/or hardcopy (drawings, surveys, reports, contracts, agreements and other official documents).	Online and/or hardcopy (drawings, specifications, calculations, reports, statements and other official documents).	Online spread sheet, no hardcopy.	Online and/or hardcopy (drawings, surveys, reports, contracts, agreements and other official documents).	Hardcopy (drawings, surveys, reports, contracts, agreements and other official documents).
	At what stage of project	Design Review and Construction Review.	Design, Construction and Operation.	Preliminary design, execution design, completion.	Design Review and As Built Review.	Design Review and Construction Review.
	Ease of document gathering	-	-	-	✓	✓/-
	Score	(1/2)	(1/2)	(1/2)	(2/2)	(2/2)
Measurability		✓/- (1/2)	✓/- (1/2)	✓/- (1/2)	✓(2/2)	✓/- (1/2)
Convenience		✓/- (1/2)	✓/- (1/2)	✓/- (1/2)	✓(2/2)	✓/- (1/2)
Total score		**7/10**	**7/10**	**6/10**	**9/10**	**8/10**

Data sources: (Fowler & Rauch, 2006); (Colwell, 2009); (Reed *et al.*, 2009); (Hui, 2003; 2009); (EC Consulting & IH Consulting, 2006).

5.3.6. Accuracy and Verification

Basically, an assessment system operates in three main stages (see Section 6.4 for more related discussions):

- Data Input (where users input their project's data and information);
- Data Processing (where particular methods are applied to analyse and evaluate, i.e. 'process', inputted data); and
- Data Output (where processed data is transfer into actual results, i.e. grade or benchmarks or percentage).

Therefore, the following issues were considered under 'Accuracy and Verification' criterion:

- Accuracy of Data Input Stage: (High: 2 points – Medium: 1 – Low: 0).
- Accuracy of Data Processing Stage: (High: 2 points – Medium: 1 – Low: 0).
- Accuracy of Data Output Stage: (High: 2 points – Medium: 1 – Low: 0).
- Verification: Define the system for verifying assessment results
    - Assessor Qualification: Who verify the assessments? What qualification they must have to be an assessor? (1 point).
    - Level of Detail of Check: To what level of detail do assessors review the applications? (1 point).
    - Third Party: Is there a third party assessment? (1 point).
    - Are the verified results widely acknowledged?

Table 5.19 summarises the data gathered and the score achieved (maximum 10 points) of each rating system for the 'Accuracy and Verification' review criterion.

Table 5.19: Accuracy and Verification

Criteria		BREEAM	LEED	CASBEE	Green Star	HK-BEAM
Accuracy of Data Input Stage		High (2/2)	High (2/2)	High (2/2)	Low (0/2)	Medium (1/2)
Accuracy of Data Processing Stage		Medium (1/2)	Medium (1/2)	High (2/2)	Medium (1/2)	Medium (1/2)
Accuracy of Data Output Stage		Medium (1/2)	Low (0/2)	High (2/2)	Medium (1/2)	Low (0/2)
Verification	Assessor Qualification	Trained and licensed by BRE.	Trained and must pass an examination. Must be a 1st-class architect.	Trained and must pass an assessor examination	Trained and certified by GBCA.	Trained and certified by HK-BEAM Society.
	Level of Detail of Check	Detailed assessment of documentary evidence.	Administrative and credit audits.	Document review.	Detailed assessment of documentary evidence.	Detailed assessment of documentary evidence.
	Third Party	✓	✓	✓/- (If required)	✓	✓
	Widely acknowledged	✓	✓	●	-	●
	Score	(4/4)	(4/4)	(3/4)	(3/4)	(3/4)
Total score		8/10	7/10	9/10	5/10	5/10

Data sources: (Fowler & Rauch, 2006); (Colwell, 2009); (Lützkendorf, Tanz & Moffatt, 2004); (Buttler & Stoy, 2009); (Leung, 2009).

Third-party verification process

Figure 5.7 compares third-party verification process of the Top Five rating systems.

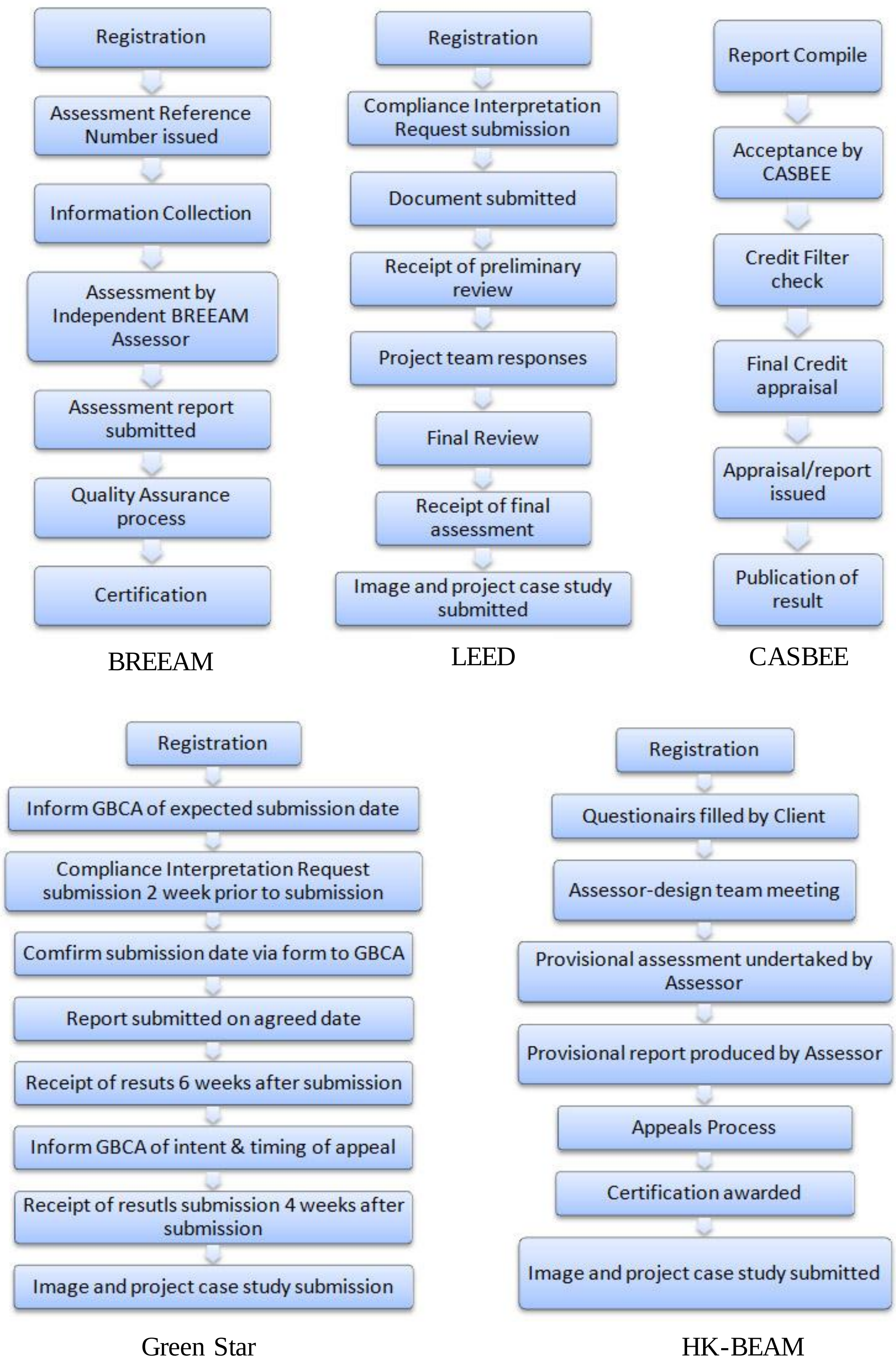

Figure 5.7: Third-party verification process comparison

5.3.7. User-friendliness

The following issues were considered under 'User-friendliness' criterion:

- Ease of use: Complexity of the system. Is it easy to get used to the system? (1 point).
- Product support:
    - Availability and responsiveness of direct request for assistance (1 point).
    - Availability of FAQs and Record of Enquiries (1 point).
    - Availability of training courses/sessions (1 point).
    - Adequacy of built-in or attached instructions/helps. Are these instructions/helps sufficient enough for users to help themselves using the system? (1 point).

Table 5.20 summarises the data gathered and the score achieved (maximum 5 points) of each rating system for the 'User-friendliness' review criterion.

Table 5.20: User-friendliness

Criteria		BREEAM	LEED	CASBEE	Green Star	HK-BEAM
Ease of use		✓	✓	-	✓/-	✓
Product support	Availability and responsiveness of direct request for assistance	✓/-	✓/-	✓/-	✓/-	✓
	Record of Enquiries and FAQs	✓/-	✓	✓/-	✓/-	-
	Availability of training	✓	✓	✓	✓	✓/-
	Built-in instructions/helps	✓	✓	✓/-	✓	✓
Total score		**4/5**	**5/5**	**3/5**	**4/5**	**4/5**

5.3.8. Development

The following issues were considered under 'Development' criterion:

- Country of Origin, Development Basis, and Developer (not marked).
- System Management: Identify the level of involvement in the development, funding and management of the rating system by Government, Private Industry or Non-Governmental Organisations (NGO) (not marked).
- System's maturity: Identify when the system was initiated and first available for public use (2 points).

- System's stability: Identify the processes that allow for full implementation of a rating system, including development, testing, and review process, systems for upgrades, process for modifications, and expected frequency of modifications (2 points).
- Update: How is the tool constantly improved? (2 points).
- Development approach: Identify if system was developed using a consensus-based approach, life cycle analysis, expert opinion approach, or other (2 points).
- Future development: The system's potential improvement and influence expansion (not marked).
- Potential contribution to the research: Is this system a valuable reference source for the research? (2 points).

Table 5.21 summarises the data gathered and the score achieved (maximum 10 points) of each rating system for the 'Development' review criterion.

Table 5.21: Development

Criteria		**BREEAM**	**LEED**	**CASBEE**	**Green Star**	**HK-BEAM**
Country of Origin		UK	U.S.	Japan	Australia	Hong Kong
Development Basis		Original	Original	Original	BREEAM, LEED	BREEAM
Developer		BRE	USBGC	JSBC	GBCA	BEAM Society
System Management *	Government		✓	✓/-		✓/-
	Private Industry	✓	✓	✓	✓	✓
	NGO	✓	✓	✓	✓	✓
System's Maturity	Launch Date	1990	1998	2001	2002	1996
	Available for Public Use	1990 (20 years)	1998 (12 years)	2002 8 years	2003 7 years	1996
	Score	2/2	2/2	1/2	1/2	2/2
Systems Stability *	Testing and Development	✓	✓	✓	✓	✓
	System for Revisions	✓	✓	✓/-	✓	✓
	Score	2/2	2/2	1/2	2/2	2/2
Update	Update period	Annually	2 years	Annually	Annually	As required
	Latest revision	2008	2009	2008	2009	2010
	Score	2/2	2/2	2/2	2/2	1/2
Development Approach *	Consensus-based	-	✓	✓	-	●
	Life Cycle Analysis	✓	●	✓/-	✓-	✓
	Expert Opinion	✓	✓	✓	✓	✓
	Score	1/2	1/2	2/2	1/2	1/2
Future development		✓	✓	✓	✓	✓
Potential contribution to the research		1/2	1/2	1/2	2/2	2/2
Total score		**8/10**	**8/10**	**7/10**	**8/10**	**8/10**

*: Data sources: (Fowler & Rauch, 2006); (Reed *et al.*, 2009).

5.3.9. Results Presentation

The following issues were considered under 'Results Presentation' criterion:

- Presentation method: End products of assessment process, ratings, result, etc. (1 point).
- Clarity: Well-defined, easily communicated, and clearly understood among multiple parties (2 points).
- Comparability: Amenable to normalisation for comparisons over varying building types, locations, years, or different sustainable design characteristics (1 point).
- Result usability: Usability of result documentations for communicating the accomplishments of the building (1 point).

Table 5.22 summarises the data gathered and the score achieved (maximum 5 points) of each rating system for the 'Results Presentation' review criterion. Table 5.23 roughly compares the evaluation results of the Top Five rating systems.

Table 5.22: Results Presentation

Criteria		BREEAM	LEED	CASBEE	Green Star	HK-BEAM
Presentation Method	End product of assessment process.	Per cent (%) of credits achieved.	Per cent (%) of credits achieved.	Spider diagram, histograms, BEE graph.	Percentage score (/100).	Per cent (%) of credits achieved.
	Ratings	Pass/ Good/ Very Good/ Excellent/ Outstanding	Certified / Silver / Gold / Platinum	C/ B-/ B+/ A/ S	1Star/ 2 Star/ 3 Star/ 4 Star/ 5 Star/ 6 Star	Platinum/ Gold/ Silver/ Bronze
	Result Product	Certificate	Award letter, certificate and plaque.	Certificate and website published results.	Certificate and website published results.	Certificate and website published results.
	Score	1/1	1/1	1/1	1/1	1/1
Clarity	Well-defined	✓	✓	✓/-	✓/-	✓
	Results easily communicated	✓	✓	✓/-	✓	✓
	Clearly Understood	✓	✓	-	●	✓
	Score	2/2	2/2	1/2	1/2	2/2
Comparability		- (0/1)	- (0/1)	✓(1/1)	● (0/1)	✓(1/1)
Result Usability		- (0/1)	- (0/1)	✓(1/1)	✓(1/1)	- (0/1)
Total score		**3/5**	**3/5**	**4/5**	**3/5**	**4/5**

Table 5.23: A broad comparison of five rating systems

BREEAM	LEED	CASBEE	Green Star	HK-BEAM
Excellent				
Very good	Platinum		Six Star	
Good	Gold	S A	Five Star Four Star	Platinum Gold
Pass	Silver	B+	Three Star	Silver
	Certified	B- C	Two Star One Star	Bronze

Data sources: (Reed *et al.*, 2009); (BEAM Society, 2011a).

5.3.10. Innovations

Table 5.24 summarises innovative features of the Top Five rating systems. Please note that only the features that are considered potential contributions to further stages of the research are counted and credited.

Table 5.24: Innovations

Rating system	Innovative features	Score
BREEAM	- Overall standards are very stringent, probably highest worldwide. - BREEAM International uses local guidance, regulations, climatic distinctiveness and environmental priorities. - Outstanding technical attributes in the following issues categories: Material and Resources, Sustainable Site. - Assessment methodology is transparent, straightforward, easy to understand, and supported by evidence-based research that has stood the test of time.	**4/5**
LEED	- Outstanding technical attributes in the following issues categories: Water, Energy, Indoor Environmental Quality, and Regional Design. - 'Core and Shell' version has many dedicated assessment criteria for high-rise structures, which will be a very valuable reference source. - LEED Online tool is very fast, smart and efficient; which would be a good case study to develop a new tool.	**3/5**
CASBEE	- Exclusive and innovative assessment methodology with highly complex weighting system. - The balance between living quality and environment loadings, which demonstrated by BEE (building environmental efficiency) indicator, is the highest priority. - LCA Calculator. - Flexibility and Adaptability. - Earthquake risk management, which is very suitable for tall-buildings.	**5/5**
Green Star	- Outstanding technical attributes in the following issues categories: Land Use and Ecology, Water. - Concise, easy to use but thorough Excel tool. - Different weighting factors for different states, so the system can be used in various regions with higher accuracy. - Good project directory with many case studies that would be good reference source.	**4/5**
HK-BEAM	- Good project directory with many case studies, of which many are tall-buildings. Would be an excellent reference source. - Good range of tall-building dedicated criteria due to Hong Kong's high tall-building density.	**2/5**

5.4. CHAPTER CONCLUSIONS

5.4.1. Executive Summary of Part A

'Part A - Reviewing' executively summarises the literature review stages of the research. First of all, the history of the development of sustainability rating systems has been reviewed (see Chapter 3). Secondly, a large number of available rating systems have been identified. A preliminary screening process has then been applied to filter out inapplicable systems for tall-buildings. 29 applicable systems were identified and put through an intensive comparative-review-process to find out the most suitable rating systems for *tall-building assessment* and for *developing a new rating system* (see Chapter 4). There are five rating systems that scored highest throughout the review process, namely:

- BREAAM (Building Research Establishment's Environmental Assessment Method) (United Kingdom);
- LEED (Leadership in Energy and Environmental Design) (United States);
- CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) (Japan);
- Green Star (Australia);
- HK-BEAM (Building Environmental Assessment Method) (Hong Kong).

Each one of these five rating systems has been intensively and comparatively reviewed in Chapter 5. They will be the main reference sources throughout the research and the main bases to develop TPSI. All other applicable rating systems were also reviewed and summarised in Appendix A. The outcomes of Part A can be used by many types of user for various purposes:

- It can be considered as an independent research into tall-building sustainable assessment rating systems. The information, analyses, valuations and comparative reviews in this report are helpful for architects, developers, and managers when it comes to choosing an assessment tool for their projects.
- It is the major part of the literature review process.
- It provides a systematic reference source for further stages of the research, which will make the looking-up and referencing activities much quicker and more convenience.

- It would also be a valuable literature for other research that related to sustainable development.

Throughout the review process, the main problems of existing rating systems that make the utilisation of them to assess tall-buildings become insufficient have been identified (see Section 5.4.2). Subsequently the visions for the main characteristics of TPSI are defined (see Section 5.4.3).

5.4.2. Gaps in Existing Rating Systems

The confusion between 'Green' and 'Sustainable'

Environmentally progressive building practice is currently described using a variety of different tags: 'green design,' 'ecological design' or 'sustainable design.' Although discussions regarding the most appropriate terminology to describe environmentally progressive buildings can be deteriorate to meaningless semantics, the distinction between the notions of 'Green' and Sustainable' is critical in structuring environmental assessment methods (Cole, 1999). These fundamental differences, surprisingly, often are neglected in existing rating systems. In original rating systems such as BREEAM or LEED, these differences were quite well defined. In later generations of ratings systems (i.e. the systems that have been developed based on one or several original ones), the line between 'Green' and 'Sustainable' gradually faded away. This issue needs to be carefully considered when developing the new tool.

The confusion between 'Quantitative' and 'Qualitative' criteria

This issue is actually a consequence of the confusion between 'Green' and 'Sustainable' definitions. Assessing 'sustainable' performance, which is largely an issue of energy and mass flows, can and should be described in quantitative terms. On the other hand, the wider range of performance issues necessary within an assessment of 'green' currently cannot avoid using more qualitative metrics to evaluate a building comprehensively. Any confusion will lead to inadequate structure of assessment criteria there for the ineffectiveness of the assessment. On the other hand, a good combination of quantitative and qualitative criteria will ensure a thorough and sufficient valuation. CASBEE and Green Star are the two systems that have remarkable efforts on balancing quantitative and qualitative measurement.

The confusion between 'Assessment' and 'Design' tool

Although conceived as 'assessment tools' to evaluate a completed building design, some existing rating systems such as BREEAM, LEED, GBTool, and CASBEE. are commonly used as 'design' tools. Whether or not a single system can function equally effectively as an assessment and design tool? If yes, then what compromises would be necessary to an assessment tool to enable it to be useful in design? The answers lie in the structure of the assessment framework and with the skill and enterprise of the users. While the later cause cannot be controlled, the former can be fixed. The distinction between an Assessment tool and a Design tool is quite unclear in many existing rating systems; namely BREEAM, LEED, HK-BEAM, CASBEE, and Green Star. There are two main reasons for this confusion:

- **a.** These rating systems divide up projects/buildings by *functions*, not by *stages of building life cycle*. For example BREEAM has different versions for residential, healthcare centres, schools, commercial centres, prisons, etc.
- **b.** The ambition to build up a tool that can be used for as many projects as possible. HK-BEAM is a typical example. It only has two versions for every type of projects: 'New building' and 'Existing buildings.'

No matter what reason it is, this confusion will cause troubles for both the system's developer (when building up assessment criteria) and users (when choosing among versions and using them to evaluate their buildings).

Applicability during Design stage

One of the major disadvantages of existing systems is they can't be used effectively during design process. The reasons for this are the same as the two reasons that cause the confusion between an 'Assessment' tool and a 'Design' tool. Most of the existing rating systems are either not designed for design process; or are too bulky to use during design stages. There is a fact that in the UK and the U.S., there are many projects that running for BREEAM or LEED certificate just because they are trying to 'look' green. The managers therefore will take advantage of rating systems' assessment criteria. They target the credits that are easy to achieve, just enough to reach the necessary points. Credits that are really significant often hard to get are normally ignored. If a rating system targets the early stages of a project, this exploitation can be naturally stopped.

However, among current existing rating systems, there is a lack of genuine design tools, or types of 'checklist' that can be used for testing or as reference during design stage.

Specialisation

This is probably the most important gap in existing rating systems. Tall-buildings have very distinctive technical and architectural features in comparison to other types of building. Low and medium-rise buildings; no matter whether they are residential, commercial centres, schools or offices; all have similar construction, operation and demolition procedures. Tall-buildings, in the other hand, have totally different procedures and therefore need specialised assessment criteria to be adequately evaluated. Existing rating systems which are commonly used to assess tall-buildings, such as BREEAM Office, CASBEE New Construction, Green Star Office Design or HK-BEAM New Buildings, seriously lack of dedicated assessment criteria for tall-buildings. Especially in the following areas: Construction technologies and procedures, foundation construction, building's service, social and economic aspects, material utilisation, energy utilisation, earthquake management, and living quality inside tall-buildings.

Localisation

Major rating systems such as BREEAM and LEED, HK-BEAM, and CASBEE always attempt to develop themselves as 'International Tools,' i.e. can be used worldwide. There are two factors that are holding back this effort:

a. *The inflexibility of assessment method:* The main reason that existing rating systems cannot be used in different countries and climate zones does not lie in the assessment criteria themselves. Sustainable aspects remain more or less the same everywhere and a set of standard can be used worldwide. In fact many existing rating tools were developed based on the assessment criteria system of BREEAM. It is the importance of component aspects toward overall performance that need to be changed. Green Star – the Australian rating systems presents a good example of how to tackle this issue. It developed a dynamic weighting system for assessment criteria sections. This weighting system can be changed according to locations and climate zones and therefore increase the accuracy of the evaluation (the assessment criteria remain the same).

b. *The use of local standards*: When assessing a criterion, these tools often refer to national standards with particular characteristic that cannot be applied in different countries. This can be solved by:

- Using international standard instead (e.g. ISO) or national standard that are accepted worldwide such as ASHRAE.
- Simplified the national standards and integrate them into the tool, so the users do not need to refer to external standards anymore.

Bulkiness

Most of existing rating systems are very bulky. It often takes several days or even several weeks to finish an assessment (data collecting, data inputting, document gathering, etc.). The systems of assessment criteria of existing tool such as BREEAM, LEED, CASBEE, and Green Star are often very rich in technical contents. Normally, an individual architect cannot even finish the assessment process on his/her own because of lacking specialised technical knowledge. This is necessary because assessing sustainability, especially environmental aspects, of a building is a sophisticated process. On the other hand, it is also necessary to have more concise and handy tools/versions that can produce quick results. This becomes particularly essential in design stage, where these tools are likely to be used again and again to test different design solutions.

5.4.3. Visions for TPSI Rating System

This section only presents holistic visions for TPSI rating scheme; details of foundations for the development of TPSI are presented in Chapter 6. These visions are realised in to the features of TPSI, which are introduced in Chapter 7.

'Management' tool

Design rating tools and performance rating tools each have their strengths and weaknesses. Furthermore, it is important to note that one player in the building sector sees as strength at one phase of a building's life cycle, maybe a weakness to another player or in another phase.

- A design-rating tool encourages decision-making at the design stage, which is crucial for the overall sustainability. A design tool often provides no incentive for efficient evaluation when the building is in use.

- Performance in practice however may not be as good as the potential, particularly in relation to on-going energy use where building management and tenant activities play an important role. This is the strong point of performance tool.

However, this does not mean that a design tool cannot be used throughout the life cycle of a project. In fact, a good design tool *should* be flexible enough to offer different types of evaluations. Users should be able to produce quick assessments (i.e. preliminary assessment) during sooner stages of their project; on the other hand they should have the choice to carry out more robust and detailed assessments as their project develop. TPSI will be a 'Management' tool that can be used to manage a project right from the beginning and throughout its life cycle.

Specialisation

TPSI will be specialised for tall-building assessment only (i.e. building with more than 20 stories – see Section 6.2 for the definition of tall-buildings and the reason for choosing this threshold). This specialisation allows the development of a dedicated system of assessment criteria and assessment method, therefore increasing the accuracy of the evaluations over other rating schemes. This improved accuracy is of significance and is one of the main contributions of this research. The specialisation of TPSI is reflected in various features, including:

- Rearrangement of general sustainability criteria to reflect the difference between tall-building projects and other types of projects.
- Supplementation of specialised assessment criteria.
- A dynamic weighting system that can adapt to different types of high-rise projects in different context.

Concise and handy tool

The new rating system is expected to be very user friendly. Assessment criteria will be simplified and presented in an easy-to-understand way. The data inputting process will be speeded up. Technical inputs that are difficult to retrieve and quantify will be limited. All in order to build up a handy tool that can produce quick and sufficient evaluations. It will be most suitable at design stage when comparing different design schemes and making decisions. TPSI will be available in form of an Excel tool (or coded software) and a Technical Manual for referencing.

The harmony of Quantitative and Qualitative criteria

As established in Section 5.4.2, the confusion between quantitative and qualitative criteria is one of the major gaps in existing rating systems. Not only this confusion needs to be cleared in TPSI; a certain level of harmony must be achieved between quantitative and qualitative assessment criteria. Qualitative criteria are vital to a design tool, while quantitative criteria are essential to any assessment system and to improving the accuracy of the evaluation process.

Improved results presentations

Results of the assessment process will be presented in a well defined and easy to communicate manner. The comparability of the outputs will be enhanced so that they are well understood and transferable between different parties. Various types of results presentations will be available, including scores, ratings, charts, graphs, and issues' summaries. It is essential that the users must be able to improve their design/projects from the generated results – in each section/category of sustainability and on a holistic scale. Therefore sectional and overall results must be available simultaneously and instantly as users progressing. Microsoft Excel is chosen as the platform to develop the TPSI Calculator because of its popularity and capacities. Microsoft Excel can produce a wide range of charts and graphs. More importantly, its ability to utilise Macro codes ensures the integration of intricate features in to TPSI Calculator.

Flexibility in conjunction with Accuracy

The accuracy of sustainability rating systems in different contexts (i.e. locations, climates, urban zones, etc.) has always been a major concern. Basically, existing systems' precision compromises when being used in diverse conditions. Systems such as CASBEE and HK-BEAM – which are designed for a particular country – provide an accredited level of accuracy. Their assessment criteria and requirements are often very strict. However, they cannot be used for other countries. International tools such as BREEAM and LEED, on the other hand, tend to settle for neutralised criteria in order to cover a wider range of contexts. The importance of sustainable aspects also varies in different conditions - this presents an even bigger problem. TPSI will be able to adapt itself to different contexts and different types of tall-building projects by applying a dynamic and flexible weighting system. This will help TPSI become a global tool with enhanced accuracy.

Improved standard

TPSI will set a higher standard for sustainable tall-buildings. It will effectively improve the quality and accuracy of sustainable tall-building assessment activities. Assessment criteria system of the Top Five rating systems will be adopted and improved. See Chapter 6 and Chapter 7 for the development of TPSI's assessment criteria system.

CHAPTER 6: THEORETICAL FOUNDATIONS FOR THE DEVELOPMENT OF TPSI

6

6.1. CHAPTER INTRODUCTION

'Part B - Developing' is the second and most important stage of the research, which aims to develop the first version of TPSI (see Figure 2.3 and Figure 2.8 for the research framework). The results and findings of Part B are presented across Chapter 6 and Chapter 7. The 'Developing' stage consists of the following main steps:

- Defining theoretical and literature foundations to develop TPSI;
- Building up the system of assessment criteria;
- Developing the assessment methodology;
- Combining everything to form a completed rating system.

This stage is an intricate, interactive process with repetitive test-fail-improve rounds. The development of TPSI also utilises references, case studies and development bases/models from multi-parties. This chapter summarises the key foundations for the development of TPSI, which presents a holistic view of the main issues when developing the system and strategies to tackle them. Chapter 7 introduces the first version of the TPSI System – TPSI 2012 Version.

6.2. CRITERIA FOR THE DEFINING AND MEASURING OF TALL-BUILDINGS

6.2.1. Re-defining 'Tall-building'

It is first critical to define what is understood by the term 'tall-building' or 'high-rise building' within TPSI. The Emporis Standards Committee defines a high-rise building as *"a multi-story structure between 35-100 meters tall, or a building of unknown height from 12-39 floors"* (Emporis Standards Committee, 2011). Some structural engineers define a tall-building as *"any vertical construction for which wind is a more significant load factor than earthquake or weight"* (Wikipedia, 2011a). This direction tends to quantify the term 'tall' towards an actual number.

On another hand, according to Abel (2003), the definition of what may constitute 'tall' depends upon the urban, cultural and societal context. For centuries, building height was controlled by the limit of a person's ability to build staircases, thus setting a maximum attainable height of around four or five stories (Yeang, 1996). The term therefore varies from country to country. For example, in Dubai, it commonly refers to buildings of more than 180 metres (590 ft). Some commonly used definitions are:

- The CTBUH's (Council on Tall Buildings and Urban Habitats, based in Chicago, US) set of definitions that based on context, proportion and building technologies (see Section 1.1.4).
- The London Plan defines tall-buildings as *"buildings that are significantly taller than their surroundings and/or have a significant impact on the skyline and are larger than the threshold sizes set for the referral of planning applications to the Mayor. Tall-buildings are taller than the overall building height in an area…"* (Greater London Authority, 2011).

The context-based descriptions are currently the dominant direction when defining tall-buildings. However, to serve the purpose of an assessment system, there must be an actual number/threshold to eliminate the potential disagreement between parties involved.

After considering all aspects, especially TPSI's essence and methodology, the threshold of 20 stories has been chosen. There are many reasons for this choice, but the most important one is: *20 stories is the threshold where all the design, planning, construction, maintenance and deconstruction of a building change dramatically*.

This threshold is actually set forth long ago by the renowned architect/engineer Fazlur Khan (1969) – a major figure of early American high-rise buildings scene. Khan classified structural systems for tall buildings relating to their heights with considerations for efficiency in his 'Heights for Structural Systems' diagrams (see Figure 6.1). According to Khan's work, 20 stories is the efficiency limit (in term of both structural and economic aspects) of concrete framed structures. He also did a similar study on steel structure and came to a further suggestion that steel structures should not be less than 20 stories to be most sufficient. Overall, Khan believes that at 20-storey threshold, developers should consider the overall approach and switch from concrete to steel structure.

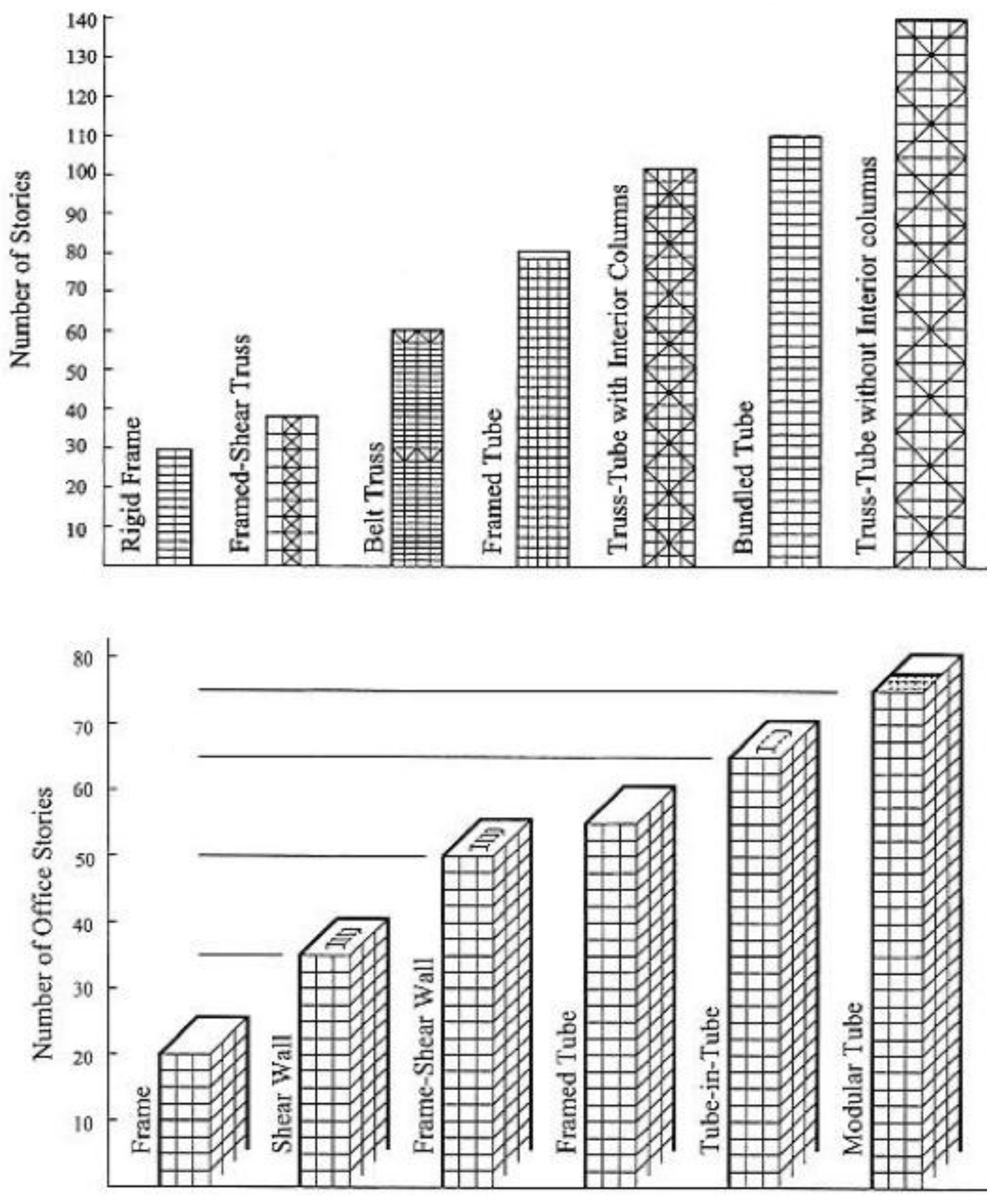

Figure 6.1. Classification of tall-building structural systems by Fazlur Khan

Note: Above: Steel - Below: Concrete. Source: (Khan, 1969)

This 20-story threshold is again confirmed by Ali and Moon in 2007. In their very thorough research, they have re-established that the Efficient Height Limit of the traditional concrete interior-rigid-frame structure is about 20 stories (Ali & Moon, 2007). When surpassing this thresholds, the elements of tallness such as lateral forces, shear lag, structure self-weight, elevator and other types of space allocations, economic, construction technologies, maintenance requirements, etc. ask for further considerations of structure in particular and design strategies in general (see Table 6.1).

Table 6.1: Classification of tall-building interior structural systems by Ali & Moon

Category/ Sub-Category		Material/ Configuration	Efficient Height Limit	Advantages	Disadvantages
Rigid Frame		Steel	30	Provide flexibility in floor planning. Fast construction.	Expensive moment connection and fire proofing.
		Concrete	20	Easily moldable. Provide flexibility in floor planning.	Expensive form work. Slow construction. Environmental Issues
Braced Hinged Frames		Steel Shear Trusses + Steel Hinged Frames	10	Efficiently resist lateral lads by axial forces in the shear truss members. Allows shallower beams compared with the rigid frames without diagonals.	Interior planning limitations due to diagonals in the shear trusses. Expensive diagonal connections.
Shear Wall / Hinged Frames		Concrete Shear Wall + Steel Hinged Frames	35	Effectively resists lateral shear by concrete shear wall.	Interior planning limitations due to shear walls.
Shear Wall (or Shear Truss) - Frame Interaction System	Braced Rigid Frames	Steel Shear Trusses + Steel Rigid Frames	40	Effectively resists lateral loads by producing shear truss – frame interacting system.	Interior planning limitations due to shear trusses.
	Shear Wall / Rigid Frames	Concrete Shear Walls + Steel Rigid Frames	60	Effectively resists lateral loads by producing shear wall – frame interacting system.	Interior planning limitations due to shear walls.
		Concrete Shear Walls + Concrete Frames	75	"	"
Outrigger Structures		Shear Cores (Steel Trusses or Concrete Shear Walls) + Outriggers (Steel Trusses or Concrete Walls) + (Belt Trusses) + Steel or Concrete Composite (Super) Columns	150	Effectively resists bending by exterior columns connected to outriggers extended from the core	Outrigger structure does not add shear resistance

Data source: (Ali & Moon, 2007)

Most recently, Goncalves and Umakoshi (2010) also supported the 20-story threshold in their book – 'The Environmental Performance of Tall-Buildings.' According to them, 20 stories is the limit when one bank of lifts is no longer sufficient to deal with the vertical distribution of people efficiently and the strategy of high-rise, mid-rise and low-rise banks of lifts needs to be introduced. They further concluded that, considering different areas of building systems, engineering, fire control, and structure and building services, the limit of 20 floors also applied. Goncalves and Umakoshi also set 60 stories as the threshold for supertall buildings because that height "imposes great challenges to all engineering fields involved in the design and operation of tall-buildings."

Please note that there are many theories and definitions of tall-buildings available. This 20-story threshold is chosen because it is most suitable for TPSI only; it is not an attempt to set a new definition that can be applied everywhere. The number of floors should include the ground floor level and be the number of main floors above ground, including any significant mezzanine floors and major mechanical plant floors. Mechanical mezzanines should not be included if they have a significantly smaller floor area than the major floors below. Similarly, mechanical penthouses or plant rooms protruding above the general roof area should not be counted.

6.2.2. Measuring the Height of Tall-buildings

Generally, a tall-building's height is recognised in three categories:

a. **Height to Architectural Top:** Height is measured from the level[25] of the lowest, significant,[26] open-air,[27] pedestrian[28] entrance to the architectural top of the building, including spires, but not including antennae, signage, flagpoles or

[25] **Level:** finished floor level at threshold of the lowest entrance door.

[26] **Significant:** the entrance should be predominantly above existing or pre-existing grade and permit access to one or more primary uses in the building via elevators, as opposed to ground floor retail or other uses which solely relate/connect to the immediately adjacent external environment. Thus entrances via below-grade sunken plazas or similar are not generally recognised. Also note that access to car park and/or ancillary/support areas are not considered significant entrances.

[27] **Open air:** the entrance must be located directly off of an external space at that level that is open to air.

[28] **Pedestrian:** refers to common building users or occupants and is intended to exclude service, ancillary, or similar areas.

other functional-technical equipment.[29] This measurement is the most widely utilised.

b. **Highest Occupied Floor:** Height is measured from the level of the lowest, significant, open-air, pedestrian entrance to the highest occupied[30] floor within the building.

c. **Height to Tip:** Height is measured from the level of the lowest, significant, open-air, pedestrian entrance to the highest point of the building, irrespective of material or function of the highest element (i.e., including antennae, flagpoles, signage and other functional - technical equipment).

6.3. DEVELOPMENT BASES/MODELS

Mainly, TPSI's assessment criteria and methodology were developed based on the advantages of the following rating systems (see Chapter 5 for more information):

- BREEAM;
- LEED;
- CASBEE;
- Green Star;
- HK-BEAM.

It is necessary to restate that TPSI is a genuine rating systems, it is not just a modification of the above 5 tools or any other rating systems. All rating systems listed in this thesis are just reference sources. As established during the Screening Analysis Process, these five systems are among the best ones that are being used to assess high-rise projects worldwide (see Section 4.6). However there are still gaps that can be improved to achieve better assessments of tall-buildings (see Section 5.4.2 and Section 5.4.3) – which are described in the followed sections.

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[29] **Functional-technical equipment:** this is intended to recognise that functional-technical equipment is subject to removal/addition/change as per prevalent technologies, as is often seen in tall-buildings (e.g., antennae, signage, wind turbines, etc. are periodically added, shortened, lengthened, removed and/or replaced).

[30] **Highest occupied floor:** this is intended to recognise conditioned space which is designed to be safely and legally occupied by residents, workers or other building users on a consistent basis. It does not include service or mechanical areas that experience occasional maintenance access, etc.

6.4. KEY COMPONENTS OF AN ENVIRONMENTAL ASSESSMENT SYSTEM

Figure 6.2 shows the key features that are either implicit or explicit in all existing building environmental assessment methods.

- The primary component is the 'Assessment' module in which performance scores are assigned to the various environmental criteria being scrutinised within the assessment process. The scope and structure of this module tends to form the major part of the development of the new rating system.
- A considerable amount of information about the case-study building and its context is required to conduct an assessment. These are represented in Figure 6.5 by the 'Input' module. Although the 'Input' module serves the 'Assessment' module, the practicalities of data collection ultimately dictate the number and type of environmental criteria evaluated during an assessment.
- The results of an assessment must be summarised and communicated. Weighting is the mechanism by which a very large number of performance criteria are reduced to a smaller and more manageable number and is a critical part of the 'Output' module. The output forms the basis for interpreting the assessment results and should logically dictate the structuring of both the assessment and input modules.
- An output profile is not particularly valuable in and of itself. It must be accompanied by an explanation of the reasons why the overall score is what it is. This links back to the information contained in the input module and through it back to strategic decisions in the building design or management.

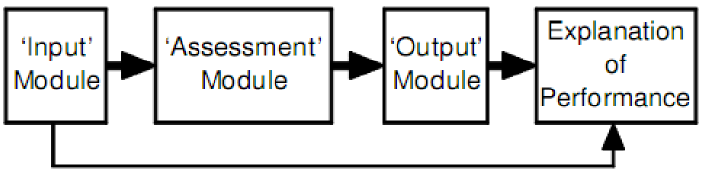


Figure 6.2: Key components of assessment methods

Firstly, on one hand it is important to distinguish these modules within a rating system so users do not 'get lost' during an assessment. On the other hand it is also necessary to allow users to 'switch' quickly between modules to increase the flexibility of use. Without this flexibility the system cannot be used as a managing tool but simply a kind of checklist instead. The distinction between these three modules is not clear in existing systems. In LEED and HK-BEAM, for example, it is difficult to tell when the inputting stage ends and the assessment stage begins. This is partly because they rely only on the use of manuals/booklets. Systems that incorporate the use of software such as GreenStar and BREEAM usually offer better navigation between assessment stages. This issue will be address in TPSI by the introduction of the TPSI Calculator alongside the Manual. The assessment stages/modules are clearly divided into tabs (see Figure 7.8) and users can freely manoeuvre between criteria – and get instant results. The use of TPSI Calculator also allows endless loops of data inputting but at the same time users can stop anytime and still get all result presentations, which is ideal for a managing tool (see Section 7.8 for more details).

Secondly, the output module is currently a relatively poorly understood aspect of assessment frameworks. This indicates the fact that environmentally responsible building design practice is still in its infancy, especially in the scope of tall-buildings assessment. By moving into relatively unexplored areas, the uncertainties are also reflected in the current definitions of the goals and intentions of building environmental assessment methods. Tools such as BREEAM, GreenStar, HK-BEAM and LEED offer only a rating as the final outcome after an excruciating evaluating process. This makes them only 'labelling' tools that are of little use during early stages of a project. TPSI criteria are divided into two broad groups, which are then divided further into eight main categories. These categories consist of smaller topics/subcategories (see Section 7.6.1). This allows TPSI's output module to utilise the criteria structure to provide different forms of result presentations such as charts, graphs, TPSI Factor, issues summaries (see Section 6.16 and Section 7.8.6). This increases the usability of assessment results when communicating between involved parties and improving the project performance, which in turn makes TPSI useful not only as a classification tool but also a managing tool.

6.5. 'GREEN' OR 'SUSTAINABLE' ASSESSMENT?

As established in Section 5.4.2, the confusion between 'Green' and 'Sustainable' practice is one of the major gaps in existing rating systems. The definition of 'Green' and 'Sustainable' needs to be clearly understood and carefully deliberated when developing the new rating system.

6.5.1. Green Building Practice

Existing building environmental assessment methods attempt to measure improvements in the environmental performance of buildings relative to current typical practice or requirements. Similarly, design guidelines are typically structured to offer direction on how to improve upon current design practices and *only implicitly acknowledge sustainability as a goal.* The assumption is that by continually improving the environmental performance of individual buildings, the combined reduction in resource use and ecological loadings by the building industry will be sufficient to fully address the environmental agenda (Cole, 1999). The notion of 'green' permits is useful in the context of building assessment in that it can be extended to distinguish and discuss varying 'shades' of green (i.e. the level of green):

- A 'deep green' building may, for example, refer to one designed from the outset to maximise the use of solar energy, day lighting and natural ventilation, as well as harvest rainwater, treat any wastes on-site and use environmentally sound materials in the most efficient way.
- 'Light green,' by contrast, may refer to buildings that have incorporated one or more green features such as high-efficiency windows, high recycled-content carpets or automatic shut-off systems for lights but are otherwise fairly conventional.

Assessment implies measuring how well or poorly a building is performing, or is likely to perform, against a declared set of criteria. Figure 6.3 illustrates the defining characteristics of a 'Green' assessment. Regarding to the definition of 'green' above, the main characteristics of a 'green' building assessment methods can be consequently identified (Cole, 1999):

a. Assessments are made relative to 'typical' practice *without having to define an ultimate goal.*

b. To define an assessment scale and assign scores to the performance; it is necessary to declare a certain 'target' performance level. This is a demanding performance that can be progressively increased as 'green' design develops.

c. Since 'green' assessment methods are invariably used as a method for encouraging building owners and designers to aim for higher building environmental performance, the range of issues is considerably *larger than that necessary to assess whether it is sustainable*.

d. Given their role of encouraging higher levels of environmental performance, 'green' assessment methods place a higher premium on comparing the performance at a regional and local scale where building owners and developers can demonstrate a marketing 'edge' over their competition. 'Green' assessments place *less emphasis of international comparability*.

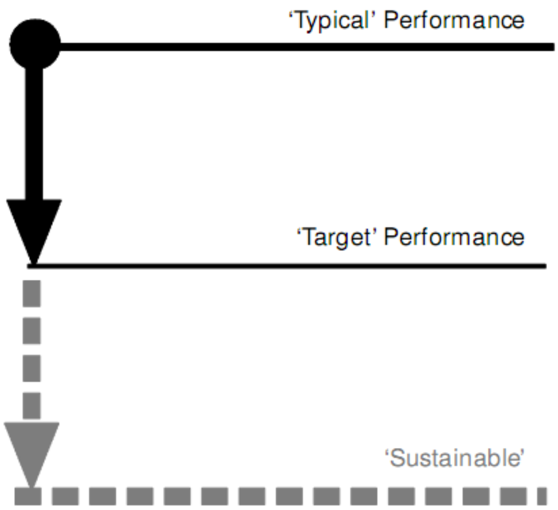


Figure 6.3: 'Green' model of assessment methods

Most of existing 'green' environmental assessment methods are voluntary in their application and have the primary objective of stimulating market demand for buildings with improved environmental performance. An underlying premise of voluntary assessments is that if the market is provided with improved information and mechanisms, a progressive client group can and will provide leadership in environmental responsibility and others will follow to remain competitiveness. Voluntary assessment protocols must meet two conflicting requirements:

- They must function as an objective and sufficiently demanding measurement to have credibility within the environmental community;
- At the same time, they also have to be attractive to building owners who wish to have something positive to show for any effort that they have placed on environmental performance.

Satisfying these two requirements often leads to compromising both the number of criteria that are assessed and where the benchmarks are set before performance points are earned (Cole, 1998). The acceptance of existing assessment methods currently derives largely from their voluntary application. Given the practical (and incentive) constraints on setting demand targets and dependency on market acceptance, it is uncertain whether this mechanism will be sufficient to create the necessary improvements in environmental performance of buildings needed to meet broader national environmental or sustainability targets. *In other words, applying 'green' assessment mechanism for TPSI could lead to the uncertainty of reference for the development of assessment criteria system.*

6.5.2. Sustainable Building Practice

Sustainability has emerged as a principal concept for the environmental discourse and must therefore give direction to the structure and application of environmental assessment methods. Sustainability has environmental, social and economic dimensions, embraces all aspects of human activities (e.g. industry, transportation, food production, etc.), and spans local actions through to equalising the major imbalances that exist between developed and developing nations. Given the political and economic interdependencies wherein the actions of one nation affect others, the concept of 'sustainability' probably only makes sense when applied at a global scale (Cole & Michell, 1999) (see Figure 6.4).

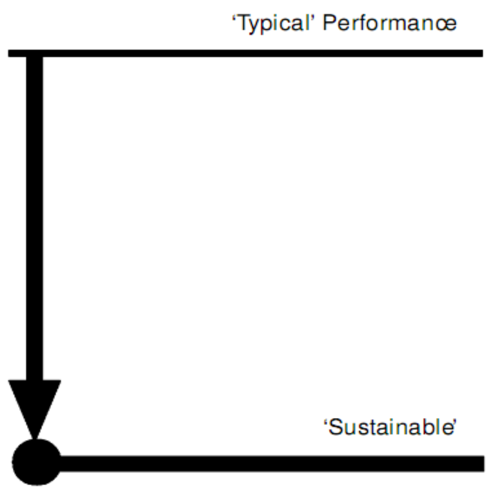


Figure 6.4: 'Sustainable' model of assessment methods

Irrespective of the social and economic context, the health of the biosphere is the limiting factor for sustainability. The persistent growth in the demand of energy and material is critical. As Rees (1999) argued: *"empirical evidence suggests that resource consumption already exceeds the productive capacity of critical biophysical systems on every continent."* He further suggested: *"Waste production already breaches the assimilative capacity of many ecosystems at every scale."* Since the management of local, regional and global mass and energy flows is of fundamental importance, physical indicators describing these flows must logically dictate the emphasis of any methodology attempting to assess a sustainable approach to human settlement and building (Cole, 1999).

Kohler (1999) criticised common major existing assessment methods (e.g. GBTool, BREEAM, and LEED) based on relative performance as both hiding *"the real mass and energy flows which determine the effective environmental impact"* and the *"differences in impact between individuals and different countries."* Cooper (1999) concentrated on this limitation and suggested that unless methods for assessing the built environment are capable of measuring performance against carrying capacity criteria, *"their ability to contribute to the sustainability debate is likely to remain limited."* Figure 6.7 illustrates the role that an environmental assessment method would have within the context of sustainability. The two defining points on the assessment scale would now be 'typical' practice and 'sustainable' practice. Assessments would be made of the extent of the progress that the building performance has made towards a declared, ecologically 'sustainable' condition. Cole (1999) had identified the following aspects of sustainable assessment:

a. It is possible to define sustainability goals at a global scale in terms of the relationship between resource use, assimilative capabilities of the biosphere, carbon sinks, although in general terms. The use of 'sustainable' targets such as zero fossil fuel use, zero greenhouse gas emissions, zero potable water use and zero sanitary waste entering municipal systems, should be promoted. In other words, assessment would be directed at identifying reductions in absolute resource use and ecological loadings by buildings, which are the true indication of a positive move towards ecological sustainability. Methods are emerging that set aggregate human resource use and ecological loadings against the limited productive and assimilative limits of the biosphere, which can be incorporated into TPSI criteria. Main examples of this strategy include (see Volume II):

- Issue 'RC1. Land Use and Reuse': introduction of 'ecological foot-printing' into the assessment, which estimates the area of productive ecosystems of which biophysical output is appropriated for the exclusive use of a certain human population. It is instructive in illustrating the immense gap between urban and non-urban areas, between developed and developing countries. It also reveals differences between different forms of buildings especially high-rise projects (Rees, 1999).
- Issue 'MA1. Material Specification': introduction of the 'Green Guide Rating' to assess the selection of materials. Other issues under Section E2.1 also utilise methods to quantify the use of certified wood, rapidly renewable materials, recycled materials, reused materials and regional material into absolute figures.
- Issue 'EL7. Refrigerant use and Leakage': introduce the use of Global Warming Potential (GWP) and Ozone Depleting Potential (ODP) into the assessment.
- Issue 'EL8. NO_X Emissions': credits awarded based on absolute NO_X emissions levels.
- Issue 'EL15. Mitigation of Ecological Impact': adopting a BRE's method to calculate the change in ecological value.

b. Sustainable assessments require an *extensive understanding and quantification of the complex links between building decisions and ecological loadings* - an objective that is currently ignored by existing systems such as BREEAM and LEED. The more efforts are put into enhancing the building performance (for a simple example, the installation of a high-speed elevator within a tall-building), the more likely it can have negative effects on the environment (in this case use more energy). How to understand this mutual connection, and moreover how to quantify this balance into an actual term, are big questions toward achieving overall sustainability. Of all the systems that had been reviewed in Part A of the research, only CASBEE tries to consider this matter thoroughly with the invention of the *BEE indicator* (see Section 5.2.3). TPSI pursues this idea by introducing the TPSI Factor (see Section 6.15.3 and Section 7.7.2).

c. Sustainability goals necessarily depend on the actions of others. Sustainability goals for tall-buildings can only be meaningfully defined if assumptions about global or regionally averaged sustainable rates of activity are made. For example, a two-fold increase in height, thus human population, changes the necessary reduction in resource use and ecological loadings by a factor of two. Given the uncertainties and time dependent nature of these assumptions, sustainability goals must be set within declared scenarios. TPSI deals with this issue by introducing a dynamic weighting system and allowing countries and organisations that adopt TPSI system to alter weighting factors of assessment criteria categories (see Section 7.8.4). This helps reflecting better the regional scenarios without modifying the assessment criteria. TPSI also special issues in order to adapt better with different scenarios and project types, which include issues that can be scoped-out (see Section 7.6.3) and issues that can be achieved by default (see Section 7.6.4).

d. The number of criteria required to evaluate the performance a building in general and a tall-building in particular can be relatively few if the performance indicators are carefully selected. For example, Lowe (1996) argues that many aspects of sustainability are linked to carbon emissions. Therefore, strategies to reduce carbon emissions to a sustainable level would carry a lot of other improvements that would not have to be independently assessed. This would be a good strategy to simplify the data inputting and assessment process. However, overdoing this strategy also means neglecting many design features. Typical examples of this approach are BREEAM and LEED. TPSI implements this strategy (which can be seen in Issue RC10 and Section E1.2 – Volume II) but at the same time also introduce many design-oriented issues (see Section 6.7 and Section 'B4. Design Feature' – Volume II).

e. Physical indicators of sustainability would be normalised by some measure of the total sustainable level of activity described by that indicator. Satisfying the human principle of equity would suggest that denominators represent globally equitable shares of the total sustainable level, e.g., using per capita share of the total carbon sink capacity to normalise carbon emissions (Cole, 1999). Typical examples of this strategy include (see Volume II):

- Issue 'IEQ16. Natural Lighting and Glare Control': using percentage of well-lit floor area to assess natural lighting quality.
- Issue 'IEQ21. View Out': using percentage of the inside wall area to assess view out adequacy.
- Issue 'IEQ26. Private Open Space' and 'IEQ27. Visual Privacy: using percentage of dwelling units as evaluation factor.
- Issue 'DF2. Provision of Space': using area/person or area/bed as evaluation factor.
- Issue 'DF5. Spatial Margin' and 'DF6. Floor Load Margin': using floor-to-floor height, wall length/area ratio and floor load capacity as evaluation factors.
- Issue 'SE3. Maximum Parking Capacity': using number of car park for every four user as evaluation factor.

f. Assessment methods set within the context of sustainability offer the powerful advantage of international comparability. Lowe (1998) points out that office buildings that consume less than 100 kWh/m^2/year or emit less than 30 kg CO_2/m^2/year would be exemplary anywhere. Moreover, he suggests that if, for example, the reason why buildings perform better in Denmark than equivalent buildings in other countries is due to efficient district heating systems, this offers important direction at the energy systems and urban design levels. This kind of standards was thoroughly established by BREEAM and LEED and has been widely acknowledged worldwide. It could be used effectively in TPSI with only some minor modifications. Examples include Issues MA1, IEQ3, EL14, and EL15 (see Volume II).

6.5.3. Reconciling 'Green' and 'Sustainable' Assessment in one single Tool

Although the distinction between 'Green' and 'Sustainable' is essential to help clarify the various roles of building environmental assessment methods, the considerable practical overlap between the two agendas suggests that they can be reconciled within a single tool. Cole (1998) showed conceptually how this might be possible, and illustrated that the problem is primarily one of partitioning of the performance issues while simultaneously clarifying and making explicit links between them (see Figure 6.5). The key point here is the mixture of quantitative and qualitative measures (see Section 6.10).

This method had been used in the Green Building Process and had been proved efficient. This method can be adopted when developing TPSI. TPSI will consist of 'Core' criteria that are fixed (i.e. 'sustainable' issues that can be found in Sections B1, E1, E2, E3 – see Volume II) and 'Secondary' criteria that are flexible (i.e. 'green' issues that can be found in Sections B1, B3, B4, E4 – see Volume II). In both 'green' and 'sustainable' assessments, all performance measures would ideally be 'actual' performance values rather than predicted. Although the issue here is primarily one of the practicalities of data collection and quality, the use of actual performance values is more critical in assessing progress toward sustainability. Todd (1998) suggests that providing qualitative and quantitative assessment scales for many of the green criteria would enable alternative types of judgements to be made, particularly where the data for the more desirable quantitative assessment is either not available of prohibitively expensive to acquire.

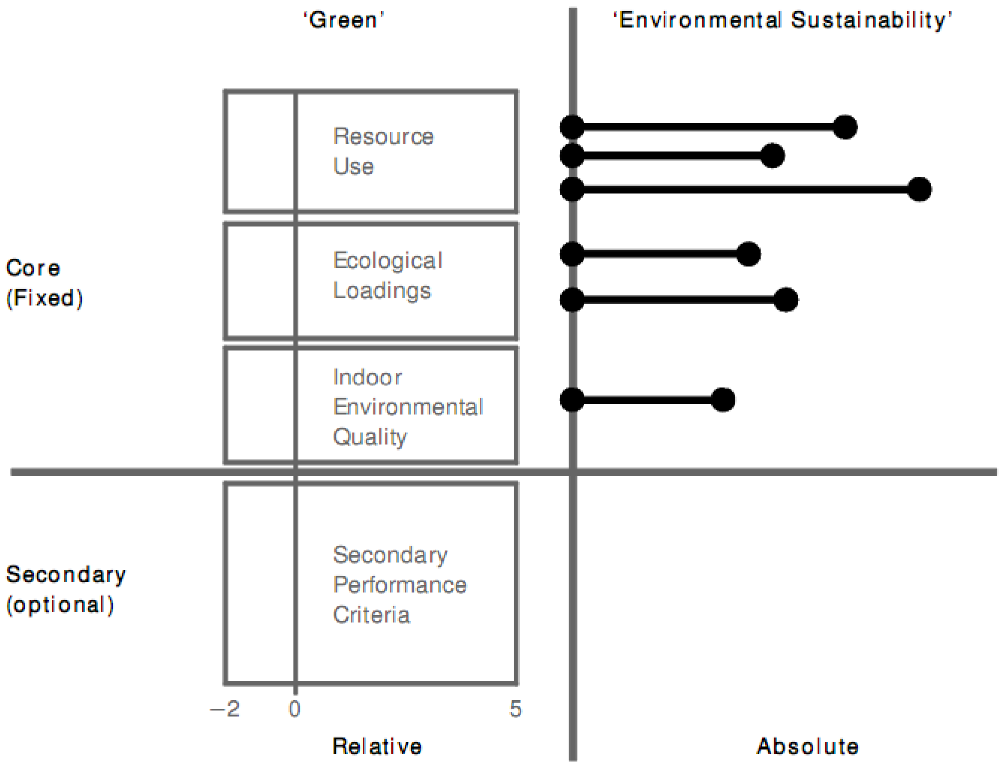


Figure 6.5: Reconciling 'Green' and 'Sustainable' agendas in environmental assessment

Data source: (Cole, 1999)

6.6. 'POTENTIAL' AND 'ACTUAL' PERFORMANCE

There is sufficient evidence to show that a building's performance in use is often markedly different from that anticipated or predicted during design. Therefore, an important decision in developing assessment methods lies in the choice to evaluate the 'potential' or 'actual' building performance.

- The obvious advantage for assessing the actual performance of the building in-use is that it captures what resources are consumed, what ecological loadings are generated and the actual indoor environmental qualities, and occupant responses to them.
- Beyond external factors such as specific weather conditions during a specific time period, actual performance depends on the behaviour of occupants, tenants and actions of building operators. This brings into play many idiosyncratic operational factors that may not be generally applicable to other buildings.
- The assessment of potential performance is based on assuming normal or default patterns of occupant behaviour and building operation, making it easier to distinguish between improvements in the physical features of buildings and improved efficiencies in their use and operation.

Real performance data is clearly of significance within the sustainability agenda where the primary objective is to assess the absolute impact of buildings. It is also of considerable importance in providing experience and feedback to the design community as to what does and does not work in practice - a critical concern in a rapidly evolving field (Wilson & Cromton, 2001). On the other hand, although potential performance is less 'real,' it can still produce useful information to guide the future actions of developers, owners, designers and anyone else who is involved with the production of buildings, even refurbishments. In recognition of the current mismatch between anticipated and actual building performance, there is an obvious need to recognise the relationship between strategic design and the ease with which a building can be managed and operated, i.e. making the design of the building management and operational systems part of the building design and procurement process (Bordass & Leaman, 1997). Most importantly, all the above reasons don't suggest that a rating system has to compromise the strictness of its standard to become more like a potential performance tool.

Tools such as BREEAM, LEED and CASBEE concentrate too much in establishing real performance data and neglecting the potential performance requirements that can have major long-term benefits. TPSI fills this gap by introducing many issues that assess the project management aspects (see Section 'B1. Project Management' – Volume II), including:

- Section 'B1.1. Overall Management': encouraging the implementation of environmental management system and mechanisms throughout the project.
- Section 'B1.2. Design Process': encouraging the incorporation of sustainable aspects in the design process in a holistic manner.
- Section 'B1.3. Construction Issues': encouraging the incorporation of the best construction methods and technologies, as well as the management of construction site impacts.
- Section 'B1.4. Contractual and Commission Process': encouraging the awareness of sustainable issues of all engaged parties. Ensuring the building service commissioning is carried out in a co-ordinated and comprehensive manner, thus ensuring optimum performance under actual occupancy conditions.
- Section 'B1.5. Operation': encouraging the sustainable operation of the building and the provision of guidance for occupants so they can operate the building efficiently.
- Section 'B1.6. Demolition': encouraging the consideration of sustainable aspects of demolition activities right from the early stages.

6.7. 'ASSESSMENT' OR 'DESIGN' TOOL?

As established in Section 5.4.3, one of the visions for TPSI is that it can be used not only as an 'assessment tool' to evaluate a completed tall-building design, but also as a 'design tool' or 'managing tool' – i.e. useful throughout earlier stages of a project. The question emerges as to whether a single tool can function equally effectively as an assessment and design tool? If yes, what compromises would be necessary to an assessment tool to enable it to be useful in design? The answers lie in the structure of the assessment framework and with the skill and enterprise of the users.

According to Cole (1999), selected criteria within assessment methods are currently being adopted as part of broader sets of design guidelines and specifications, and are gradually spreading throughout the design community in this form. However, since environmental assessment methods present an organised set of selected environmental criteria, by default, they communicate to building owners and design teams what are understood as being the most significant environmental considerations. As such existing assessment methods are used as design tools, even though they were not specifically designed to do so.

Also according to Cole (1999), a considerable amount of building design-relevant information has emerged on a broad range of environmental issues, far more than what are currently incorporated in existing assessment methods such as BREEAM and LEED. A tool designed to provide guidance on design would therefore require more detailed information than one intended for assessments but, by necessity, must still be practical in its application. Given the arguments of potential versus actual performance, the availability of information and the importance of regionally appropriate strategies, design tools logically relate more easily to methods that assess 'green' performance than 'sustainability.' Design tools for environmental assessment must:

- Be based on information that is accessible during design.
- Identify critical environmental issues and provide guidance on a range of possible design strategies to address those issues.
- Quickly assess the relative environmental benefits gained by using a particular strategy or set of strategies early in design development and compare alternative schemes, i.e., facilitate early scoring or preliminary scoring to facilitate timely decisions by the design team and clients.
- For more advanced features: permit the data needed by the assessment tool to flow seamlessly from the tools the designer uses across the design process, e.g., all the data on building area can be imported automatically from the CAD tool.
- Make links with other design criteria.

The issues that were introduced in TPSI as an effort to make it more useful during design stages include (see Volume II):

- Issues 'IEQ4. Waste Disposal Facilitites,' 'IEQ5. Environmental Tobacco Smoke (ETS) Control,' 'IEQ21. View Out,' 'IEQ26. Private Open Space,' and 'IEQ27. Visual Privacy': using actual design recommendations/specifications/ requirements to ensure the sufficiency of indoor environmental aspects.
- Category 'B4. Design Features': a category dedicated to design aspects of tall-buildings such as energy sufficiency, functionality and usability, flexibility and adaptability
- Issue 'EL3. Waste Recycle Facilities' and 'SE2. Pedestrian and Cyclist': using design specifications to judge the sufficiency of waste recycle facilities and pedestrian and cyclist facilities.

6.8. SOME IMPORTANT ASPECTS OF TALL-BUILDING SUSTAINABILITY

This section summarises some key aspects of tall-building sustainability, which are among the foundations to develop more tall-building oriented assessment criteria. See Section 6.9 for a list of TPSI's tall-building specialised criteria.

6.8.1. Location, Location, Location…

Location is the first and foremost factor that contributes to tall-buildings' sustainability. The impact of high-rise project location to sustainability has at least three components (Pank, Girardet, & Cox, 2002):

- The impact of location on economic issues (i.e. availability of land, alternative accommodation and labour, costs of land, building costs, cost of energy supplies, quality of neighbouring developments and desirability, and future flexibility).
- The impact of location on environmental issues (i.e. quality of land, biodiversity, transport links for construction workers, materials, building occupants and visitors, congestion, air quality, energy requirements, and opportunities for energy sourcing).
- The impact of location on social issues (i.e. health and safety, quality of indoor environment, degree of control over the indoor environment, impact on neighbours, and impact on the community).

6.8.2. Economic Aspects

Economic considerations are vital with any form of development. For example, the UK Government sees sustainable development as a key to sustained economic growth and therefore will view any new tall-building against the backdrop of economic success. Tall-buildings or the opportunity to develop can attract employers and develop economies. One of the main drivers for local authorities in the UK to construct new tall-buildings is to generate a sustainable community (Wilson & Cromton, 2001).

So the first issue is the economic viability of the project. A tall-building that cannot be let may be demolished, irrespective of the design life, undermining considerations to reduce its energy in use, etc. Certain building types are more lettable than others, and for a given site only certain forms of building are viable. On the other hand, developing in an 'undesirable' area, and contributing to its regeneration, can be a major contribution to sustainability. Another consideration is *"Is the market really ready for sustainable/green tall-buildings?"* or would such a building limit the potential market, as it would be considered too risky by many? Building designers may be constrained by market forces more than by technological issues.

City centre developments in general are taller than those in a rural environment mainly due to the cost of the land (TPSI gives lower weighting for land-used issues for tall-buildings in rural areas than in city centres). A brownfield site is likely to be more costly to develop, but there may be substantial cost savings (see Issue RC1 – Volume II) in terms of the existing provision of public transport (see Issue SE1 – Volume II), and no need to provide parking for occupants and visitors (see Issue SE3 – Volume II). On the other hand, there may be constraints on the construction process itself in terms of hours of access and working, congestion, and the ability to operate just-in-time materials delivery (Wilson & Cromton, 2001). The location of a building will also determine the cost of materials, both in terms of elemental costs and total building costs (see Issue MA4 –Volume II). Where the tall-building is situated can also be a significant factor in the ability to attract and retain a workforce, both in terms of ease of access and the desirability of the area (see Issue SE9 – Volume II).

Some types of development may be regarded as more sustainable than others. The benefits of converting existing tall-buildings rather than demolishing and rebuilding them in terms of reduced materials use and waste (see Issue MA6 – Volume II) will need to be balanced against the opportunities for designing a new building with low energy requirements, and which can utilise renewable energy. Densities often have to be reduced with new developments, increasing the land take and impacting on the economics (Wilson & Cromton, 2001). Tall-buildings' sustainability can also be improved through maximising the utilisation of the building. This can be through long hours of operation, or the provision of services, which can be shared with others (in the same building, in the same company or in the local community); e.g. sports, conference and canteen facilities (see Issue SE5 – Volume II).

6.8.3. Social and Ethical Issues

Sustainable Communities

The sustainable community is at the heart of the strategy on sustainable development, and sustainability has an unavoidable ethical dimension, especially with high-rise projects (see Section 'E4.1. Social Aspects' – Volume II). During any tall-building procurement process, the social needs of the building's neighbours will be high on the agenda, even if this is just a means to an end in getting planning permission. What can the local community gain from the creation of a new building? Any high-rise development provides an opportunity to provide facilities for the surrounding community, and it can be an opportunity to employ and, if necessary, train the local workforce, to contribute both in the construction phase, and in delivering the building's primary work function. There are also opportunities for engagement with the local community – from school children painting hoardings, to educational trips and work placement opportunities. What specifically can high-rise buildings contribute? For those working in and visiting them, there can be the advantages of a prime location in terms of establishing a centre of excellence, transport links, and amenity. There is also the opportunity to sustain in-house catering, banking and sporting facilities as a result of the number of people in one building.

Health and Well-being

During the construction phase, a high-rise building may take longer, increasing the disturbance to neighbours (see Issue PM7 – Volume II). A number of health and safety issues can also be raised, relevant both to occupants and visitors, and to neighbours. The majority of construction accidents occur as a result of falls both from a building and onto someone (see Issue PM8 – Volume II). Clearly there is a bigger risk of this associated with building taller buildings (Wilson & Cromton, 2001). There are also issues associated with means of escape following the threat of or actual fire, earthquake, act of terrorism or extreme weather condition. Not only is it an issue of the height of the building, but also the number of people in one place at one time. Perception of risk, even if misplaced, can be a significant factor impacting on well-being (see Issue BS10 – Volume II). Following the 2001 terrorist incidents in New York and other attacks on tall-buildings, their vulnerability to this sort of attack has been highlighted. As a result, workers and visitors may feel unsafe in high-rise buildings, which is a new issue for designers to face. Insurance premiums may also reflect this, another factor to be taken into consideration when determining the economic viability.

Positive aspects relating to a sense of well-being associated with all building types are the availability of daylight, connection with the outside World, and the view. The ability to control the immediate environment also improves overall satisfaction. In high-rise buildings, whilst there may be advantages in terms of day lighting and views out (see Issues IEQ16 and IEQ20 – Volume II), openable windows may not be possible on safety grounds or due to wind effects.

6.8.4. Land-use, Ecology and Pollution

A city centre site is often a brownfield site and therefore regarded as more sustainable than using a greenfield site. One of the main drivers for tall-buildings is to minimise the use of land. If a city centre developer wants to minimise the impact on land use, the only way to expand is upwards. There is a generally held view that if a site is a brownfield site, developing it will improve it, whereas developing a greenfield site will be detrimental however sympathetic the development is to the surrounding landscape. Nevertheless, if there are good commercial reasons for developing on greenfield sites, the important issue is to capitalise on the advantages provided. These include the opportunity to build mixed-use developments of housing and business parks, better prospects for use of renewable energy and day lighting, opportunities for rainwater collection and on-site reed beds for water filtration, and planting to encourage indigenous species.

Tall-buildings in an urban context can suffer from more problems with over shading and rights to light, can cause or be the cause of glare, and can create wind tunnels. However it should be possible to overcome all of these issues through good design. Pollution can be thought of in terms of emissions to air, land and water. The most significant emission to air is CO_2 and NO_X. Emissions to land are mostly solid waste materials. Regarding water pollution, this is most likely to occur during the construction stage as a result of spills and water run-off. Good practice can overcome this for any building form. Action can also be taken at large areas of car parking to ensure that there surface is permeable and so reduce incidence of flooding; and at larger sites, water can be treated on-site (Cole & Larsson, 1998) (see Section E3.2 – Volume II).

6.8.5. Energy Aspects

Energy Demand

Energy demand is not the major issue within a tall-building; it is how this energy has been generated. The major driver is to reducing greenhouse gas emissions and in the short term any reduction in building energy demand contributes to this aim (see Issue RC10 – Volume II). Hours of occupation impact on the suitability of different HVAC strategies, so that Combined Heat and Power (CHP) may be well suited for a 24-hour operation building, but such occupancy may prohibit natural ventilation with nighttime purging. Indeed, natural ventilation of offices will be harder to achieve in the taller high-rise buildings, due to increased wind speeds and noise associated with openable windows at height. The need to install lifts in tall-buildings will increase energy demands, but the day lighting potential is better than in low-rise deep plan buildings. There are always trade-offs between different environmental considerations associated with supplying the energy used within a building, but low energy use is a fundamental key to sustainable development.

Energy Sources

All buildings in the modern World use energy, and modern culture emphasises the electronic age. The architectural, engineering and construction industries are also advocating e-construction. The Movement for Innovation (i.e. M4I – see Appendix A.20) have many demonstration projects looking at rethinking the construction process, and the use of electronics to aid information flows would advocate that more and more buildings require electrical energy. If a building is then to be truly sustainable that energy should be generated on site tapping into natural energy sources (see Issue RC12 – Volume II). The key to having a net zero CO_2 building is the ability to create energy on site. This is influenced by the geographical location, as well as specific site constraints. For example, if a solar array were to be placed on a building in London this would only generate half the energy of the same collector area situated in Southern California. However, even in the UK, there is still great potential to capture the massive solar resource with vertically mounted building integrated photovoltaic devices.

Certain locations will be able to benefit from wave energy, and a coastal scheme in the UK could easily generate four times the energy of a similar scheme off the coast of equatorial Africa. There is believed to be over 5000 times more energy in wave and tidal energy than we currently use in the World (Wilson & Cromton, 2001). Tall-buildings are ideally suited to utilise wind resources. Wind turbines can exploit higher wind speeds around tall-buildings or at the top and can be designed for low noise emissions. The published report on 'Wind Energy for the Built Environment' (Campbell & Stankovic, 2001) funded by the European Commission looks at the integration of wind turbines into tall-buildings.

A tall-building can take advantage of renewable energy sources in the same way that a low-rise structure can, but the choice of source might be different. There are likely to be more opportunities to use wind energy in high-rise buildings, and there may be unrestricted solar access depending on the proximity of neighbouring buildings, but there will be less space to install a rooftop solar array. Bill Dunster's Flower Tower prototype Eco-functional tower block incorporates a vertical-axis wind turbine and this combined with photovoltaic panels installed on the roof and the wall elements make the building largely self-sufficient in energy (Townsville SOE, 2011). The Mayor's energy strategy for London (Greater London Authority, 2004) has targets to help meet the UK nationwide target of 10% renewable energy obligation and looks at achieving a 20% level by 2020. Domestic hot water can easily be generated from rooftop mounted solar plate exchangers or evacuated tube solar thermal collectors. Alternatively, with either built form, 'green energy' can be purchased, leading to no or low emissions from electricity consumption.

Operational and Embodied Energy

Many of the low energy buildings use thermal mass and natural ventilation solutions to produce low operational energy. However with very low operational; energy buildings, their embodied energy is a much more significant part of the total. It can be argued that in cooler climates mechanical ventilation systems can be more economic than naturally ventilated solutions due to the ability to recover heat from the exhaust air to preheat the fresh air. The local climate of a development really determines the type of solution that is required, and more and more people now talk about the holistic approach within the sustainable development debate. The software package from the BRE called Envest (see Appendix A.9) has 'Ecopoints' to help benchmark the environmental performance of buildings. This is an excellent starting point, and provides the opportunity to evaluate different built forms. With a steel or concrete frame structure Envest will often favour low-rise building forms. Timber constructions will provide the lowest embodied energy and this construction form is not applicable to high-rise buildings. TPSI, however, adopts another baseline building energy performance established by BRE as the prerequisite for its evaluations (see Issue RC-P1 – Volume II).

The most important factor in materials selection has to be functionality. Therefore tall-buildings face more constraints than low-rise developments. Both have the potential to use modular components, reducing time on site, and development costs. Designing to avoid the need for bespoke components should be more efficient, and the use of standard sizes will reduce waste. For low impact materials, distance travelled to site can be a key component of their overall impact (Wilson & Cromton, 2001).

Many man-hours have been spent researching embodied energy within materials, but is this really the best environmental indicator for selection of materials? For instance aluminium requires large amounts of energy to create it, but this energy may be from a totally renewable source i.e. hydro, and the material is inherently recyclable. Another issue is the boundary taken when looking at the emissions. For example of cement, it the factory generates energy on site, are the emissions from producing the cement being compared on the same basis as those from another product, where the electricity is imported and the emissions occur elsewhere? There is a need for an environmental impact indicator that looks at how the material has been created and whether the material ultimately can be easily recycled. Therefore, TPSI abandons the use of embodied energy materials assessment mechanism, but instead concentrate on other aspects such as the selection of certified, renewable, recycle and regional materials, as well as the efficient use of materials in building components (see Category 'E2. Material Aspects' – Volume II).

6.8.6. Waste

Waste management often revolves around the 'three-Rs' notion (or the 'waste hierarchy'): Reduction, Re-use, and Recycling. The use of reclaimed and recycled materials is discussed in details within the joint CIRIA/DETR Publication on this subject (Coventry, Woolveridge & Hillier, 1999). Opportunities exist in buildings for recycling of waste, but space for compactors and waste segregation at ground level may be more restricted in high-rise developments. That's why credits should be given to designs that provide dedicated spaces for compactor/baler installations. Waste management issues are dealt with under Section E.3.1 (see Volume II).

6.9. TALL-BUILDINGS ORIENTED CRITERIA

Two of the most important aspects in developing a sustainability rating tool include: *building up the system of assessment of criteria*; and *developing the assessment method*. As established in Chapter 4, five rating systems were identified as the most suitable ones available to assess tall-buildings' sustainability worldwide. They were the ones that had the highest overall score, namely BREEAM, LEED, CASBEE, HK-BEAM and Green Star (see Table 4.6). TPSI will be developed based on these five systems. However, this does not mean that these five systems have the most appropriate set of criteria for tall-building assessing. For example, CASBEE's overall score was among top five (70.5/100) but it only had 10.5/20 under 'Applicability' criteria. While as some average-ranked systems; such as CEEQUAL, Green Globes, NABERS and SBTool/GBTool; had quite high 'Applicability' scores (13/20, 14/20, 14/20 and 14/20, respectively) (see Table 4.5 and Table 4.6, Section 4.6). TPSI's assessment criteria system, therefore, should be developed based on those systems that scored the highest under 'Applicability' criteria instead of overall score.

Considering the lacking in existing rating systems' assessment criteria and various tall-buildings' sustainable features, the following main aspects will be specially considered and incorporated in the TPSI System (see Table 6.2):

Table 6.2: List of TPSI's tall-building oriented Issues

Areas	Issues
Project Management	- 'PM3. Site Investigation': introducing extra requirements of the study of site conditions for high-rise construction and reactions to potential issues. - 'PM6. Choice of Construction Process': encouraging the incorporation of best high-rise construction methods and technologies. - 'PM8. Construction Safety': ensuring the implementation of best practice in term of high-rise construction safety. - 'PM10. Commissioning': introducing extra requirements of the commission process of tall-building special services. - Issue 'PM13. Demolition Management Plan': encouraging the early consideration of issues related to the tall-building demolition process.
Indoor Environmental Quality	- Issue 'IEQ6. Construction IAQ Management': introducing extra requirements of indoor air quality during construction such as flush-out process of HVAC system. - Section 'B2.5. Ventilation': introducing extra requirements of ventilation quality such as the natural ventilation of residential units, controlled ventilation for different areas within a tall-building. - Issue 'IEQ16. Natural Lighting and Glare Control': dealing with lighting and glare issues associated with tall-buildings. - Issue 'IEQ21. View Out': encouraging the provision of adequate view for all units within a tall-building.
Building Services	- Issue 'BS7. Service Life of Building Components': encouraging the consideration of building components' service life such as the structural frame, HVAC and vertical transportation systems. - Issue 'BS9. Security': introducing extra requirements of securities measures and facilities for tall-buildings. - Issue 'BS10. Fire Safety and Evacuation': encouraging the implementation of best practices in respect of tall-buildings fire safety and evacuation. - Section 'B3.4. Vertical Transportation': dealing with various issues regarding the energy-efficiency of vertical transportation systems. - Issue 'BS13. Earthquake Resistance': encouraging the implementation of best practices in respect of earthquake resistance.
Design Features	- Section 'B4.1. Design for Energy Efficient': enhancing the building energy efficiency through environmentally considered planning and design. - Section 'B4.2. Design for Functionality and Usability': dealing with tall-building oriented aspects such as the provision of space, maintenance management of façade and other building components. - Section 'B4.3. Design for Flexibility and Adaptability': dealing with aspects such a spatial flexibility of floor plans, floor-to-floor height allowance, wall length/area ratio, floor load margin, adaptability of building services.
Resources Consumption	- Issue 'RC2. Land Use Efficiency': encouraging the consideration of different land-take schemes.

Material Aspects	- Section 'E2.2. Efficient Use of Materials': introducing tall-building oriented issues such as reuse of existing building façades and structural systems, modular and standardised design, prefabrication, efficient structure design, design for robustness.
Environmental Loadings	- Issues ' EL4. Compactor/Baler': encouraging the provision of a compactor/ baler to a tall-building to reduce aid the waste management process. - Issue 'EL12. Light Pollution': preventing the light pollution caused by building's tallness/size/façade glazing/external light installations. - Issue 'EL13. Overshadowing and Views': ensuring the building's tallness and size cause no concern in respect of preserving daylight and views. - Issue '`EL18. Surrounding Microclimate': ensuring the microclimate around the building suffers no negative impacts such as wind deflection and amplification, and heat islands.
Social and Economic Aspects	- Issue 'SE3. Maximum Car Parking Capacity': discouraging the provision of car park in the basement of tall-buildings, thus promoting the use of public transportations. - Issue 'SE6. Local Character': encouraging tall-building development to carry an increased obligation to return positive benefits to local environment. - Issue 'SE9. Affordability of Rental/Cost Levels': assessing whether rents or costs of residential units in the building will be affordable for the target market. - Issue 'SE11. Mixed-use Development': encouraging the considerations of opportunities for mixed-used development.

6.10. QUALITATIVE AND QUANTITATIVE CRITERIA

A defining characteristic of TPSI is that it will embrace a broader range of performance issues than that found in existing assessment methods. Existing methods temper the range of assessment issues by remaining within the bounds of objective, scientifically acknowledged and verifiable issues. In this sense, they only provide a partial view of environmental performance. However, moving into new areas where the measures of the performance are currently poorly defined requires more qualitative descriptions in the measurement scale. Such scoring techniques can be easily criticised as lacking the objectivity necessary to establish trust in the assessment system:

- Criteria expressed qualitatively are open to wider interpretation by assessors and therefore the assigning of points can vary considerably depending on those making the assessment.
- It requires a great deal of time, energy, and commitment from an unbiased third party to be successful.

Again, a distinction can be made between assessing 'green' and 'sustainable' performance. As stated in Section 5.4.2, assessing sustainable performance - which is largely an issue of energy and mass flows - can and should be described in quantitative terms. On the other hand, the wider range of performance issues necessary within an assessment of ‘green’ performance currently cannot avoid using more qualitative metrics to evaluate a building comprehensively. TPSI’s assessment criteria system will have to be a harmonic combination of quantitative and qualitative criteria. The following solutions can be adopted to reduce the disadvantages of incorporating more qualitative criteria:

- Greater care and precision has to be given to the descriptions of the assessment scales for qualitative criteria to reduce misinterpretation.
- Within the presentation or summarising of performance results, the qualitative criterion scores are kept distinct from the quantitative performance data that is assumed to be more objective, reproducible and therefore more reliable. This would avoid the perception that after a massive effort of data collection and input, the final performance scoring and profile can be potentially ‘skewed’ by a subjective and biased judgment.

Notable qualitative assessment criteria of TPSI include:

- Category ‘B1. Project Management’: Issues PM1, PM2, PM5, PM11, PM12, PM13.
- Category ‘B2. Indoor Environmental Quality (IEQ): Issues IEQ5, IEQ9, IEQ20, IEQ21, IEQ26, IEQ27.
- Category ‘B4. Design Features’: Issues DF1, DF3, DF7.
- Category ‘E1. Resources Consumptions’: Issues RC2, RC13.
- Category ‘E2. Material Aspects’: Issues MA10.
- Category ‘E3. Environmental Loadings’: Issues EL4, EL5, EL6, EL13.
- Category ‘E4. Social and Economic Aspects’: Issues SE1, SE4, SE5, SE6, SE7, SE9, SE11.

6.11. RAISING THE BAR ON SUSTAINABLE PERFORMANCE

Wallace (2010) established that, performance contribution of a project is measured and assessed in three dimensions: Span of participation, span of influence and range of sustainable performance (see Figure 6.6). The first two dimensions reflect the extent to which the project team sought to find new opportunities to improve sustainable performance, opportunities not necessarily within what is considered normal project boundaries. The third dimension - the range of sustainable performance - reflects the extent to which efforts are made to raise the bar on one or more dimensions of sustainable performance while not diminishing overall sustainable performance.

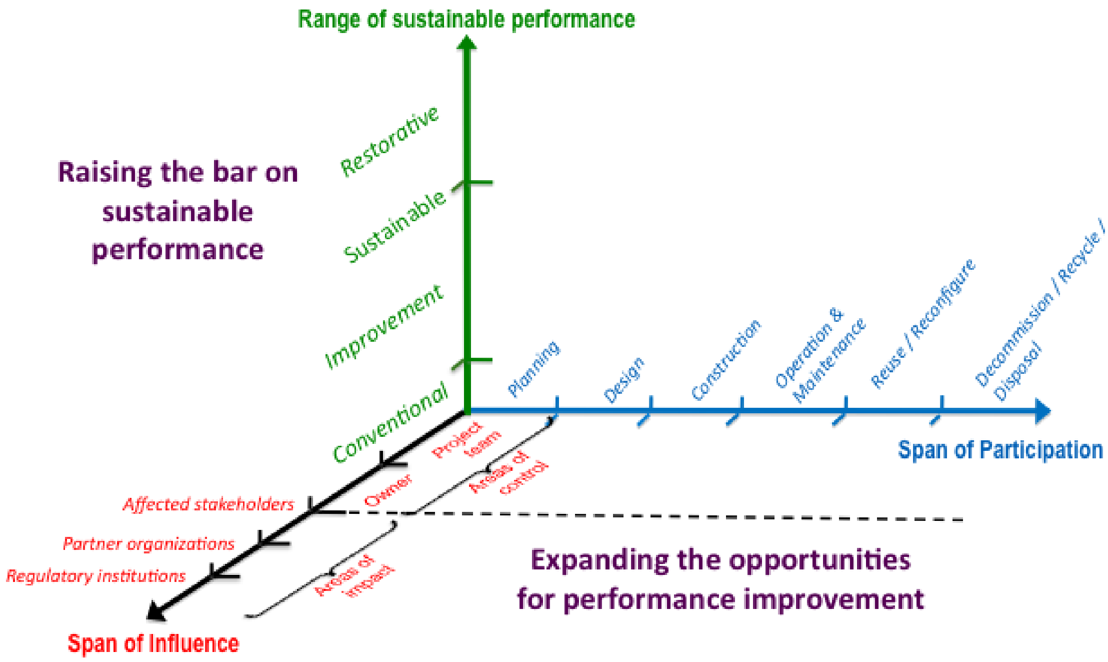


Figure 6.6: The three dimensions of performance contribution

Source: (Wallace, 2010)

The range of sustainable performance is defined by Wallace (2010) as improvements achieved over and above conventional approaches and practices. As depicted in Figure 6.7, there are four distinct levels of performance:

- *Conventional:* Meeting the applicable laws and regulations. Meeting the current state of the practice.
- *Improvement:* Improvements that exceed the current state of the practice, but which fall short of practices that can be labelled sustainable. As such, they should be characterised as transitional, i.e., improvements over conventional that, if continued, can lead to conditions of sustainability, but are not an end in themselves.
- *Sustainable*: Improvements that meet conditions of sustainability.
- *Restorative*: Improvements that exceed conditions of sustainability, designed to restore degraded economic, environmental and social conditions, bringing

society's economic development into equilibrium with the World's resources and ecosystems and well as its economic and socio-cultural systems.

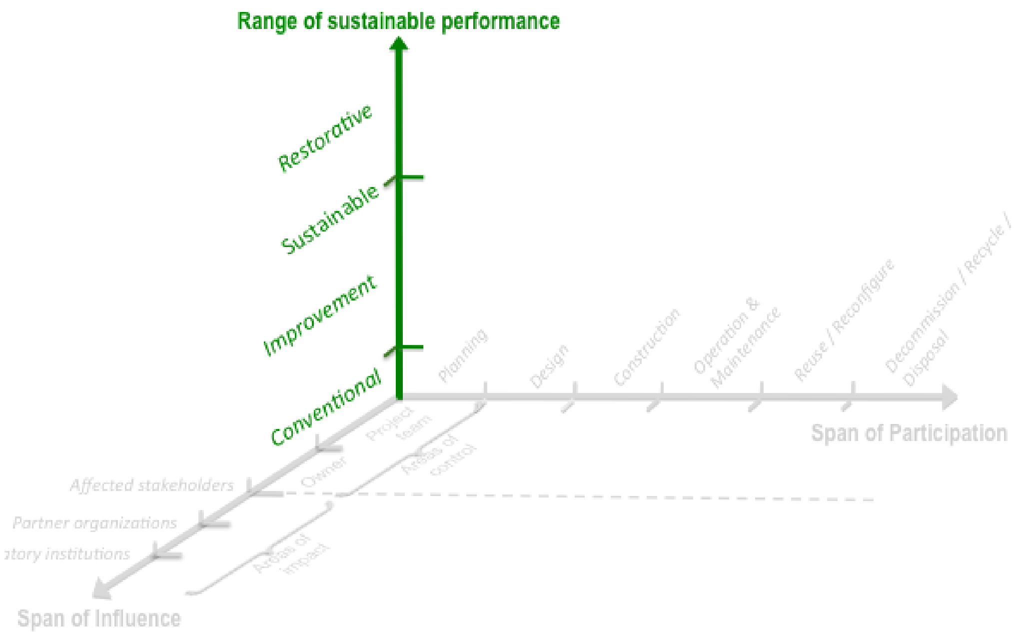


Figure 6.7: Range of sustainable performance

Source: (Wallace, 2010)

The purpose of defining these four levels of performance is to take into account that the current scope and extent of society's resources consumption and ecological carrying capacity is well in excess of sustainable conditions. To be effective, projects must strive to be restorative in order to return consumption to equilibrium conditions. Even though it may be well above conventional performance, performance that falls below sustainable levels will not contribute to conditions of sustainability (Wallace, 2010). As McDonough and Braungart (2002) have pointed out numerous times, such performance is simply 'less bad.'

In term of developing TPSI rating system, it is recognised that achieving restorative performance will take considerable time. However, it is important to set the sustainable performance bar at appropriate levels so as not to create the illusion of having contributed to achieving sustainability when in fact the performance was only less bad. The relationship of objectives for project sustainability and practices is illustrated in Figure 6.8. For each goal and related objectives and indicators there exists a set of corresponding practices currently in use, designed to achieve some currently acceptable level of performance. For some of these dimensions, regulations and standards have been issued that designate acceptable (often legal) levels of minimum performance for given situations. For others, no regulations or standards may exist. In these cases, these particular dimensions were not considered as important in the design or operation of facilities or equipment prior to our understanding of the issues of sustainability (Wallace, 2010). For example, in the U.S., some municipalities are now requiring that government building achieve some level of certification under the LEED rating system.

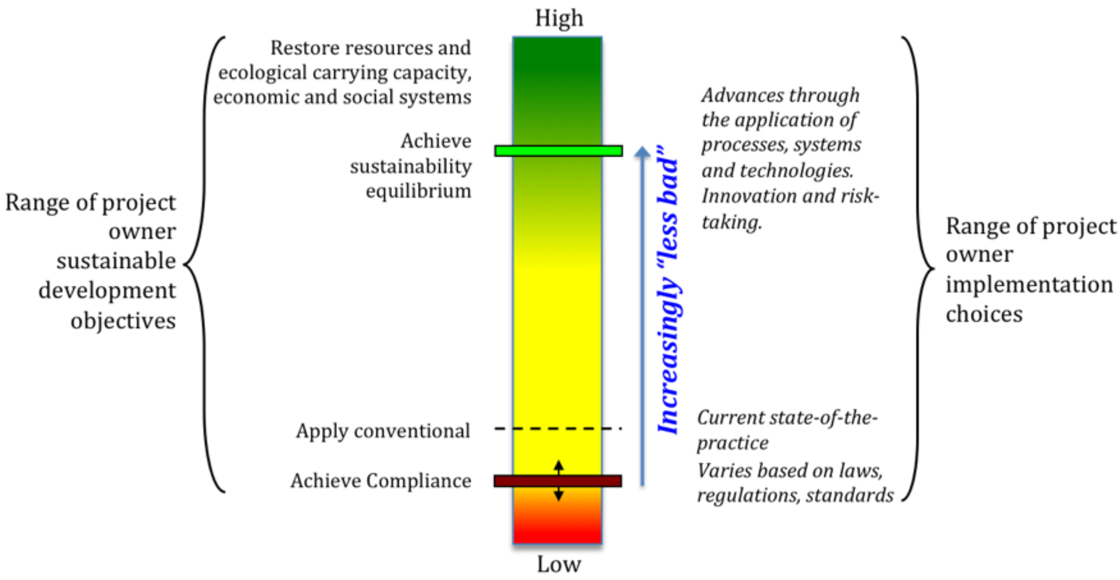


Figure 6.8: Sustainability project objectives and their relationship to engineering state-of-the-practice

Source: (Wallace, 2010)

Defining sustainability goals and objectives in terms of the engineering state of the practice has a practical benefit. It gives context to the current level of performance relative to the level of performance required to achieve conditions of sustainability. In addition, it shifts attention to matters that are important for performance improvement (Wallace, 2010):

1) What level of performance is delivered by conventional means, i.e., the current state of the practice?
2) What are the benchmarks for improved performance beyond conventional?
3) To what extent can this project raise the bar on sustainable performance?
4) What will it take to restore resources, ecological carrying capacity and socio-economic stability in order to achieve conditions of sustainability?

Overall, Wallace (2010) concluded that, by examining and comparing each dimension to the project owner's project goals and objectives, and evaluating potential technologies and approaches, the developer and the owner can determine the level of contribution that can be made towards improving sustainable performance. Similar efforts by other project owners and engineers will create an experience base of improvements in performance that, over time, will have the effect of raising the state of the practice on multiple dimensions of sustainability (see Figure 6.9).

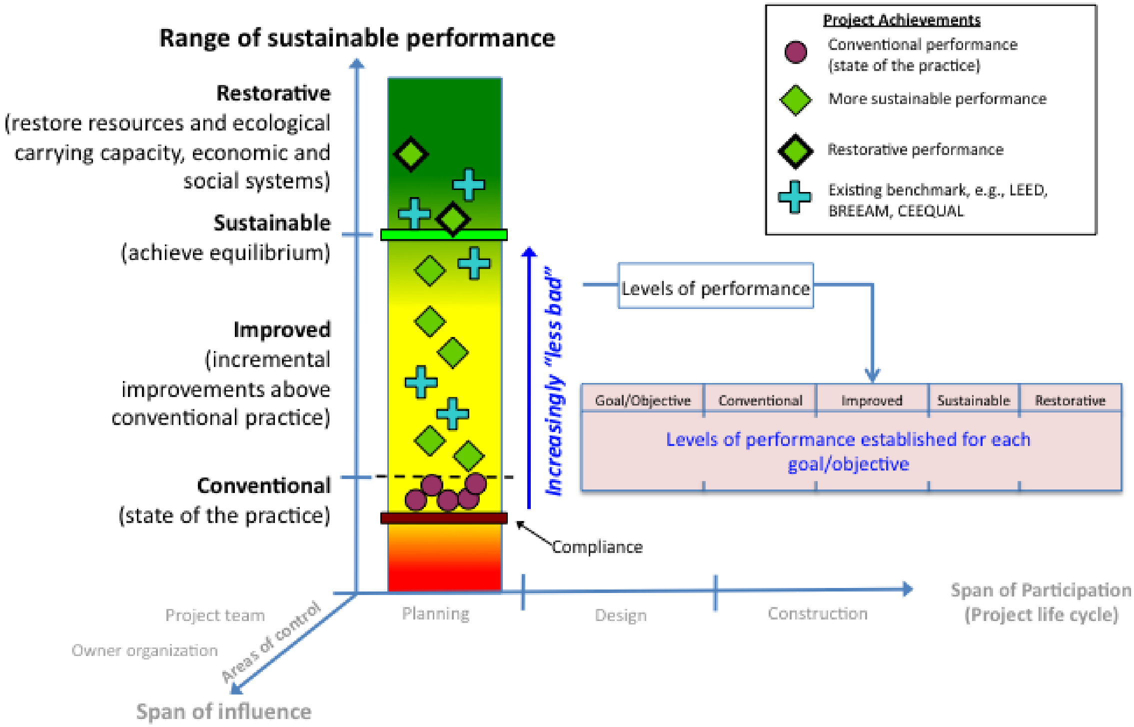


Figure 6.9: Raising the bar on sustainable performance

Source: (Wallace, 2010)

6.12. SCALE OF MEASUREMENT AND THE USE OF REFERENCE BENCHMARKS

All existing assessment methods implicitly embody a scale of measurement. Such a scale forms the basis for allocating performance points that are subsequently used to obtain an overall performance score. In short, it decides the main structure of the 'Assessment' module (see Figure 6.2). A primary emphasis of assessments is, therefore, to use the selection of the criteria to define the direction of environmental progress and to measure the degree of progress being made in improving the performance of buildings either relative to other similar buildings in the case of 'green' building design, or natural production and assimilative capabilities of ecosystems in the case of 'sustainable' design.

Irrespective of the goals of a building environmental assessment, it is necessary to characterise current performance levels. A common, but often unstated, baseline for assessment is a 'typical' or 'average' performance and, as such, recognition is given for better than 'industrial-normal-performance.' If scrutinised, this choice of benchmark is an extremely difficult one to both define and quantify the assessment criteria in a consistent manner (Cole, 1998). SBTool/GBTool (see Appendix A.23) is a good example in term of developing assessment benchmarks (SBTool/GBTool, BREEAM Offices and LEED Core and Shell are the main sources of adopted benchmarks for TPSI criteria). It attempted to define explicit reference performance levels for all performance criteria. It was actually a join program by many National Teams worldwide in order to develop a rating tool that can be used widely all over the World. The original proposal was to have the National Teams establish 'reference buildings' (i.e. buildings which considered commendable) to establish benchmark performance levels.

A reference building was considered as a building of the same size and type as the case-study building, but designed assuming industry norms. The use of the reference building concept is well established in energy simulation procedures in North America, but in GBC '98,[31] it was proposed to extend the concept to cover a wider range of issues. It assumed that this reference building would characterise industry benchmarks for that building type and region across all applicable performance issues and provide a base for performance scoring that could be derived and stated with some confidence. Typically, performance information is normalised in some way to facilitate comparison. For example, energy use is typically compared on a per m^2 basis to normalise for size, or per degree-day to account for variations in climate. Propositions were made to introduce

[31] **GBC '98**: Green Building Challenge 1998. Green Building Challenge is an international collaborative effort to develop a building environmental assessment tool that exposes and addresses controversial aspects of building performance and from which the participating countries can selectively draw ideas to either incorporate into or modify their own tools. The program began in 1996 and has engaged over 75 teams in project assessments, displayed at GBC'98, SB2000, SB02, SB05 and SB08 conferences. It is now continuing under a different name: SB Challenge (Sustainable Building Challenge) with the next international conference will be in Helsinki in October 2011 (see Section 4.23 for more information).

normalisation for occupancy (i.e., by introducing a per person factor) to account for differing use patterns and operating schedules. Examples of this strategy include:

- Issues IEQ-P1 and IEQ10: reference benchmark adopted from ASHRAE.
- Issue IEQ1, IEQ2, IEQ3, IEQ4, IEQ25: reference standard and benchmark adopted from ISO.
- Section 'B2.8. Acoustic and Noise': acoustic reference benchmark adopted from ISO, ANSI and ASTM.
- Issue 'IEQ26. Private Open Space': open space criteria based on HK-BEAM.
- Issue DF2, DF5, DF6: design specifications normalised based on CASBEE.
- Issue 'RC4. Annual Water Consumption': baseline for water consumption based on HK-BEAM.
- Issue RC-P1 and RC10: baseline building energy performance adopted from ANSI/ASHREA/IESNA Standard.
- Issue 'MA1. Material Specification': reference specifications based on UK Green Guide Rating.
- Issue 'MA9. Efficient Structural Design': reference threshold established based on multiple sources.
- Issue 'EL8. NOX Emission': reference benchmark adopted from BREEAM.
- Issue 'EL11. Noise Pollution': reference benchmark adopted from BS (British Standards Institution).
- Section 'E3.3. Ecology and Microclimate': calculation method of the change in ecological value and reference benchmark adopted from BREEAM.
- Issue 'SE3. Maximum Car Parking Capacity': car parking space limitation adopted from BREEAM.

Problems may also occur when the benchmark is derived as a statistical average value. Even though these statistics may be normalised for area (e.g., annual energy use/m^2 of floor area), the local climate conditions, occupancy patterns and operating schedule for the case-study building may be radically different from the average (Cole, 1998). However, the fact that TPSI is specialised for tall-buildings only will eliminate many of these disadvantages. Normalisation becomes less critical if the complete definition of the reference building is used, since the case study building is compared to the performance of a similar sized building (eliminating /m^2 issues), in the same location (eliminating climatic differences) and same use (eliminating occupancy differences).

The tool's accuracy will be much improved if it has the ability to adaptably change the weighting of assessment criteria regarding to the tall-buildings' inputs (i.e., number of floor, function, type of structure, etc.) (See Section 7.8.4).

6.13. TARGET PERFORMANCE LEVELS

Assessment methods require the declaration of a target or upper level on the assessment scale. An important issue when assessing relative performance is whether the measurement scale is 'open' or 'closed.' An 'Open scale' has the advantage of accommodating performances in advance of those initially anticipated when defining the upper limit of the assessment scale. 'Closed scale' is more common with examples can be named: BREEAM, LEED, HK-BEAM, and SBTool/GBTool. These rating systems chose a closed assessment scale for all criteria and set demanding targets for each. This offers advantages in the application of weighting factors to summarise the performance results and the ability to provide a common format for the output profiles. *However, this also diminishes the ability to reveal and highlight priority issues*. Choosing a closed scale approach itself, TPSI tries to fill this gap by introducing core issues or *Prerequisite issues* that have to be fulfilled in order to achieve other related issues (see Section 7.6.5). This is also an effort to limit the 'work-around' problem commonly seen in BREEAM and LEED, where building developers ignore important – and often difficult to achieve – issues to go for easier one so their buildings can 'look' sustainable. TPSI Prerequisite Issues are:

- 'IEQ-P1. Minimum Ventilation Performance': prerequisite for all issues under Section 'B2. Indoor Environmental Quality.'
- 'RC-P1. Basic Energy Performance': prerequisite for all issues under Section 'E1.3. Energy Use.'
- 'MA-P1. Timber Used for Temporary Works': prerequisite for all issues under Section 'E2.1. Selection of Materials.'

In order to further improve the closed scale approach, TPSI also introduces an 'Innovations' category where users can claim extra credits for exemplary performance and out-of-the-box achievement such as implementation of innovative strategies and technologies (see 'Innovations' category – Volume II).

Some of the performance targets in existing tools were set in absolute terms such as zero CFC/HCFC emissions or 100% reuse of the floor area of an existing building. The majority was set at a percentage of current typical practice, e.g., 75% of reduction in operating energy use compared to that of a reference building. The choice was to be both demanding, yet within the bounds of attainability with current knowledge and existing technologies. An assumption implicit in having fixed target performance levels is that they can be 'ratcheted up' in later versions of the assessment tool as experience develops (Cole & Michell, 1999). This approach can also be seen throughout TPSI assessment criteria system.

An underlying premise in existing systems is that a common set of features for building performance assessment procedures can be defined that are applicable to all buildings in all regions. Furthermore, if these 'core' criteria are made explicit, they can provide a clear starting point for developing customised methods for specific building types, geographic regions and specific intentions. LEED Core and Shell version is one of the good foundations to start building up TPSI core criteria. The customising of the assessment scales by the various National Teams during GBC and SBC process is a further illustration of the different agendas that currently define building environmental assessments. Whereas some National Teams either accepted the relative default assessment scales, other replaced them with absolute performance values. Allowing this freedom would eventually lead to inconsistency of assessment criteria between so many version of the tool. TPSI adopts a different approach from GreenStar: keeping the criteria intact and allowing the countries to vary weighting factors of criteria categories (see Section 7.8.4).

6.14. SCALING INCREMENTS

There are three general approaches to summarising the results of a sustainable assessment:

a. A simple designation of points for achieved performance in each of the various environmental areas, using different scoring systems for each and without concern for the significance of one criterion relative to the others. By assuming that all the assessment criteria are of equal importance, a simple aggregation is used to provide a total score. LEED is the typical example of this approach.

b. Using a common scale as the basis for assessing for all and applying weightings to acknowledge the different significance of each criterion prior to producing the overall score. This is the common approach of most existing rating systems, including BREEAM, HK-BEAM, Green Star, and SBTool/GBTool.

c. Using a specialised structure of scale to pursuit a particular goal. This is the case of CASBEE with the invention of the 'BEE' factor to illustrate the balance between building's performance and its environmental loadings. Complex scales and formulas are applied to evaluate this balance (i.e. the 'particular goal').

Existing assessment methods typically use a different scale of measurement for different performance issues and often identify a number of points or credits available for specific criteria without any explicit declaration of why or how they relate to each other. Examples include BREEAM and Green Star. By contrast, some systems such as GBTool use a consistent scale for all assessments and explicitly declare the benchmarks: zero (0) on the performance scale for 'typical' practice and five (5) for the most demanding performance. A negative value is included to account for performances worse than typical. This common -2 to +5 scale was used for all assessed sub-criteria and criteria. Similar method is used by HK-BEAM: a scale from 0% to100% is applied for all six criteria categories. This approach is very advantageous because it can assess the building's performance in each aspect beside the overall evaluation.

TPSI will adopt both the second and third approach. Users should be able to evaluate their design in each issue category as well as overall performance; and the output should be able to reflect the reciprocal influences between various sustainability aspects (see Section 6.16 for discussions on results communications and Section 7.8.6 TPSI assessment result presentations).

6.15. BOUNDARIES OF ASSESSMENT

The scope and 'boundaries' of an environmental assessment method are very important. Figure 6.10 shows a conceptual framework that can be used to illustrate the scope and boundaries of environmental issues in current building assessment methods as well as will be in TPSI. It consists of three primary 'dimensions': *Criteria*, *Time* and *Scale*.

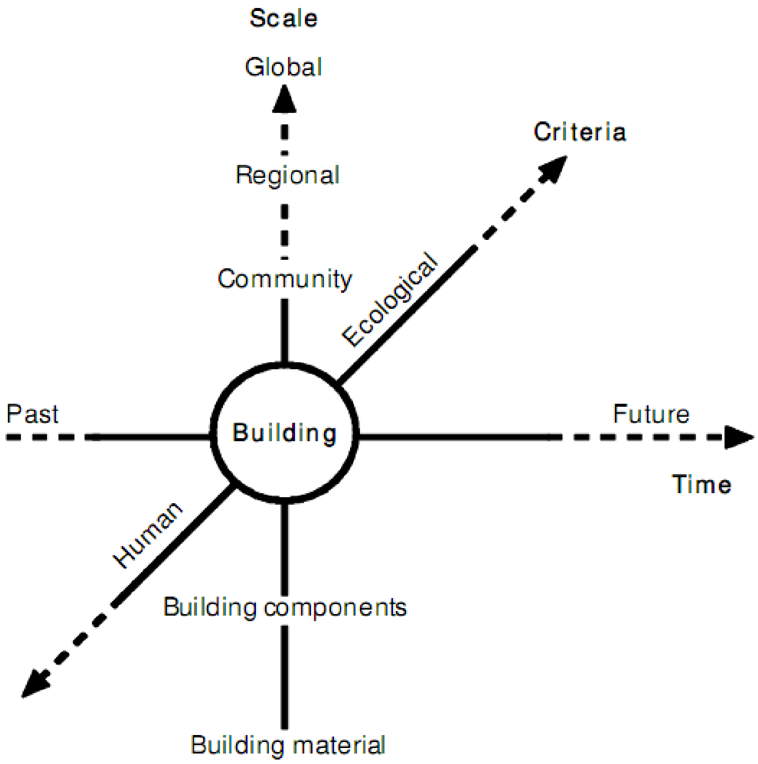


Figure 6.10: Three dimensions of environmental assessment

Source: (Cole, 1999)

6.15.1. Criteria

The *Criteria* dimension references the extended set of considerations within environmental assessment, distinguishing between ecological concerns (resource use, ecological loadings, etc.) and human concerns (indoor environmental quality, economics, social, etc.). Each of these sets of issues can be further subdivided into:

- Performance criteria that can be currently quantifiable and that can be confidently defined and assessed, such as energy use, water use etc. These are shown as solid lines in Figure 6.10.
- Performance criteria that can currently only be described qualitatively such as loss of biodiversity, design choices, etc. These are open to wider interpretation and therefore their assessment is less certain. These are shown as broken lines.

6.15.2. Time

The *Time* dimension is that explicitly covered with Life Cycle Assessment[32] methodologies. The concept of Life Cycle Assessment has been generally accepted within the environmental research community as the only legitimate basis on which to compare alternative materials, components and services and is, therefore, a logical basis on which to formulate building environmental assessment methods. Adopting Life Cycle Assessment approaches would seem an appropriate basis for structuring performance criteria within building environmental assessment tools but may not be possible for all criteria (Beetstra, 1997). In Figure 6.10, both the distant past and long-term future are less clearly known and certain than the immediate past and future. As such, they are distinguished by periods of relative confidence (shown as a solid line) and speculation (broken line) respectively.

6.15.3. Scale

Whereas considerable progresses have been seen in the environmental performance and Life Cycle Assessment of individual materials and components as well as their aggregation to whole building performance, the links between building and community and regional scale are less well developed. (TPSI will expand the criteria to include contextual issues that relate to site selection, building location and closeness to amenities - see Section B1.2 and Section E4.1, Volume II).

Figure 6.11 demonstrates a simple observation conducted by Baldwin (1998), which shows the importance of contextual conditions. Life Cycle Energy profiles of two buildings in UK were compared. Building 1 is a 1970s prestige air-conditioned office building in the centre of London well served by public transports. Building 2 is a late 1980s atrium building near the centre of Manchester with good car parking facilities. The critical issues are that the magnitude of the staff travel energy is similar to that of the building construction and operating energy, and that there are clearly marked

[32] **Life Cycle Assessment:** is potentially the most important method for assessing the overall environmental impact of products, processes or services. It is also sometimes referred to as 'Life Cycle Analysis' (LCA), 'eco-balance,' and 'cradle-to-grave analysis.' The term 'Life Cycle Assessment' is also used to specify a tool that can be used to assess the environmental impacts of a product, process or service from design to disposal i.e. across its entire life cycle, a so called cradle to grave approach. The impacts on the environment may be beneficial or adverse. These impacts are sometimes referred to as the 'environmental footprint' of a product or service. A Life Cycle Assessment involves the collection and evaluation of quantitative data on the inputs and outputs of material, energy and waste flows associated with a product over its entire life cycle so that the environmental impacts can be determined.

differences associated with the mode of transport. This becomes even more fundamental when it comes to large-scale, high-rise buildings with hundreds or thousands of occupants.

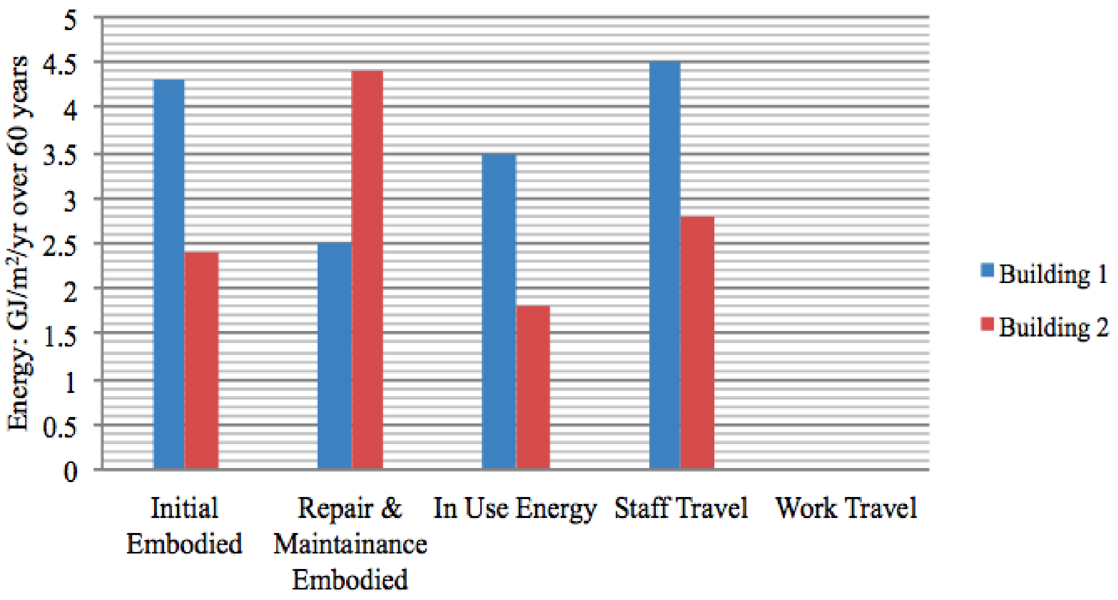


Figure 6.11: Annual life cycle energy (per m^2 of floor area) for two UK office buildings

Data source: (Baldwin, 1998)

Though building location and other contextual issues are important, whether or not they can be controlled by the design, has created significant discussion regarding their legitimacy for inclusion in either a building assessment or design tool. This debate reveals the current gaps between modelling and assessing building environmental impacts and community environmental impacts and, more generally, between the disciplines of architecture and urban planning.

Scale is clearly the critical dimension necessary to fully discuss building environmental performance in a comprehensive manner and, as has been emphasised earlier, is a prerequisite within the context of sustainability. The individual building, though useful in the 'green' building debate, is an inappropriate scale to define and discuss optimal environmental performance within a sustainability model (Cole & Larsson, 1998).

6.16. COMMUNICATING THE RESULTS

6.16.1. Output Format

Although it is generally accepted that environmental criteria must be organised in ways that facilitate meaningful dialogue and application, the structuring of criteria within the assessment method is most important during the output of the performance evaluation. It is at this stage that the complete performance profile of the building is evident and when the 'story' of the performance must be told in a coherent and informative way. An effective output profile from TPSI should encompass the following:

- Provide a comprehensive view of a building's environmental performance.
- Enable consideration of the balance between the building performance and environmental loadings.
- Enable selective analysis of various performance areas.
- Enable comparisons.
- Graphical results.

6.16.2. Comprehensive View

Since the primary strength of building environmental assessment methods is their comprehensiveness, the output must provide an *overall picture of the performance*. Clearly there are practical and cost implications associated with data collection and assessment - the more criteria the greater the difficulties. There are also limits to what can reasonably be comprehended from an output profile.

TPSI will be structured hierarchically in four levels: *Performance Areas*, *Categories*, *Criteria* and *Sub-Criteria* with the higher levels logically derived from the weighted aggregation of the lower ones. This structure enables a building performance to be described at *consecutively detailed levels*. It would also be possible to make assessments at the various levels and thereby gaining a quick overview of building performance. However, it now appears uncertain that it will ever be possible to make a simple and single evaluation of the efficiency of, for example, building Resource Use without an aggregation of the assessments of the constituent resource issues (energy, land, water and materials). Therefore, like all existing tools, TPSI will be only usable if one starts from the most detailed level of sub-criteria and proceeds upwards through the criteria by means of a weighting process, to the overall category scores. This remains the only meaningful way to describe and report on building performance in all sustainability rating systems.

This feature of TPSI is similar to HK-BEAM's assessment methodology. Users can see how well their building/design performs under each of six categories. The final classification is based on both aggregate score and individual score of six categories (see Table 6.2 and Table 6.3).

Table 6.2: HK-BEAM categories - Credits and weight

Categories	Credits	Weight
Site Aspects	22 (+3 Bonus)	25%
Materials Aspects	22 (+1 Bonus)	8%
Energy Use	42 (+2 Bonus)	35%
Water Use	9 (+ 1 Bonus)	12%
Indoor Environmental Quality	32 (+ 3 Bonus)	20%
Innovation and Additions	5 Bonus +1	

Data source: (BEAM Society, 2010b)

Table 6.3: HK-BEAM award classification

Award Classifications	Overall	SA	EU	IEQ	IA	
Platinum	75%	70%	70%	70%	3 credits	(Excellent)
Gold	65%	60%	60%	60%	2 credits	(Very Good)
Silver	55%	50%	50%	50%	1 credits	(Good)
Bronze	40%	40%	40%	40%	-	(Above average)

Data source: (BEAM Society, 2010b)

6.16.3. Balance between the Building's Performance and Environmental Loadings

TPSI generalise the balance between building performance and environmental loadings into the 'TPSI Factor' (see Section 7.7.2). This feature of TPSI is adopted and improved on CASBEE's assessment methodology. Other than evaluate buildings in each assessment category, CASBEE also produces the 'BEE' value to demonstrate the balance between the building's performance and environmental loadings. Six assessment categories are divided into two groups: *Q- Building Environmental Quality and Performance* and *LR- Reduction of Building Environmental Loadings*. The 'BEE' factor is defined as Q/LR (see Figure 6.12). Refer to Section 5.2.3 for more details on the assessment methodology of CASBEE.

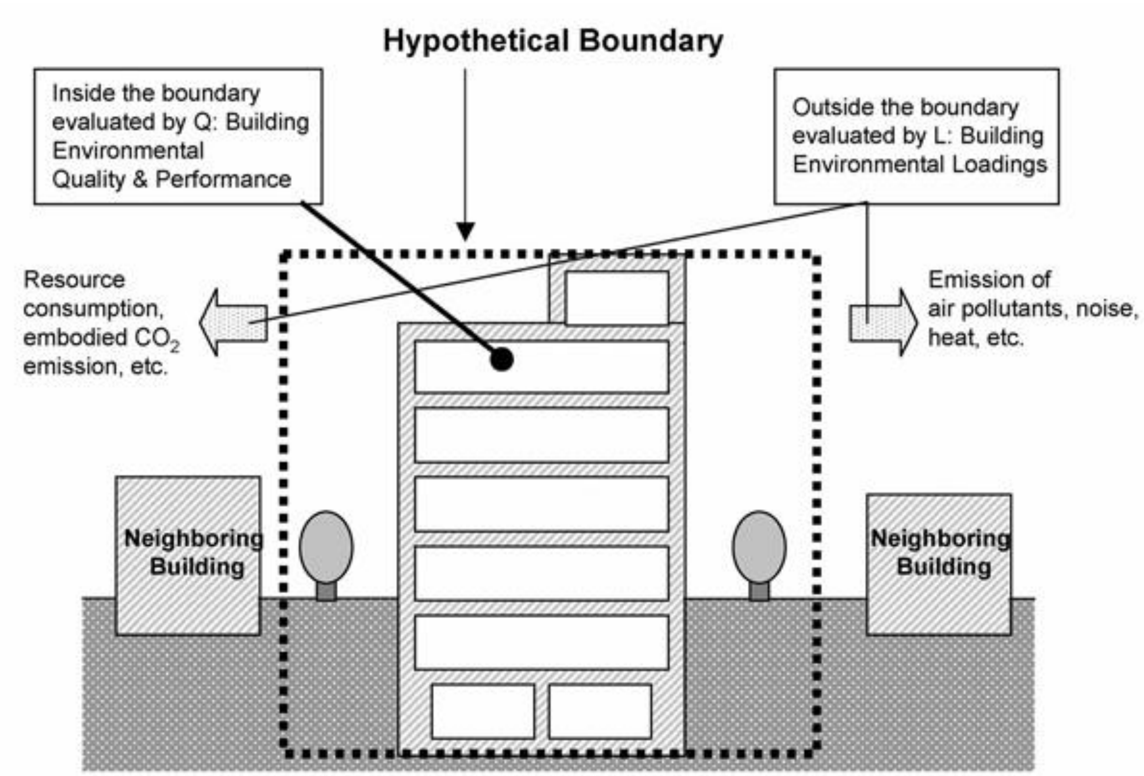


Figure 6.12: CASBEE's assessment methodology

Source: (JSBC, 2010b)

This concept of 'BEE' factor is the main innovation of CASEE compared with other 'families' of rating systems. It is also one of the reasons that CASBEE is among prominent rating tools nowadays. The 'BEE' factor, originally derived from eco-efficiency, establishes the connection between the quality and quantity of environment. It also expresses the goal of sustainable buildings: through minimum environment impact to get maximum quality improvement (Tian, Qin & Lin, 2005). A further advantage of 'BEE' is the innovative visual way it demonstrates the improvement of building performance (see Figure 5.4, Section 5.2.3).

On the other hand, this mechanism poses an important issue. Although the 'BEE' factor assumes all the assessment criteria of CASBEE, basing the final ranking on a single factor may reduce the meticulousness of the assessment. An improvement of TPSI over CASBEE is that: in TPSI this kind of factor will only be a part of the evaluation/ranking (see Section 7.7.2). In order to incorporate a factor like this in TPSI's result profile, the assessment criteria need to be intentionally structured and categorised with such an aim in mind right from the beginning (see Section 7.4 for TPSI criteria structure).

6.16.4. Selective Analysis

Different aspects of the output may hold greater interest for different users, and thus the output must allow analysis of more detailed areas of performance. The nesting principle discussed above provides an elegant means to view performance in detailed or general terms, and to clearly distinguish between qualitatively different environmental issues. It is evident that greater partitioning of the performance results is necessary:

- The separation of more objective assessment criteria and scores from those that are more open to interpretation would improve the confidence given to any aggregated score.
- The partitioning of tall-building related criteria and operations and management performance issues.

6.16.5. Enable Comparisons

Whether the assessment method is a design/managing tool, persuasion mechanism or stand-alone assessment method, an important requirement is that it enables comparisons between the performance of the case-study building performance and other known and declared references. Figure 6.13 schematically shows the output profiles of five hypothetical performance criteria for two buildings, and highlights four types of 'comparisons' that may be expected to be made using TPSI result profiles:

a. For a specific building performance criterion, the requirement of assessing relative to a declared benchmark. This is a requirement of all assessment methods and the choice of benchmarks by which a criterion is measured is a defining characteristic of an assessment method.

b. A comparison of the performance score of one criterion with that of others for the same building. Given that sustainable tall-buildings are recognised as much by the integration of systems and strategies, revealing the individual performance scores side-by-side, for example, in an output bar diagram can highlight where trade-offs and compromises had been made.

c. For a specific performance criterion, the requirement of comparing with other tall-buildings either in the same location or internationally. This comparison raises a host of issues regarding the use of 'relative' or 'absolute' scoring values and how the performance values or scores are normalised.

d. A comparison of the overall performance profile with that of other tall-buildings, again either locally or internationally. Invariably this requires the reduction of the overall assessment score to a single value or label. This can also be in form of a comparison of a synthesised value such as TPSI Factor (see Section 7.7.2).

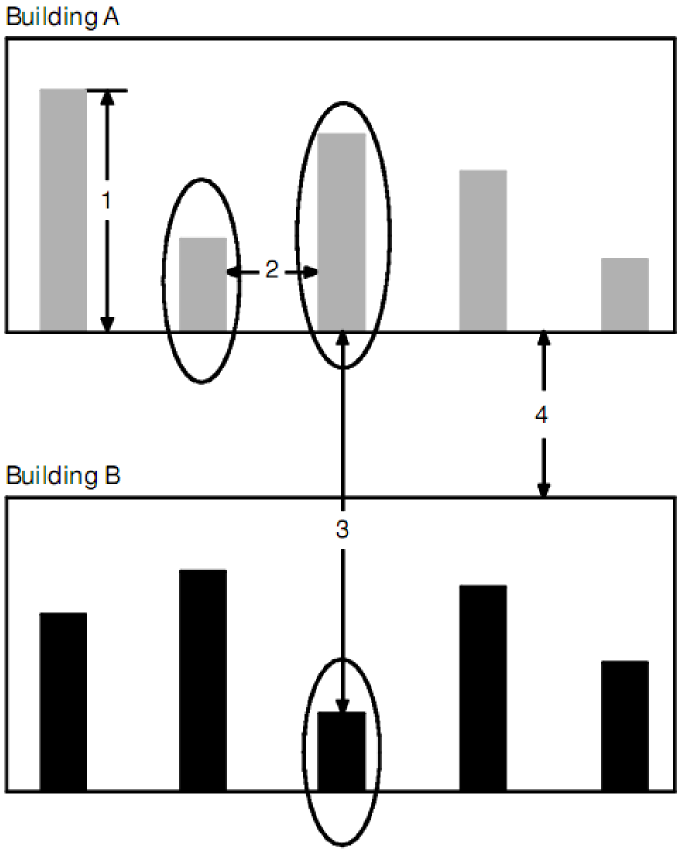


Figure 6.13: Four types of comparisons made in the new assessment system

6.16.6. The Use of Weighting Factor

Building environmental assessment methods cover a wide range of performance issues, e.g., BREEAM assesses approximately 112 individual sub-criteria and criteria; HK-BEAM: 132; GBTool: 120. It is necessary to reduce these assessment scores to a manageable number in the output modules. Weighting is now recognised as an essential part of building environmental assessment methods although there are still some disputes. The two critical issues are: *the basis for deriving weightings* and *the manner in which the weighting process affects the interpretation of the aggregated result*. In a rating system, normally a series of criteria were offered as a basis for developing appropriate weightings such as:

- Is the effect upon the environment irreversible?
- Is the effect upon the environment long lasting?
- What number of people is affected by the issue covered within the criterion?
- Does the practice in question require an extraordinary effort to counter?

This kind of approach was used by many rating systems including BREEAM, HK-BEAM, and Green Star. However, no clearly defined methodology was proposed. An important criticism was that these recommendations mix the *importance* of a criterion or sub-criterion in terms of its effect on human health, well-being, and the environment, with the *difficulty* of achieving it. This, again, relates to a recurring topic throughout this chapter: whether the assessment is attempting to give an objective environmental profile of a building, or to acknowledge practical and cost implications of attaining improved performances?

Todd (1998) identified that in developing appropriate weightings: *"The key to understanding the relative importance of environmental criteria lies in the selection of final endpoints - ones which reflect potential impacts on the environmental components of concern, not simply the changes in quality or quantity of environmental media (air, water, soil). Thus, the question of importance should not be whether air pollution is more important than water pollution, for example, but instead whether air pollution or water pollution exerts a greater specific potential impact on endpoints of concern."* Although this represents the most conceptually appropriate direction for developing weightings in environmental assessment, the development of the links and relationships between buildings and impacts advocated in the approach will require considerable research and data collection before it can be fully realised. Todd's approach to the derivation of weightings in effect seeks the equivalency between the impacts of various resource use or ecological loadings. This concept is currently applied in other aspects of environmental performance, although in a more modest way. For example, greenhouse gases (CO, NO_X, and CH_4) are combined based on their *CO_2 equivalence*, or the Ozone Depletion Potential of various refrigerants is specified in terms of their equivalence to effects of R-11. Typical examples can be named as Green Star and BREEAM.

There are of course counter arguments on the validity of using weightings for assessment systems. In the very early stage of the development of sustainability rating tools, Papamichael and Protzen (1993) argued that weightings systems only work under such circumstances where the relative significance of the components can be confidently stated, which are almost never. These concerns centre on the inability to derive relative weightings with any precision and interdependence of many performance criteria, particularly those that are more qualitative by nature. However, tracing back to the root of everything, rating the sustainability of a building is by all means a relative measurement at the first place. Until these days, weighting is still officially the most reliable approach and will be adopted by TPSI.

In TPSI, weighting will be linked to the 'nesting' principle (see Section 6.16.2) and the desire to be able to present performance scores in varying degrees of detail. In this context weighting represents an explicit declaration of the importance of a criterion against others. Although weighting is used extensively in existing rating systems, their result presentations often do not make immediately apparent which environmental categories should have priority. This can lead the users to conclude that all the issues are of equal importance. This should be improved in TPSI, for example by using more graphical presentations. Weighing is also a great and simple way to solve the 'context' issue raised earlier in this chapter. By slightly adjusting the weighting for each issue category, the whole system of criteria can also be adjusted to adapt to different context. This method has proved its efficiency with the success of Green Star. (Green Star uses adjustable weighting system to adapt itself to different locations of Australia). In TPSI, this approach can be pushed even further: *adjusting weighting system to adapt to different contexts and different features of tall-building projects* (see Section 7.8.3 and Section 7.8.4).

6.16.7. Explanation of Performance

The notion of 'environmental labelling' is often used in conjunction with environmental assessment as a logical outcome. The labels currently used are typically a classification of the performance into descriptive categories. For example, BREEAM categorises its assessment results into labels such as *Fair*, *Good*, *Very Good* or *Excellent*. Similarly, the summary of performance in LEED is judged as meeting a *Bronze*, *Silver*, *Gold* or the best - *Platinum* performance benchmarks through the simple addition of the various performance scores. In GBTool, a percentage scale is applied at the criterion, category and whole building level. After producing the percentage score for all categories, a special factor, which demonstrates the balance between building's performance and environmental loadings, will be calculated. The final percentage score for the whole building will base on both the categories' score and the special factor's value. A rating from 0 to 5 will be awarded for the building based on the final percentage score. TPSI also utilises a five level scale with the weighting factors apply at category level. The ranking of a project is dependent on its Total Score and the TPSI Factor. The rankings associated with their assessment are described in Section 7.7.3.

6.16.8. Links

A performance profile usually offers a graphic display of the scored criteria that signals areas of progress relative to declared benchmarks. But this is only a means to an end - the primary roles are (Cole & Michell, 1999):

- *Link to cause*: There must a means of explaining why the performance is what it is good or bad. That is, the output must provide a link back to its cause or origin. Whereas some of the characteristics of the building that were collected to perform an assessment, additional information may be required to explain the performance.
- *Link to action*: Since the output represents the link with action, the output must link with information that offers a basis for improving on deficient performance.

These links are not properly highlighted in existing labelling tools. Users of BREEAM, LEED, HK-BEAM or GreenStar only receive a ranking by the end of the evaluations. In TPSI, thanks to the graphical result presentations, users will see very clearly in the assessment profiles what areas of their project need to be improved. User can have a picture of how the building performs in each category and sub-category in comparisons with other aspects. TPSI also attempts to offer useful and detailed information on how to improve building performance (or link to action - presented in the 'Background and Notes' section of each TPSI Issue – see Volume II).

6.17. CHAPTER CONCLUSIONS

This chapter summarised the main arguments, origins, and theoretical foundations for the development of TPSI. It offers a deep insight into the core of environmental rating schemes, identifying their advantages and addressing their prominent problems. The sections in this chapter represent the key issues revolve around TPSI in particular and every environmental rating systems in general. Developing a rating system is a multi-strategy process, which requires integrated perspectives and different research methods. The contents of this chapter provide a framework when building up a sustainability rating system. Overall, it would be a valuable reference source for related research and studies. In Chapter 7, the features of TPSI will be introduced. Chapter 7 will also implicitly describe how the outcomes of this chapter are reflected and incorporated in the first version of TPSI (TPSI 2012 Version).

CHAPTER 7: TPSI - TALL-BUILDING PROJECTS SUSTAINABILITY INDICATOR

7

7.1. CHAPTER INTRODUCTION

Based on the results of the literature review process and the theoretical foundations established in Chapter 6, the first version of TPSI has been developed (TPSI 2012 Version). In this chapter, the main features of TPSI are described and introduced. *Please note that all the descriptions and illustrations provided in this chapter are applied to TPSI 2012 Version only.* The contents of TPSI's assessment issues were developed based on references from 29 'Applicable Tools' (see Section 4.5.1 and Appendix A) - the list of reference sources can be found in Section 7.3. Section 7.2 gives a holistic overview of TPSI. Section 7.4 and Section 7.5 outlines the structure of TPSI and the types of assessments that it covers. The components of TPSI are introduced throughout Section 7.6, Section 7.7 and Section 7.8. Finally, TPSI's system of assessment criteria is summarised in Section 7.9. *TPSI is not only a PhD research but also a copyrighted rating system. The completed TPSI 2012 Version is available to readers and examiners on demand.*

7.2. TPSI – THE DEFINITION

TPSI - Tall-building Project Sustainability Indicator is a tool for evaluating and rating high-rise buildings in terms of their environmental performance. TPSI offers comprehensive assessments of tall-buildings' performance, covering various aspects of sustainability. Assessments are ranked into five categories/grades (A, B, C, D, and E) as well as graphs, charts and other types of outcomes presentations.

A Unique Standard that Defines Tall-building Sustainability

TPSI provides users with a single performance labelling system that demonstrates the overall qualities of a high-rise building, regardless of its status (i.e. a new, refurbished or in-use building). TPSI embraces a range of good practices in planning, design, construction, management, operation, maintenance and demolition of a tall-building project. It emphasises indoor environmental quality and amenities as key performance indicators, with proper consideration of the local, regional and global environmental impacts. Especially, TPSI takes into account the balance between a tall-building's performance and the loadings to the environment in order to achieve that level of performance.

A Management Tool

TPSI is intended to be incorporated right from the very first stages of a project. TPSI can produce quick and sufficient evaluations, which are most suitable at design stage when comparing different design schemes and making decisions. At the same time, it also flexibly offers options to carry out detailed and rigorous evaluations. A tall-building project that follows TPSI's guidance will be safer, healthier, more comfortable, more functional, and more efficient.

An International Tool

TPSI has a dynamic assessment mechanism, which ensures efficient and effective functioning in different contexts (i.e. locations, climate zones, building characteristics). TPSI can automatically change the weights of its assessment criteria to adapt to different settings (i.e. environmental and technical data inputted by users). This is realised by the use of TPSI Calculator (see Section 7.8).

The Purposes of TPSI

TPSI seeks to:

- Enhance the quality of tall-buildings worldwide;
- Stimulate demand for tall-buildings that are more sustainable, giving recognition for improved performance and minimising false claims;
- Provide a comprehensive set of performance standards for tall-building projects that can be pursued by developers and owners;
- Reduce the environmental impacts of tall-buildings throughout their lifecycle;
- Ensure that environmental considerations are integrated right from the onset of a tall-building project rather than retrospectively.

The establishment of TPSI's characteristics represents the significances of the research, as well as the distinctiveness of TPSI System. This is very important in guaranteeing the contributions of the research, since there is hundreds of sustainability rating tools worldwide and their development is approaching a saturate state.

7.3. TPSI'S DEVELOPMENT BASES

The contents of TPSI's assessment criteria were developed base on references from the rating schemes listed in Table 7.1. Refer to Section 7.6 for more details on the development of TPSI's assessment criteria system.

Table 7.1: Development bases of TPSI Technical Manual

No.	Tools	Website
1	BEES (US)	http://www.bfrl.nist.gov/oae/software/bees.html
2	BREEAM (UK)	http://www.breeam.org
3	CASBEE (Japan)	http://www.ibec.or.jp/CASBEE/english/
4	CEEQUAL (UK)	http://www.ceequal.co.uk
5	CEPAS (Hong Kong)	http://www.bd.gov.hk/english/documents/index_CEPAS.html
6	DQI (Design Quality Indicator) (UK)	http://www.dqi.org.uk
7	Earth Advantage (US)	http://www.earthadvantage.org
8	EEWH (Taiwan)	http://gsp.stsipa.gov.tw/eng/main03_2.html
9	Envest 2 (UK)	http://envestv2.bre.co.uk/
10	Green Building Certification System (Korea)	http://www.greenbuilding.or.kr
11	Green Globes (US, Canada, UK)	http://www.greenglobes.com/
12	Green Leaf Eco-Rating Program (US, Canada)	http://greenleaf.auduboninternational.org/
13	Green Mark (Singapore)	http://greenmark.sg/
14	Green Star (Australia)	http://www.gbca.org.au/
15	HK BEAM (Hong Kong)	http://www.hk-beam.org.hk
16	HQE (France)	http://www.assohqe.org
17	LEED (US)	http://www.usgbc.org/
18	Living Building Challenge (US)	http://ilbi.org/
19	M4i (UK)	http://www.m4i.org.uk/
20	MSBG (US)	http://www.msbg.umn.edu/
21	NABERS (Australia)	http://www.nabers.com.au
22	"Quality of Life Counts" Indicator (UK)	http://www.defra.gov.uk
23	SBTool/GBTool (International)	http://www.iisbe.org/sbtool
24	SBAT (Africa)	n/a
25	SE Checklist (UK)	http://southeast.sustainability-checklist.co.uk/
26	SPeAR (UK)	http://www.arup.com/Services/Sustainability_Consulting.aspx
27	SPiRiT (Sustainable Project Rating Tool) (US)	https://eko.usace.army.mil/fa/sdd/
28	Scottsdale's Green Building Program (US)	http://www.scottsdaleaz.gov/greenbuilding
29	TERI GRIHA (India)	http://www.grihaindia.org/

7.4. THE STRUCTURE OF TPSI

Basically, the TPSI system comprises of 2 components:

- The 'TPSI Calculator': in form of a Microsoft Excel Tool. The TPSI Calculator is the main assessment software;
- The 'TPSI Technical Manual': in form of a booklet. The TPSI Technical Manual provides guidance on assessment criteria/procedure and required evidence according to the issues presented in the TPSI Calculator.

Users will claim 'credits' for their tall-building project by demonstrating compliance with the assessment criteria that are detailed in the 'TPSI Technical Manual.' The achieved credits will be inputted into the 'TPSI Calculator' accordingly. The 'TPSI Calculator' will then produce assessment results in form of ratings (percentage), charts, graphs, and issues summary. More details on the Technical Manual and the Calculator can be found in Section 7.6 and Section 7.8.

The Excel Tool – Technical Manual model is not a new format. In fact it is one the most common formats among existing sustainability rating systems. The literature review has revealed that many prominent systems adopt this Excel – Booklet model, including BREEAM, CASBEE, and Green Star. There are still some issues with this mechanism in existing systems, especially the design of the Excel tool and the smoothness when switching between the Excel tool and the booklet. However, it is obviously the most suitable format for TPSI because of the following reasons:

- The proven success of this model in reality.
- The availability of reference sources, supports, case studies and development models.
- The advantages of Microsoft Excel (i.e. popularity, reliability, the suitability with TPSI's intended features, wide range of built-in charts and graphs, the simultaneous generation of assessment results, the ability to utilise Macro codes, and other capabilities) – see Section 7.8 for more details.
- The added benefits when distributing the system.
- The ease when exchanging results and in-process assessments between parties.

7.5. SCOPE OF ASSESSMENT

During an assessment, when using the TPSI Calculator, users are asked to input information about building types, stages of assessment, types of projects, etc. These data would radically affect the final results. This section describes the scope of TPSI assessment and helps clear up potential confusions when working with the system.

7.5.1. Types of Buildings that can be Assessed by TPSI

TPSI is specialised for buildings of *more than 20 stories or more than 60 meters height*, regardless of their functions (see section 6.2 for more information on this choice of threshold).

7.5.2. Stages of Assessment

TPSI is most suitable to be used during the following stages:

- **Design Stage:** a Design Stage Assessment represents the performance of the tall-building prior to the beginning of operations on site. To complete an assessment at this stage the design must be advanced to the point where the relevant information is available to enable user to demonstrate, in a robust manner, the building's performance against the reporting and evidential criteria of the TPSI Technical Manual. A design stage assessment can't be verified by a third party due to the lack of actual documental evidences.
- **Post-Construction Stage:** The Post-Construction Assessment represents the final 'as built' performance and TPSI rating. A post-construction assessment can be verified by a third party if all documental evidences are available.

7.5.3. Types of Projects that can be Assessed by TPSI

A TPSI assessment can be carried out at the above stages for the following types of tall-building project:

- Whole new tall-building;
- Major refurbishments of existing tall-buildings;
- New build extensions to existing tall-buildings;

- A combination of new-build and existing building refurbishment;
- New build or refurbishments which are part of a larger mixed use building;
- Existing building fit-out.

Major refurbishments to existing tall-buildings

For the purposes of a TPSI assessment, a major refurbishment project is defined as a project that results in the provision, extension or alteration of thermal elements and/or building services and fittings. TPSI is not designed to assess a minor refurbishment of an existing building (i.e. works that do not result in the provision, extension or alteration of thermal elements and/or building services and fittings); or a change of use. Related definitions are as follow:

- 'Thermal elements' include walls, roofs and floors.
- 'Fittings' include windows (including roof-lights), entrance doors.
- 'Building services' include lighting, heating, mechanical ventilation/cooling, vertical transportations and other tall-building specified services.

New build extensions to existing buildings

TPSI can be used to assess new building extensions to existing buildings and, where the existing building is undergoing major refurbishment, the new build extension and existing building. When assessing only a new-built extension to an existing building, in some TPSI issues, it is necessary to consider services/facilities within the existing building, where such services/facilities will be integral to the new extension or used by the occupants of the new extension. Guidance is provided in the 'Background and Notes' section within the specific TPSI issue where relevant (see Section 7.6).

Building fit-out

TPSI can be used to assess a fit-out of an existing building, whether it is the first fit-out of the shell of a new building/unit or subsequent re-fit of an existing building/unit. Although there is no standard definition, typically a tall-building fit-out will include:

- Raised floors;
- Suspended ceilings;
- General lighting;
- Extension of the mechanical and electrical services above the ceiling from the riser across the lettable space;

- Finishes to walls;
- Window blinds;
- Vertical transportations;
- Safety services;
- Communication and IT systems;
- Other tall-building specified services.

7.6. ASSESSMENT CRITERIA SYSTEM – THE 'TPSI TECHNICAL MANUAL'

The TPSI Technical Manual is a technical guidance document that has been created to support users during the assessment process. Hard copies of the Technical Manual are available to readers and examiners on demand. Electronic copies of the Technical Manual are also available with hyperlinked headings for easier navigation. Users who use TPSI Technical Manual as well as the TPSI Calculator have to agree with the according Terms and Conditions.

7.6.1. Assessment Criteria System

TPSI covers eight 'Categories' of sustainability. These eight Categories are then divided up further into two main 'Groups':

- The '**B Group'** which stands for Building Performance;
- The '**E Group'** which stands for Environmental Performance.

There is one additional category which allows users to earn extra credits for innovative features of their project or for exceeding the design standard stated in the Technical Manual. Table 7.2 summarises the categories and groups.

Table 7.2: TPSI's assessment categories

B-Building Performance	**E-Environmental Performance**
B1. Project Management (PM)	E1. Resources Consumption (RC)
B2. Indoor Environmental Quality (IEQ)	E2. Material Aspects (MA)
B3. Building Services (BS)	E3. Environmental Loading (EL)
B4. Design Features (DF)	E4. Social and Economic Aspects (SE)
Innovations	

Each category is detailed in the Technical Manual and consists of a number of 'Sub-Categories' (see Table 7.3). Under these sub-categories are 'Issues.' There are 119 default issues in total, covering all aspects of sustainable tall-buildings development. Each issue seeks to improve an aspect of sustainability of a tall-building by defining a performance target and assessment criteria that must be met to confirm the target has been achieved. A certain number of 'credits' are available for each issue. By default, there are 223 available credits. Where a performance target has been achieved the number of available credits will be awarded. Refer to Section 7.9 for summary of TPSI's assessment criteria system and according available credits.

Table 7.3: Summary of TPSI categories and sub-categories

B-Building Performance	**E-Environmental Performance**
B1. Project Management (PM) B1.1. Overall Management B1.2. Design Process B1.3. Construction Issues B1.4. Contractual and Commission Process B1.5. Operation B1.6. Demolition	**E1. Resources Consumption (RC)** E1.1. Land Use E1.2. Water Use E1.3. Energy Use
B2. Indoor Environmental Quality (IEQ) B2.1. Prerequisite B2.2. Water Quality B2.3. Hygiene B2.4. Indoor Air Quality (IAQ) B2.5.Ventilation B2.6. Thermal Comfort B2.7. Lighting and View B2.8. Acoustics and Noise B2.9. Other Issues	**E2. Material Aspects (MA)** E2.1. Selection of Materials E2.2. Efficient Use of Materials
B3. Building Services (BS) B3.1. Building Amenities B3.2. Basic Building Equipment B3.3. Security and Safety B3.4. Vertical Transportation B3.5. Earthquake Resistance	**E3. Environmental Loading (EL)** E3.1. Waste E3.2. Pollution E3.3. Ecology and Microclimate
B4. Design Features (DF) B4.1. Design for Energy Efficient B4.2. Design for Functionality and Usability B4.3. Design for Flexibility and Adaptability	**E4. Social and Economic Aspects (SE)** E4.1. Social Aspects E4.2. Economic Aspects
Innovations IN1. Innovative Strategies and Technologies IN2. Exemplary Performance	

7.6.2. The Format of TPSI Technical Manual

In the TPSI Technical Manual, each TPSI issue is structured into the following sections:

- **Issue information:** category, sub-category, issue ID, issue title.
- **Aim**: broadly outlines the objective of the issue i.e. the aspect of sustainability it intends to improve.
- **Credits available**: maximum number of credits available for meeting the performance target.
- **Issue summary**: outlines the performance target and how credits are awarded.
- **Exclusion**: outlines the cases when the issue (or part of the issue) can be 'scoped-out' from the assessment OR when the issue can be achieved without considering the assessment criteria.
- **Assessment**: details the performance target/benchmark, assessment criteria and evidence required. To prove that an issue is fulfilled, the design team/client must provide adequate data and documents as 'evidence.' This section outlines the typical examples of the types of information that must be collected. This procedure is only necessary when a TPSI assessment needs to be verified by a third party. During a self-assessment process evidence can be ignored.
- **Background and Notes**: provides relevant information, definitions and footnotes to support the assessment and compliance of the project.

Figure 7.1 and Figure 7.2 show a sample TPSI issue. Please note that this TPSI issue has been edited for the purpose of demonstration.

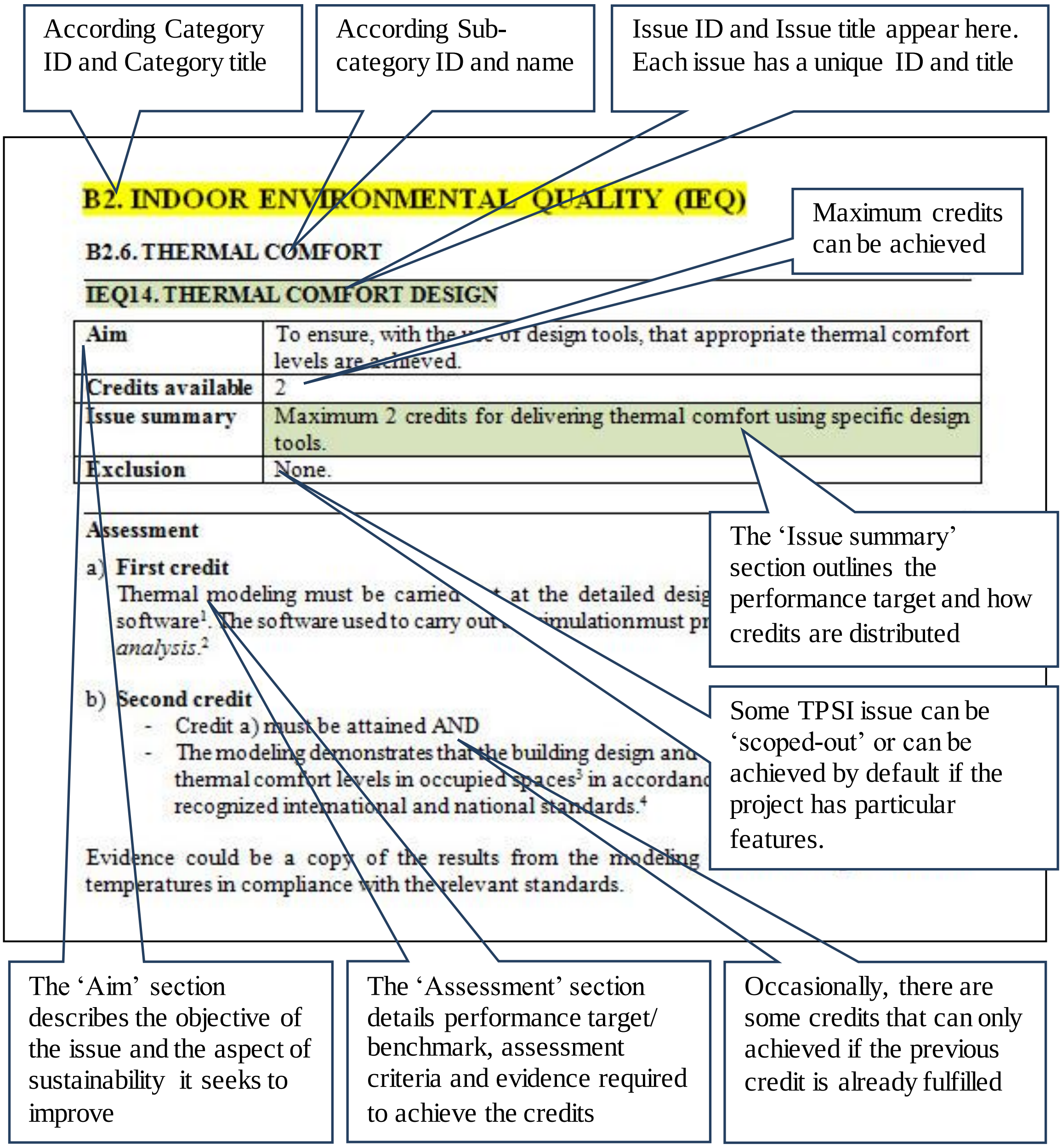
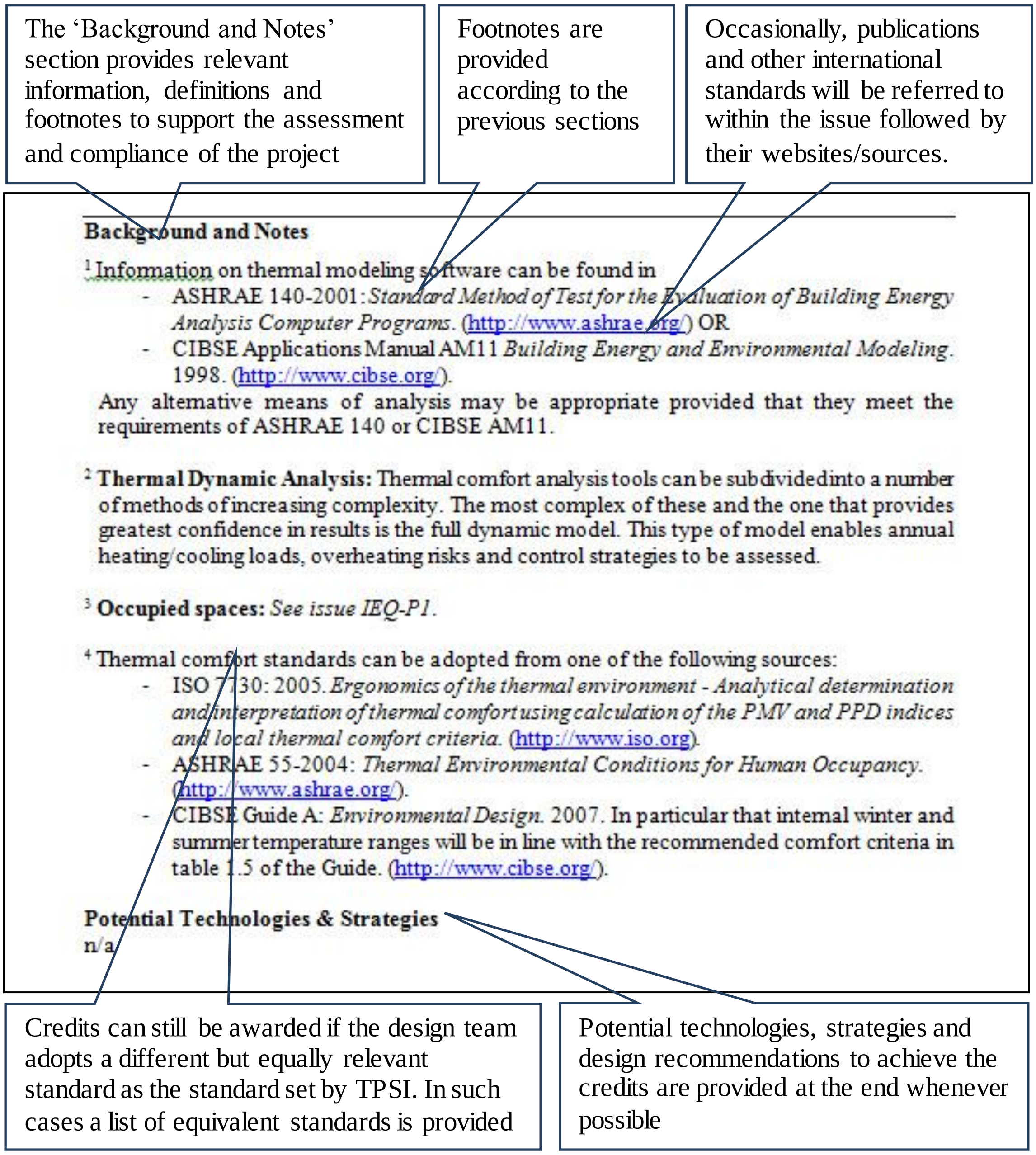


Figure 7.1: Example of a TPSI issue 1



Background and Notes

[1] Information on thermal modeling software can be found in

- ASHRAE 140-2001: *Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs*. (http://www.ashrae.org/) OR
- CIBSE Applications Manual AM11 *Building Energy and Environmental Modeling*. 1998. (http://www.cibse.org/).

Any alternative means of analysis may be appropriate provided that they meet the requirements of ASHRAE 140 or CIBSE AM11.

[2] **Thermal Dynamic Analysis:** Thermal comfort analysis tools can be subdivided into a number of methods of increasing complexity. The most complex of these and the one that provides greatest confidence in results is the full dynamic model. This type of model enables annual heating/cooling loads, overheating risks and control strategies to be assessed.

[3] **Occupied spaces:** *See issue IEQ-P1*.

[4] Thermal comfort standards can be adopted from one of the following sources:

- ISO 7730:2005. *Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria*. (http://www.iso.org).
- ASHRAE 55-2004: *Thermal Environmental Conditions for Human Occupancy*. (http://www.ashrae.org/).
- CIBSE Guide A: *Environmental Design*. 2007. In particular that internal winter and summer temperature ranges will be in line with the recommended comfort criteria in table 1.5 of the Guide. (http://www.cibse.org/).

Potential Technologies & Strategies

n/a

Figure 7.2: Example of a TPSI issue 2

7.6.3. Issues that can be 'Scoped-out'

Occasionally, there are some issues that can be 'scoped-out' if the project has specific features/characteristics. This means that particular issue is not applicable for such a project. When this is the case, that issue is excluded from the assessment and that issue's credits do not contribute to the overall result. The conditions under which an issued can be scoped-out are described in the 'Exclusion' section of that issue. For example, issue 'IEQ6. Construction IAQ Management' (see Section B2.4, Volume II) can be scoped-out for "Residential and similar buildings not provided with central air-conditioning and ventilation systems." When this is the case, the two credits of this issue are subtracted from the total credits. The number of available credits now would be: 223 – 2 = 221 credits (see Figure 7.3).

B2.4. INDOOR AIR QUALITY (IAQ)

IEQ6. CONSTRUCTION IAQ MANAGEMENT

Aim	To ensure that building ventilation systems are not contaminated as a result of residuals left over from construction activities.
Credits available	2
Issue summary	a) 1 credit for implementing a Construction IAQ Management Plan. b) 1 credit for undertaking a building 'flush-out' or 'bake-out' and replacement of all filters prior to occupancy.
Exclusion	Residential and similar buildings not provided with central air-conditioning and ventilation systems.

Figure 7.3: Example of a TPSI issue that can be scoped-out

7.6.4. Issues that can be Achieved by Default

Occasionally, there are some issues that can be achieved by default if the project has specific features/characteristics. This means all or a part of that issue's available credits are awarded without going through the assessment process. The conditions under which an issued can be achieved by default are described in the 'Background and Notes' section of that issue. Issue 'EL14. Protection of Ecological Value' (see Section E3.3 – Volume II) is an example of these cases (see Figure 7.4).

E3.3. ECOLOGY AND MICROCLIMATE

EL14. PROTECTION OF ECOLOGICAL VALUE

Aim	To encourage development on land that already has limited value to wildlife and to protect existing ecological features from substantial damage during site preparation and completion of construction works.
Credits available	1
Issue summary	1 credit for fulfilling specific requirements in order to protect the site's existing ecological value.
Exclusion	None.

Assessm

Background and Notes

No features of ecological value: *Where the construction zone is defined as 'land of low ecological value' and where the surrounding site contains no features of ecological value, this credit can be awarded by default.*

Figure 7.4: Example of a TPSI issue that can be achieved by default

7.6.5. Prerequisite Issues

Among TPSI issues there are three 'Prerequisite Issues':

- IEQ-P1. Minimum Ventilation Performance;
- RC-P1. Basic Energy Performance;
- MA-P1. Timber Used for Temporary Works.

Prerequisite Issues have no available credit, which means users get no credits for fulfilling these issues. A Prerequisite Issue is placed at the top of a section; they need to be fulfilled in order to achieve all other issues under that section. For example, issue IEQ-P1 is the prerequisite for all issues under Section 'B2. Indoor Environmental Quality' (issues IEQ1 to IEQ27). If Issue IEQ-P1 is not fulfilled, user will get 0 credits for all issues from IEQ1 to IEQ27 without going through the assessment process, user will then have to skip to the next section (i.e. Section 'B3. Building Services') – see Volume II. Figure 7.5 shows a sample prerequisite issue.

B2. INDOOR ENVIRONMENTAL QUALITY (IEQ)

B2.1. PREQUISITE

IEQ-P1. MINIMUM VENTILATION PERFORMANCE

Aim	To ensure that a minimum quality and quantity of outdoor air is supplied to indoor spaces in order to support the well-being and comfort of occupants.
Credits available	Required.
Issue summary	Demonstrate compliance with the specific minimum requirements in respect of Outdoor Air Quality and Minimum Ventilation Rate.
Exclusion	Residential and similar buildings without central air conditioning.

Assessment

This issue is the prerequisite for all issues under Section B2. Indoor Environmental Quality (issues IEQ1 to IEQ27). It must be fulfilled in order to score under issues IEQ1 to IEQ27.

Evidence could be a report prepared by a suitably qualified person detailing the outdoor ventilation performance. The report must include:

Figure 7.5: Example of a TPSI prerequisite issue

7.6.6. Innovation Issues

Beside eight main categories, users can earn extra credits under 'Innovations' category. 'Innovation' category is weighted like every other category. There are two ways to earn innovation credits, according to two Innovation Issues types (see Section 'IN. Innovations' – Volume II):

- **Issue 'IN1. Innovative Strategies and Technologies':** This issue gives maximum 5 credits for the adoption of practices, new technologies, techniques and strategies that are not currently recognised by existing TPSI issues.
- **Issue 'IN2. Exemplary Performance':** This issue gives maximum 11 credits for the achievement of exceptional performance over and above the stated performance criteria under TPSI issues.

7.6.7. Development Background of TPSI's Assessment Criteria System

The development of TPSI's Assessment Criteria System is an inheriting process, which implemented a multi-strategies method. This method is based on the framework adopted by SBTool/GBTool, which was analytically summarised by Cole (1998, 1999). Chapter 6 presents a detailed narration of this framework and related issues. Principally, the main task was to establish a set of standards for sustainable tall-buildings. How to implement this set of standards into a rating tool is a different task, which requires the development of an assessment methodology (see Section 7.7).

Assessment Criteria System

As shown in Table 7.1, TPSI's Assessment Criteria System were established based on the contents of 29 applicable tools. The most important referenced sources of standards, however, are mainly from BREEAM, LEED, CASBEE, HK-BEAM and CEEQUAL. It is remarkable that many of the existing standards take root from BREEAM and LEED, resulting in the similarity of the criteria systems. Despite being among the Top Five rating systems, Green Star's standards did not contribute much to the content of TPSI's assessment criteria. Its contributions are mainly related to the assessment methodology (see Section 7.7).

Firstly, the literature review process (especially the case-studies examination, Screening Analysis, and the comparative review of 29 applicable tools) had helped identifying the suitable standards for assessing tall-building projects. These standards were collected, restructured and modified based on the visions set out for TPSI (see Section 5.4.3) and the theoretical foundations established in Chapter 6. Tall-building specialised issues were revised and supplemented where necessary. A 'raw' set of sustainability aspects/issues for tall-building projects was established.

Secondly was the task of classifying the issues into categories and groups. This classification must serve the purpose of TPSI assessment, especially the concept of TPSI Factor (see Section 7.7.2). This is where the development of the Assessment Criteria System intersects with the design of Assessment Methodology.

Thirdly, there came the matter of expressing these issues into assessment criteria, which in turn must be measurable and quantifiable into actual 'credits' (i.e. 'points'). Another concern is that the standards must be applicable and recognised worldwide. Two strategies were applied during this stage:

- *Converting*: standards are rephrased and/or structured into assessment criteria, which award credits based on the level of fulfilment. This strategy is used for issues that user can finish the assessment without referring to an external standard.
- *Referencing to international standards*: standards that are recognised worldwide such as ISO,[33] ASHRAE,[34] ANSI,[35] and ASTM International,[36] are used for issues where external referencing is needed. Adopted local/national standards are 'translated' into equivalent international standards.

TPSI Technical Manual

Manuals of four rating systems were studied when designing TPSI Technical Manual's format, namely:

- BREEAM;
- LEED;
- CEEQUAL;
- HK-BEAM.

[33] **ISO**: International Organisation for Standardisation <http://www.iso.org/iso/home.html>.

[34] **ASHRAE**: The American Society of Heating, Refrigerating and Air Conditioning Engineers <http://www.ashrae.org/>.

[35] **ANSI**: The American National Standards Institute <http://www.ansi.org/>.

[36] **ASTM International** (American Society for Testing and Materials) <http://www.astm.org/>.

The biggest concerns were the user-friendliness and convenience when switching between the Calculator and the Technical Manual. LEED's Manuals are very concise, but their simplicity can cause confusions due to the lack of references and notes. BREEAM Manuals, on the other hand, are too complicated and users would just keep losing track of their assessments. CASBEE Manuals have very rich graphics and illustrations, which is a big advantage. CEEQUAL Manuals express mostly every criterion in words and seriously reduce their effectiveness. HK-BEAM Manuals are surprisingly well organised and easy to follow, with very good sectioning and heading.

As illustrated in previous sections, a visual and interactive approach was used when developing TPSI Technical Manual. Categories are named and colour-coded to so users can easily identify their groups and their sub-categories (see Section 7.6.2). Issues are given IDs, their name and summaries are also highlighted. The same summaries are used in the TPSI Calculator. The issues' contents are presented in sections according to available points. Tables and graphics are implemented whenever possible for better appearance and interaction. The electronic formats (Microsoft Words and PDF) with hyperlinked headings would also radically enhance the effectiveness.

7.7. ASSESSMENT METHODOLOGY

There are two main elements that determine a building's rating:

- The *Total Score;* and
- The *TPSI Factor.*

7.7.1. The Total Score

The Total Score is calculated as follows:

- For each TPSI issue, the users must determine the number of credits achieved in accordance with TPSI's assessment criteria (detailed in TPSI Technical Manual).
- The percentage of the credits achieved is calculated for each TPSI Sub-category and Category.

- A weighting system is applied to all Categories to reflect the importance of each Category. This weighting system is not fixed but instead dynamic, i.e. it can be changed based on the building's characteristic. See Section 7.8 for more information on default weighting factors and the dynamic weighting system.
- The percentage of credits achieved is then multiplied by the corresponding TPSI Category's weighting factor. This gives the 'Category Score.'
- Eight Category Scores and Innovation Score are added together to give the Total Score.

7.7.2. The TPSI Factor

The TPSI Factor is calculated as follows:

- As shown in Table 7.2 and Table 7.3, the assessment criteria are grouped into 2 main categories: the 'B Group' which stands for 'Building Performance,' and the 'E Group' which stands for 'Environmental Performance.' The main idea behind this is to assess the balance between the building's performance and the loadings to the environment in order to achieve that performance level (see Figure 7.6).
- The percentage of the credits achieved is calculated for both groups. These are expressed as the *Total Score for B* and the *Total Score for E*.
- The TPSI factor is defined as B/EL (EL (Environmental Loadings) = 100% - Total Score for E).
- B and EL are plotted on a graph, with EL on the X axis and B on the Y axis. The higher the B value and the lower the EL value, the steeper the gradient and the more sustainable the building is (see Figure. 7.7).
- A TPSI Factor can fall into one of five areas (A, B, C, D and E) according to five TPSI ranking levels (see Section 7.7.3).

Please note that this chapter and particularly this section only describe the mechanism behind a TPSI assessment. The users do not have to do any of these calculations themselves, including the calculations related to special issues (i.e. issues that can be scoped out or can be achieved by default, prerequisite issues, etc.). They only have to claim the credits using the TPSI Calculator. All the calculations and results are automatically generated.

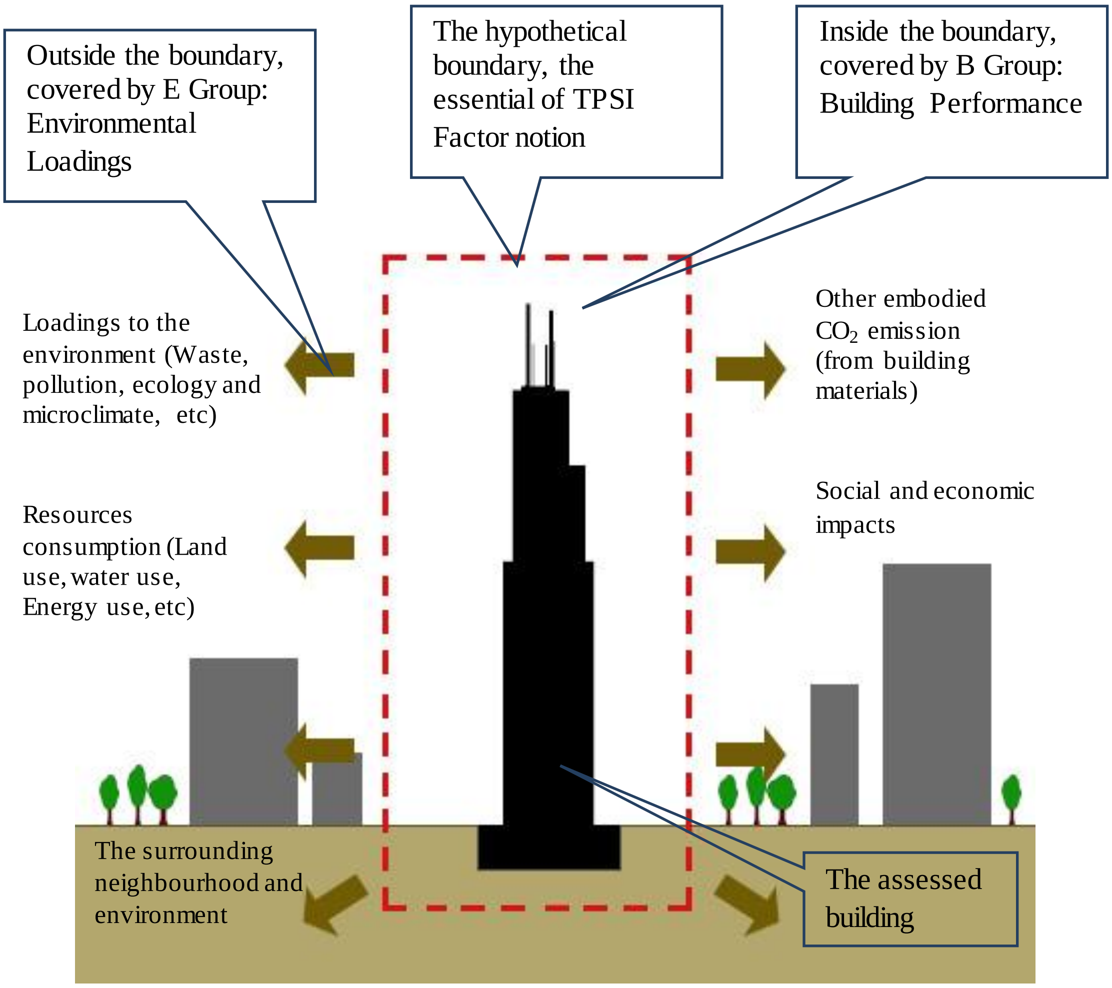


Figure 7.6: The idea behind TPSI Factor

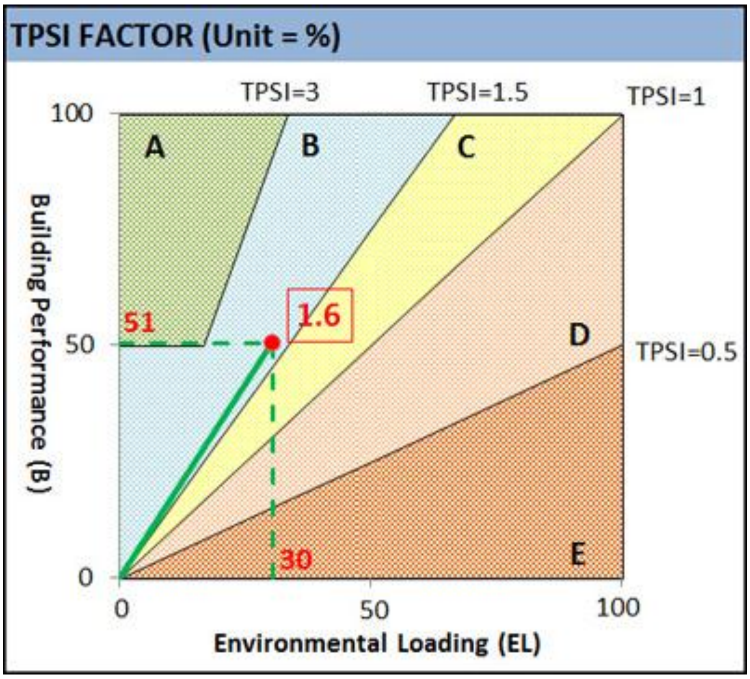


Figure 7.7: A sample calculation of TPSI Factor

7.7.3. TPSI Ratings

TPSI introduces a labelling classification of five levels to rate the sustainable performance of a tall-building project (A, B, C, D, E - with A being the best practice). The ranking of a project is dependent on its Total Score and the TPSI Factor. The rankings associated with their assessment are shown in Table 7.4.

Table 7.4: TPSI ranking

Rank	Total Score	TPSI Factor	Comments
E	< 25 %	< 0.5	Unclassified
D	≥ 35 %	≥ 0.5	Pass
C	≥ 50 %	≥ 1	Good
B	≥ 75 %	≥ 1.5	Excellent
A	≥ 85 %	≥ 3.5	Outstanding

7.7.4. Development Background of TPSI's Assessment Methodology

There is a common misconception that the success of a design-rating environmental tool is determined by its assessment criteria system. As stated in Chapter 2, the development of environmental rating tools is an inheritable process with new tools being developed based on existing standards. The standards for building sustainability have been long established and fortified by organisations such as ISO, ASTM, ASHRAE, BRE, and USGBC. This is again demonstrated in Table 4.3: 11/29 of the Applicable Rating Systems are developed based on BREEAM or LEED. Even with the systems that claim to be original, the similarity between their assessment criteria and that of BREEAM or LEED is quite noticeable.

Studying the assessment criteria systems of the rating schemes according to the development timeline (see Figure 3.2), it is obvious that sustainability standards haven't evolved much since the 1990's. The rating systems may have different interpretations of the criteria, but the essences and principles remain consistent. In the case of TPSI, even though many efforts have been taken to create a unique set of standards for sustainable tall-buildings, overall they cannot be too departed from the long established standards.

The main factor that creates a managing-rating environmental tool, instead, is the assessment method. The essence of performance tools such as BREEAM, LEED, CEEQUAL, and CASBEE is the generation of *the final rating*. Their single most important task is to produce a concluding result that represents the overall performance of the object building. Generating the final result is also essential in TPSI, but equally important is the capacity to help users *interactively improve* their buildings during early stages of the projects. The following factors are the most essential when developing TPSI's assessment methodology:

a. Adaptability: the assessment methodology must allow flexible exploitation of the criteria system. In other words, the criteria must be able to adapt themselves to different contexts, thus making TPSI a global tool. This has been realised by the employment of dynamic weighting factors.

b. Different levels of results: users should be able to see their projects' performance on various levels. TPSI's assessment mechanism offers four levels of results generations: Sub-Category scores, Category scores, Group scores and Overall score. This allows users to easily manage their projects by small clusters of sustainability issues while working their way up the hierarchy of assessment criteria. At the same time, the result presentation must be clear and systematic so users do not get lost among these levels.

c. Interactivity: users should be able to views these results simultaneously as they progress, in graphical formats rather than just overall rankings. It must be convenient for them to switch between sub-categories, categories, and the results presentation, as well as keeping track of their process.

d. The TPSI Factor.

The main inspirations for the development of TPSI's assessment methodology come from BREEAM, LEED, Green Star and CASBEE. However, it was not an imitating method but a complex adopting and improving procedure as depicted throughout Chapter 6. Section 7.8 describes how the assessment methodology is encompassed in the TPSI Calculator.

7.8. ASSESSMENT PROCESS – THE 'TPSI CALCULATOR'

7.8.1. Overview of the TPSI Calculator

TPSI Calculator is a Macros-enriched Microsoft Excel tool. In order to run TPSI Calculator, users must have Microsoft Excel 97-2003 or later versions installed on their computer. Macros contents must be enabled for full functions of the tool. The descriptions in this section are for TPSI Calculator 2012 Version. TPSI Calculator tool is password-protected so users cannot change the core contents of the software; they can only input the project information and claim credits where allowed. The TPSI Calculator contains of 13 tabs in total as summarised in Figure 7.8. Figure 7.9 shows a screenshot of TPSI Calculator 2012 Version.

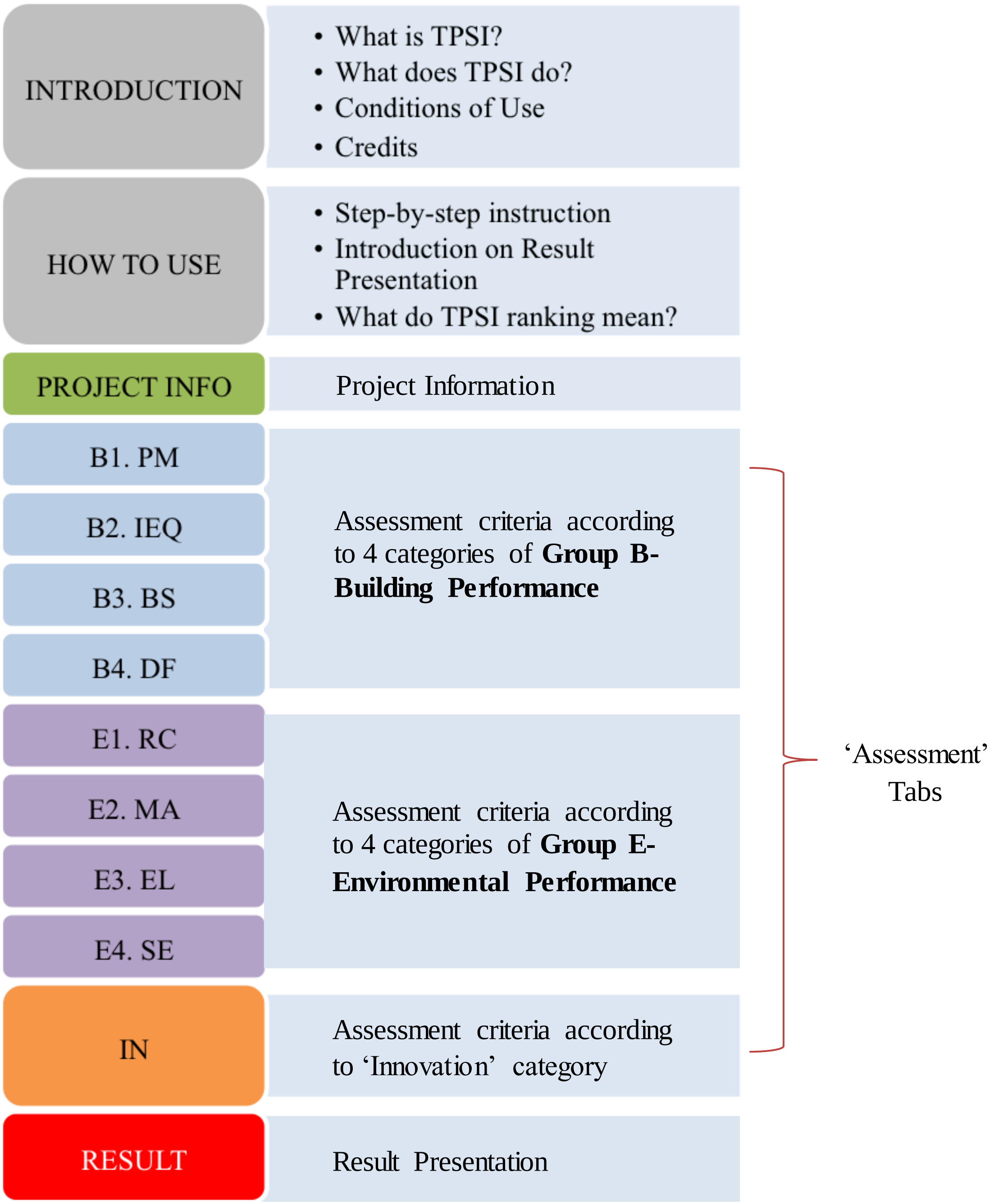


Figure 7.8: Summary of TPSI Calculator's tabs

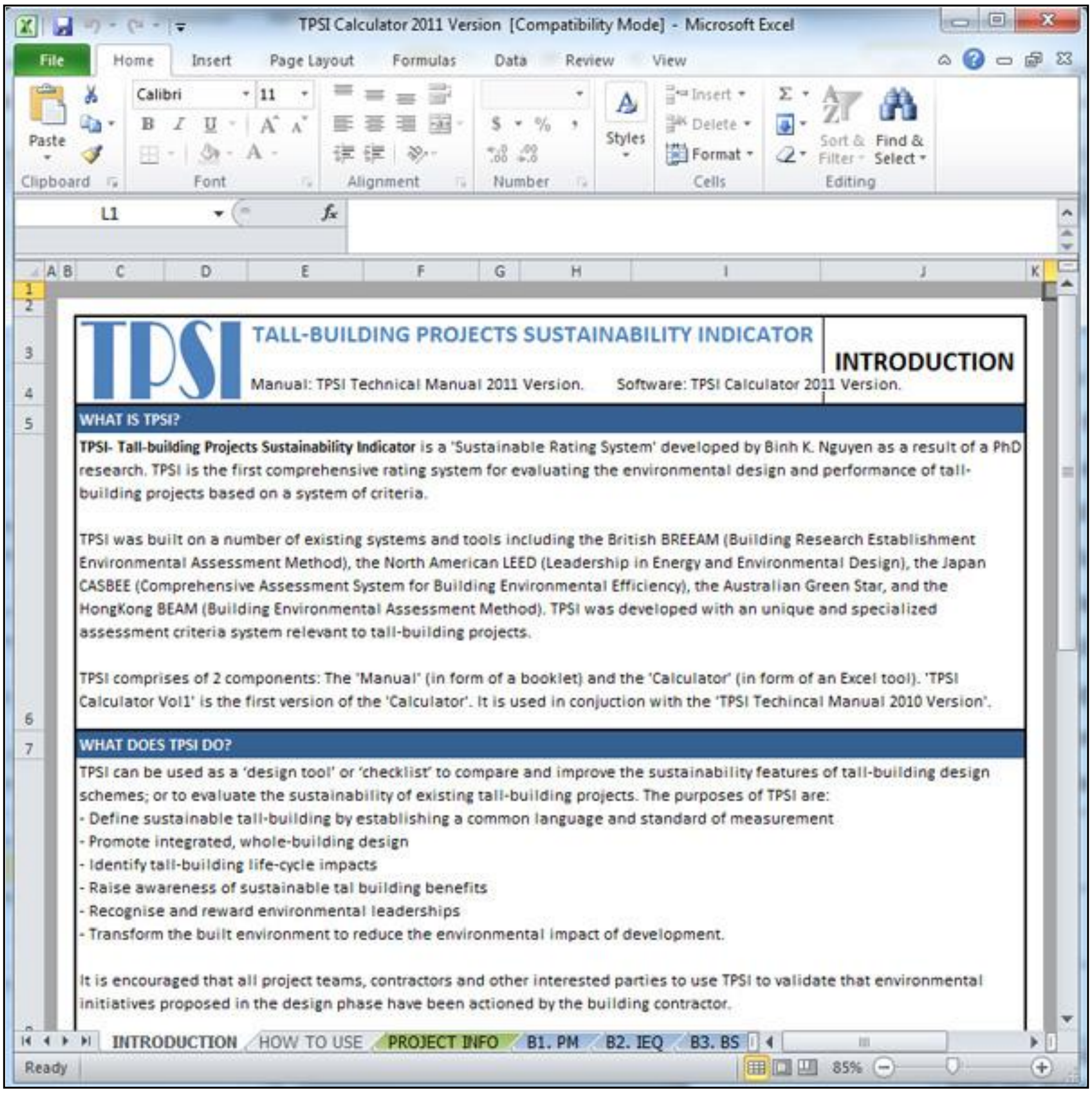


Figure 7.9: 'Introduction' tab - Screenshot

7.8.2. How to Use?

The simplified steps to assess a tall-building project using TPSI are as follow:

1. Enter the required project details into the 'Project Info' tab. Refer to the notes at the end of the 'Project Info' tab for instructions on inputting related information.
2. Switch to the next tab ('B1. PM'). Input the archived credits for each issue by selecting from the drop-down lists. Summarise the design considerations for the related category in the box at the end of the tab.

3. During the assessment process, refer to the TPSI Technical Manual 2012 Version for further guidance on assessment criteria/procedure and required evidence in order to score under each corresponding issue.
4. For some particular issues, there are options to scope out some or all available credits. Select the appropriate available credits from the drop-down list and then input achieved credits as in step (2). Refer to the TPSI Technical Manual 2012 Version for requirements needed to scope out available credits.
5. Repeat steps (2) - (4) for all remaining tabs (from ‘B2. IEQ’ to ‘IN’).
6. Switch to the last tab (‘Result’) for assessment results.

7.8.3. Default Weighting Factors

A weighting system is applied to all Category Scores to reflect the importance of each category. The default weighting factors applied to each assessment criteria category is as in Table 7.5. However, this weighting system is not fixed, it can automatically change based on the project’s characteristics.

Table 7.5: Default weighting factors

Categories	B1	B2	B3	B4	E1	E2	E3	E4	IN
Weighting factors	11%	14%	9%	8%	18%	8%	15%	9%	8%

The default weighting factors were determine by consulting the criteria systems of the Top Five rating systems. The simplified steps are as follow:

1. The criteria of each one of the Top Five rating systems were collected and reorganised into the same structure as TPSI’s assessment criteria system. For example, the 10 categories of BREEAM are broken down; BREEAM issues are rearranged into a new structure of nine categories – the same as TPSI. The other four rating systems (LEED, CASBEE, Green Star and HK-BEAM) are treated the same way. This proved to be a practical task since a similar procedure had already been done during the Comparative Review of Top Five rating systems (see Section 5.3).

2. The contributions of the categories towards the overall assessment (i.e. categories' weighting factors) are calculated for *each rating system*. The weighting factor of one category is calculated as follow:

$$Category's\ weighting\ factor = \frac{Category's\ available\ credits}{System's\ available\ credits}\ (\%)$$

3. Average weighting factors are calculated for nine categories. The weighting factors calculated for the Top Five rating systems, in fact, did not fluctuate much from each other (see Table 7.6).
4. These average factors are generally adopted by TPSI with modifications, which assume the considerations of tall-building specified issues. Based on these chosen weighting factors, credits are redistributed to TPSI issues. This weighting factors system is tested in various case-study projects until a consistent assessment result is reached.

Table 7.6: The weighting factors calculated for the Top Five rating systems

Systems \ Categories	B1	B2	B3	B4	E1	E2	E3	E4	IN
BREEAM	12%	13%	12%	9%	19%	8%	16%	9%	7%
LEED	10%	12%	8%	8%	14%	8%	14%	9%	9%
CASBEE	12%	11%	10%	7%	17%	8%	15%	11%	9%
Green Star	15%	15%	8%	7%	15%	8%	17%	7%	8%
HK-BEAM	11%	14%	7%	9%	20%	8%	18%	9%	7%
Average weighting factors	12%	13%	9%	8%	17%	8%	16%	9%	8%
Chosen weighting factors	11%	14%	9%	8%	18%	8%	15%	9%	8%

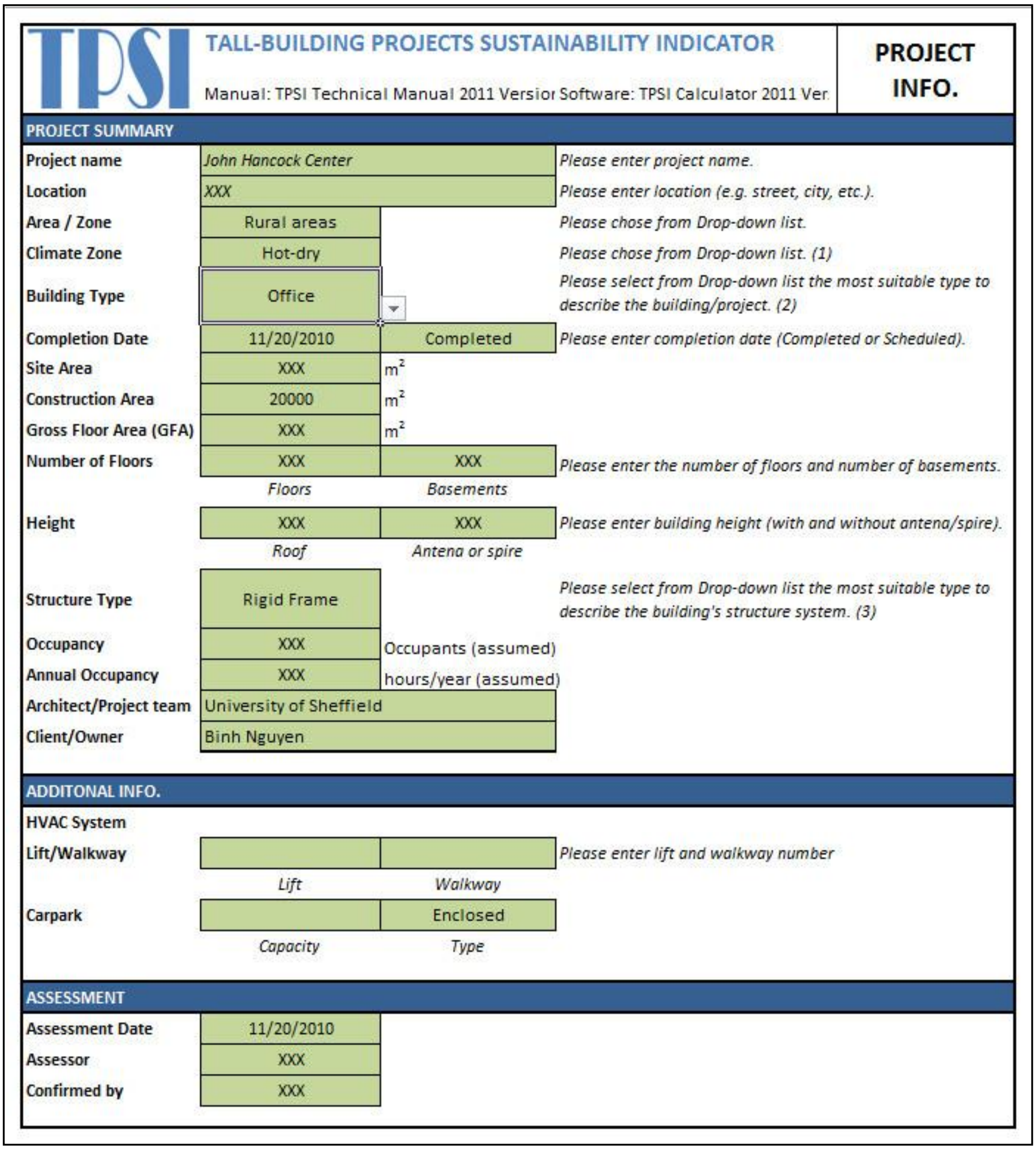
7.8.4. 'Project Info' Tab and the Dynamic Weighting System

It is very critical to understand that the value of weighting factors, important as it is, *should not be central* to an environmental rating tool. Assigning weighing factor to reflect the importance of a certain aspect toward overall sustainability is indeed a very good strategy. However, even with internationally renowned systems such as BREEAM or LEED, the allocation of credits (another expression of weighting factors), is always an internal process and cannot be correct everywhere. A single set of weighting factors cannot represent the interrelation of sustainability aspects of all countries and regions worldwide.

For example, Singapore and Vietnam are two neighbour countries in South East Asia with similar climate. However, in Vietnam water is just one of the regular sustainability aspects; while in Singapore the water sources is very scarce. The domestic resources only meet about 50% of Singapore's water demand (Baumgarten, 1998). To meet the demand, currently Singapore has to desalinise water at high costs and also treats sewage with reverse osmosis for industrial and portable use (Wikipedia, 2011b). Water is given the highest priority among all sustainability issues is this country. A well-established set of standards can be used in both Vietnam and Singapore (Green Mark and LOTUS, the Singapore and Vietnam national rating tools respectively, are both developed based on BREEAM and LEED – see Table 4.1). On the contrary, the weight of assessment issues cannot be the same. Overall, it is impossible that a single set of weighting factors can work equally well with every climate zone and/or country.

Trying to establish an 'ideal' set of weighting factors, is therefore a rather pointless endeavour. In fact, it is more reasonable to allow the alteration of weighting factors according to different context (i.e. the Dynamic Weighting System). Green Star has adopted this strategy successfully: employing different weighting factors for different states of Australia, so the system can be used in various regions with higher accuracy. By applying a dynamic weighting system, TPSI can adapt itself to different contexts and different types of tall-building projects. Changing the weighting factor of each category means changing its contribution towards the overall score and also reflecting its varied importance in different contexts, and therefore it produces a more accurate evaluation. This is an important advantage of TPSI over other existing rating systems.

Figure 7.10 and Figure 7.11 show some screenshots of the 'Project Info' tab. This is where users fill in information about their tall-building project (project name, location, completion date, construction and gross floor area, number of floors, height, occupancy, climate zone, building type, special technical systems, structure types, etc.). All these data will be used to calculate the weighting factor for each criteria category.



TALL-BUILDING PROJECTS SUSTAINABILITY INDICATOR

Manual: TPSI Technical Manual 2011 Versior Software: TPSI Calculator 2011 Ver.

PROJECT INFO.

PROJECT SUMMARY

Project name	*John Hancock Center*		*Please enter project name.*
Location	*XXX*		*Please enter location (e.g. street, city, etc.).*
Area / Zone	Rural areas		*Please chose from Drop-down list.*
Climate Zone	Hot-dry		*Please chose from Drop-down list. (1)*
Building Type	Office		*Please select from Drop-down list the most suitable type to describe the building/project. (2)*
Completion Date	11/20/2010	Completed	*Please enter completion date (Completed or Scheduled).*
Site Area	XXX	m^2	
Construction Area	20000	m^2	
Gross Floor Area (GFA)	XXX	m^2	
Number of Floors	XXX	XXX	*Please enter the number of floors and number of basements.*
	Floors	*Basements*	
Height	XXX	XXX	*Please enter building height (with and without antena/spire).*
	Roof	*Antena or spire*	
Structure Type	Rigid Frame		*Please select from Drop-down list the most suitable type to describe the building's structure system. (3)*
Occupancy	XXX	Occupants (assumed)	
Annual Occupancy	XXX	hours/year (assumed)	
Architect/Project team	University of Sheffield		
Client/Owner	Binh Nguyen		

ADDITONAL INFO.

HVAC System			
Lift/Walkway			*Please enter lift and walkway number*
	Lift	*Walkway*	
Carpark		Enclosed	
	Capacity	*Type*	

ASSESSMENT

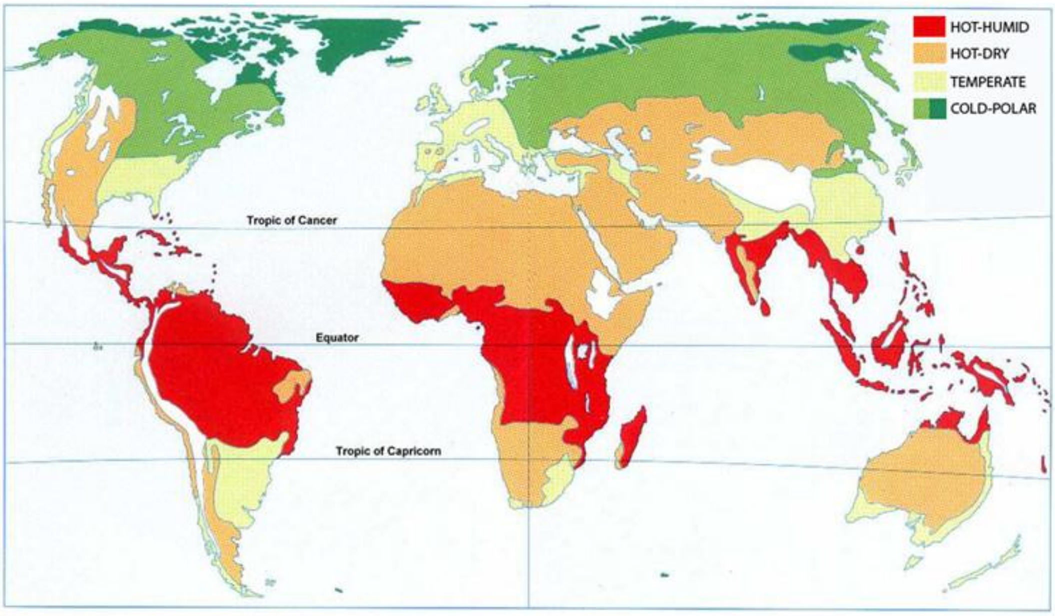
Assessment Date	11/20/2010
Assessor	XXX
Confirmed by	XXX

Figure 7.10: 'Project Info' tab – Screenshot 1

NOTES

(1) Climate Zones

For the purposes of the assessment, the climate zones are defined as the below image. The climate zone definition was adopted and simplified from Köppen climate classification.



(2) Building Types

Building Type	Types included
Mixed-use	Mixed-use buildings.
Office	Offices, government buildings, etc.
Commercial	Repartment stores, supermarkets, shopping centers, showrooms, etc.
Residential	Apartments, condominimums (detached houses are excluded), etc.
Hotel	Hotels, inns etc.
Health-care	Hospitals, medical centers and other health-care building types.
Education	Elementary schools, junior high schools, high schools, universities, technical colleges, higher vocational schools, and other education building types.

(3) Structure Types

The structure types and their efficient height are shown in the bellow image.

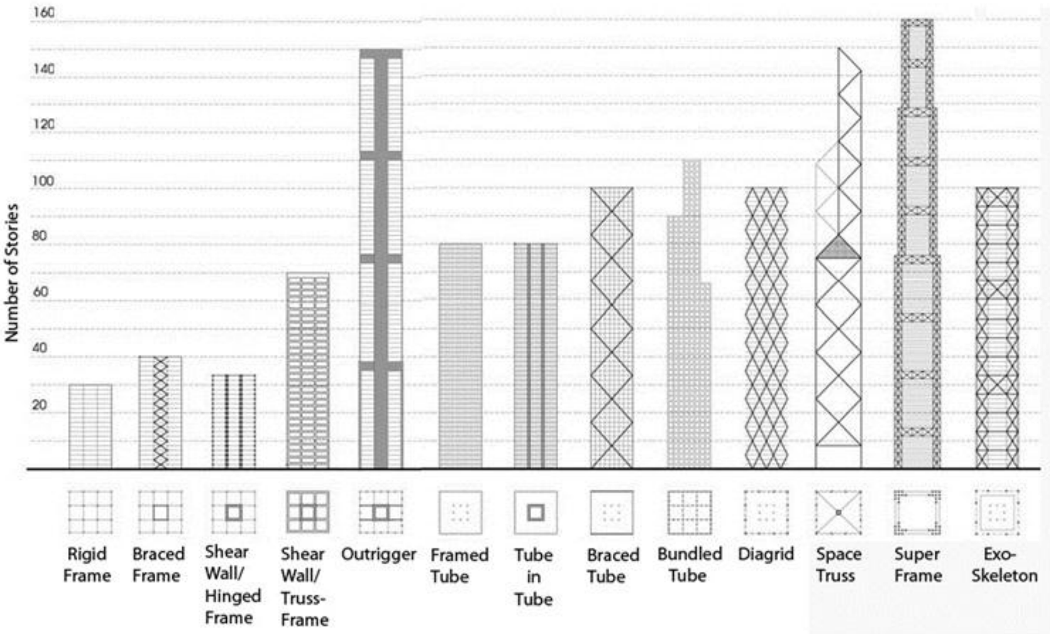


Figure 7.11: 'Project Info' tab – Screenshot 2

TPSI 2012 Version's weighting factors are dependent on three factors:

- Climate zones (Cold-polar, Hot-humid, Hot-dry or Temperate);
- Project's social context (City-centres or Rural Areas);
- Building types (Mixed-use, Office, Commercial, Residential, Hotel, Health-care or Education).

The data field for the selection of weighting factors according to these variables is presented in Appendix B. In the future, this weighting system can be developed further to take into account other factors such as structure type, building's occupancy, floor area, number of floors, etc. Potential further research is discussed in Chapter 10.

The TPSI's dynamic weighting system is a result of a long and intensive research into climate sensitive design and sustainability of tall-buildings, with main reference sources are assessment criteria of major existing rating systems such as BREEAM, LEED, Green Star, and CASBEE. Readers who are interested in knowing more about this weighting system can reveal a hidden tab of the Excel tool named 'Data' (use the password 'TPSI' when asked). This hidden tab contains all TPSI's data fields, from which one can figure out roughly the mechanism behind all TPSI calculations and evaluations as well as the Excel Macros involved.

7.8.5. 'Assessment' Tabs

Users will claim credits for their project using nine 'Assessment' tabs equivalent to eight main categories and Innovation category. These nine 'Assessment' tabs are similar in term of layout. Figure 7.12 shows a sample screenshot of one of the 'Assessment' tabs.

Users claim credits by choosing from the drop-down lists. The total available credits of the current category and the credits achieved are shown in the bottom of the tab. The Section Score or Category Score (updated automatically as users claiming the credits) is shown in the top-left corner. The category's weighting factor and Category Score after weighted is shown in the top-right corner.

In an 'Assessment' tab, each TPSI issue is structured as followed (see Figure 7.12):

- **Sub-category ID and Name.**
- **Issue ID.**
- **Issue Name.**
- **Issue Aim**: broadly outlines the objective of the issue as shown in the TPSI Technical Manual.
- **Issue Summary**: outlines the performance target and how credits are awarded (only briefly, users will have to refer to the TPSI Technical Manual for full contents of the issues).
- **Issue's available credits:** shows maximum credits that can be awarded and options to scope out credits.
- **Issue's achieved credits:** here is where users claim credits for their project.
- **Note.**

TPSI is very suitable for a project in-progress. Users do not have to finish off an 'Assessment' tab before switching to another one. They can freely examine and work with TPSI issues in the provided order or according to their own priority, thus gradually improves their project's aspects as it is being developed.

Users can use the 'Save As' function of Microsoft Excel to save their current assessment for further stages of the projects. They then can wipe every entry they inputted and carry out a new assessment. It is intended for TPSI Calculator to have no function to tell users when they 'finish' an assessment. In other words, there is no end to an assessment loop, but at the same time users can stop whenever they want, even without finishing all the issues (and still have a completed results presentation). Users would keep improving their projects until they are satisfied with the performance. They can come back later and record new enhancements if the project has further developments. This serves the purpose of making TPSI a managing tool that users would use throughout their project stages, not just simply a rating tool.

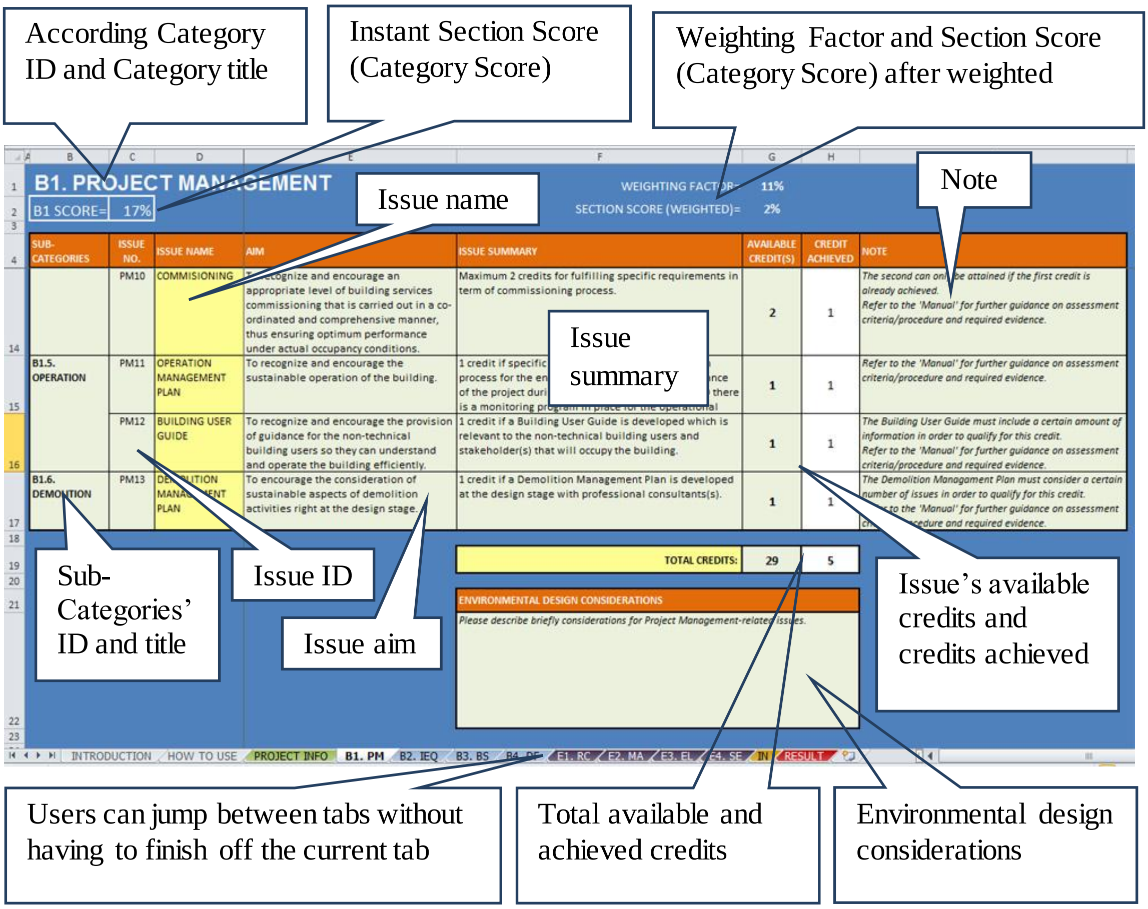


Figure 7.12: A sample screenshot of one of the 'Assessment' tabs

Prerequisite Issues

For Prerequisite Issues, there is no credit to earn; instead the Drop-down lists provide 2 options: 'Achieved' or 'Not-Achieved.' Figure 7.13 shows an example of how a Prerequisite Issue works in TPSI Calculator:

- By default the option 'Not-achieved' is always picked. In this case, users cannot score under issues that are covered by this Prerequisite Issue – the cells to claim credits are locked and turned to grey.
- Once the Prerequisite Issue is fulfilled and the option 'Achieved' is picked, the locked cells will return to normal.

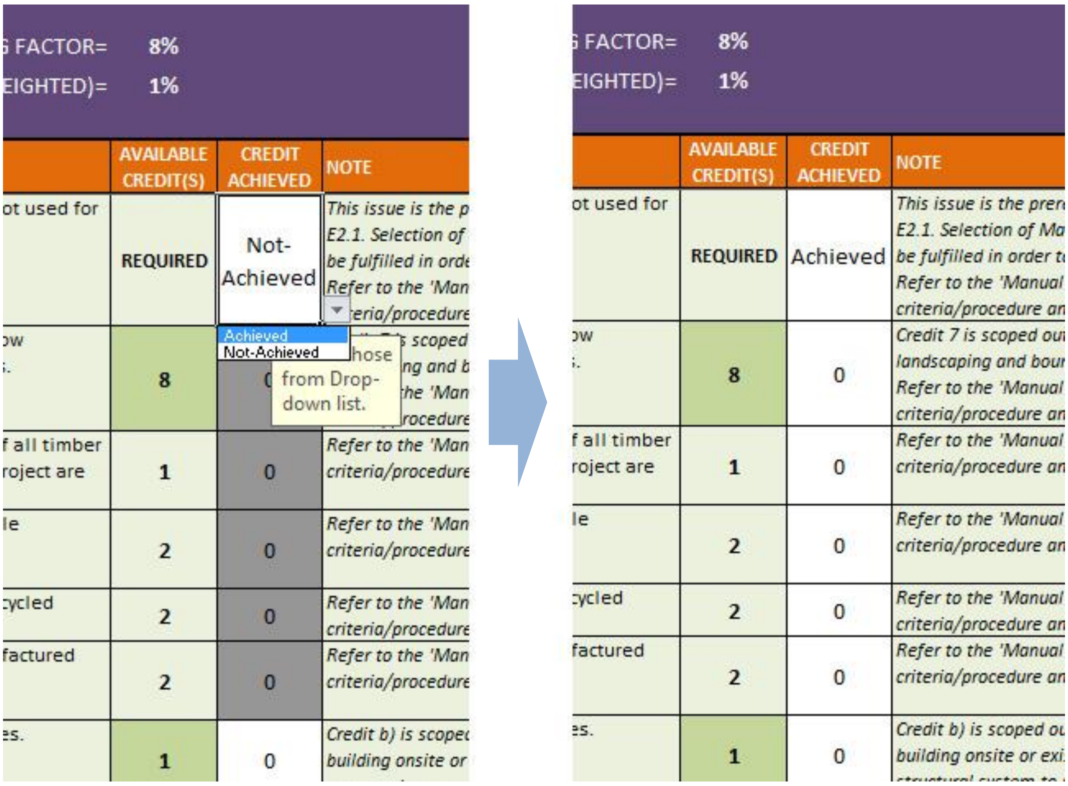


Figure 7.13: How a prerequisite issue works in TPSI Calculator

Issues that can be scoped-out

When an issue can be fully or partly scoped-out, its' 'Available Credit(s)' box is coloured in dark green as an indication (see Figure 7.14). When clicking this box, users will be able to choose the available credits option that is suitable to their current situation. TPSI will automatically update the change in total available credits and assessment results accordingly. The according 'Note' box and the equivalent issue in TPSI Technical Manual will provide further relevant information.

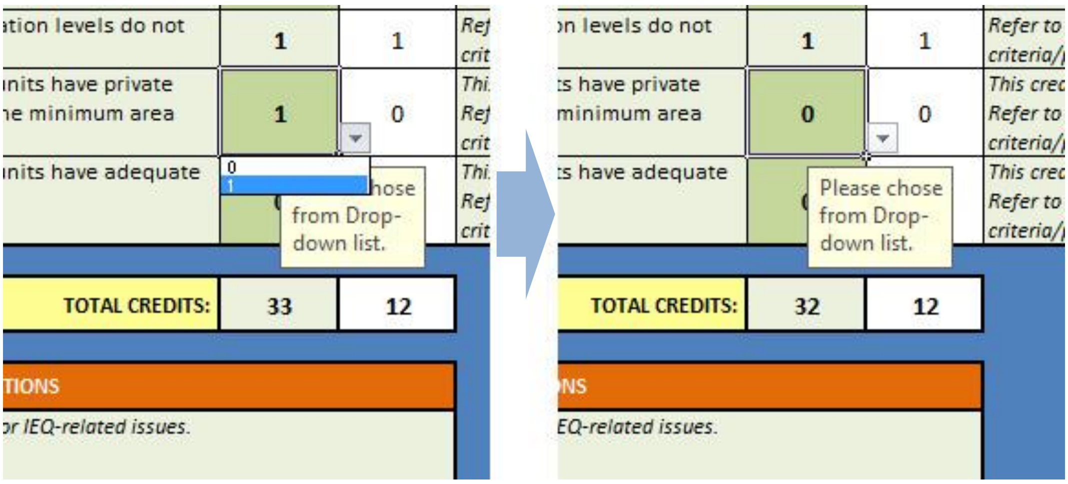


Figure 7.14: Example of how to fully/partly scope-out an issue in TPSI Calculator

7.8.6. 'Result' Tab

The 'Result' Tab presents the assessments, evaluations, charts, graphs, design recommendations, issues summary, overall ranking and other outcomes of the evaluation process. Figure 7.15, Figure 7.16 and Figure 7.17 show sample screenshots of the 'Result' tab and different types of result presentations available.

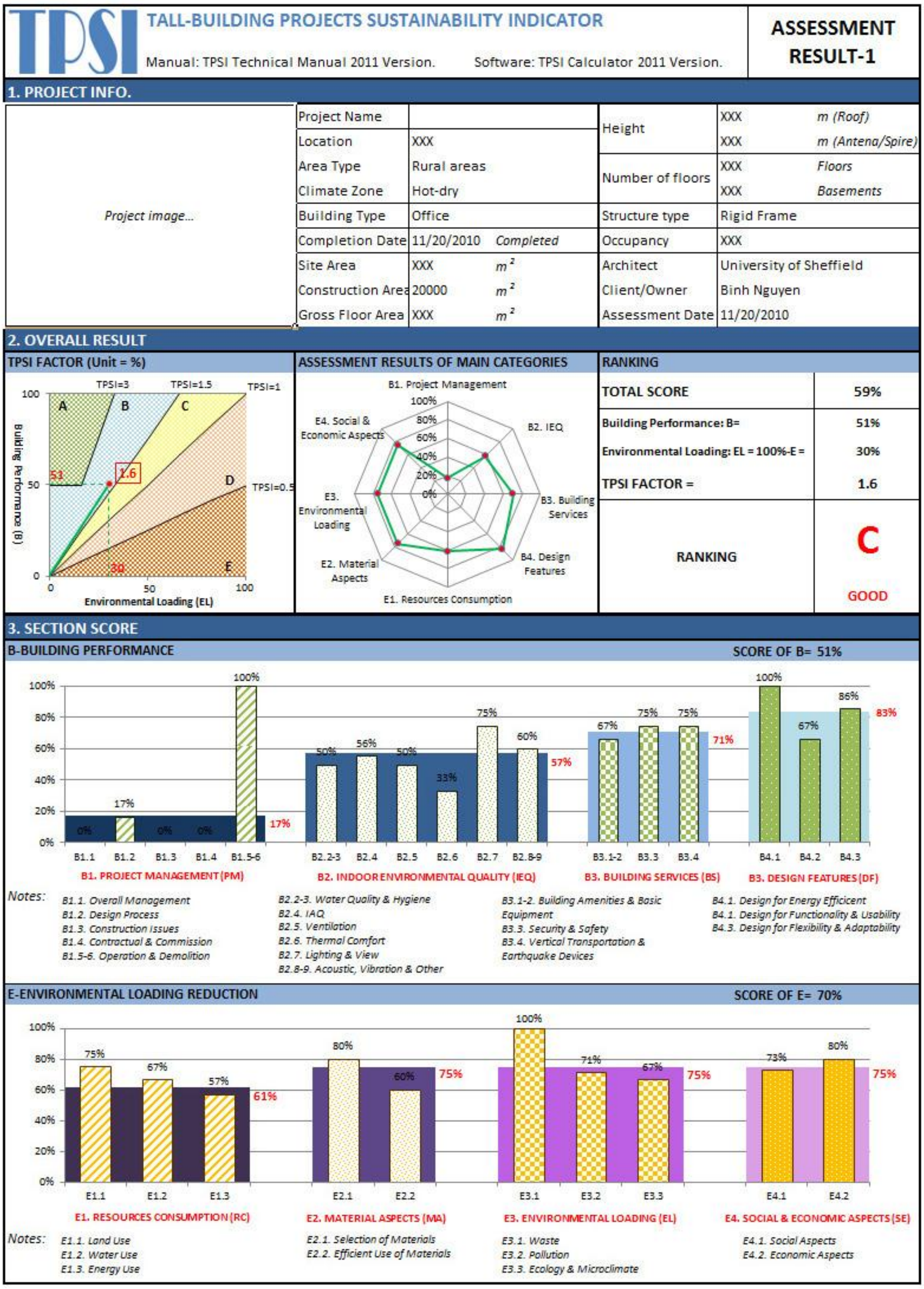


Figure 7.15: Sample screenshot of the 'Result' tab – Ranking, charts and graphs

TPSI TALL-BUILDING PROJECTS SUSTAINABILITY INDICATOR

Manual: TPSI Technical Manual 2011 Version. Software: TPSI Calculator 2011 Version.

ASSESSMENT RESULT-2

ISSUES SUMMARY

	Available credits	Credits achieved
B1. Project Management (PM)	**29**	**5**
PM1. Basic Principles	3	0
PM2. Environmental Management	5	0
PM3. Site Investigation	3	0
PM4. Whole-life Approach	2	0
PM5. Site Design Appraisal	1	1
PM6. Choice of Construction Process	1	0
PM7. Construction Site impacts	4	0
PM8. Construction Safety	2	0
PM9. Contractual & Procurement	3	0
PM10. Commissioning	2	1
PM11. Operation Management Plan	1	1
PM12. Building User Guide	1	1
PM13. Demolition Management Plan	1	1
Section Score	*Before weighted* **17%**	*Weighted* **2%**
B2. IEQ	**35**	**20**
IEQ-P1. Minimum Ventilation	Required	Achieved
IEQ1. Water Quality	1	1
IEQ2. Plumbing and Drainage	1	0
IEQ3. Biological Contamination	1	0
IEQ4. Waste Disposal Facilities	1	1
IEQ5. ETS control	1	0
IEQ6. Construction IAQ Management	2	1
IEQ7. Outdoor Sources of Air Pollution	2	1
IEQ8. Indoor Sources of Air Pollution	3	3
IEQ9. IAQ in Car Parks	1	0
IEQ10. Increased Ventilation	1	1
IEQ11. Natural Ventilation	1	1
IEQ12. Localized Ventilation	2	1
IEQ13. Ventilation in Common Areas	2	0
IEQ14. Thermal Comfort Design	2	1
IEQ15. Thermal Zoning	1	0
IEQ16. Natural Lighting & Glare	2	1
IEQ17. Interior Lighting 1	2	1
IEQ18. Interior Lighting 2	1	1
IEQ19. High Frequency Lighting	1	1
IEQ20. Lighting Zones and Control	1	1
IEQ21. View Out	1	1
IEQ22. Room Acoustics	1	0
IEQ23. Noise Isolation	0	0
IEQ24. Background Noise	1	1
IEQ25. Indoor Vibration	1	0
IEQ26. Private Open Space	1	1
IEQ27. Visual Privacy	1	1
Section Score	*Before weighted* **57%**	*Weighted* **8%**
B3. Building Services (BS)	**17**	**12**
BS1. Access for Persons wt Disability	1	1
BS2. Amenity Features	1	0
BS3. Water Supply & Drainage System	1	1
BS4. Electrical Equipment	1	0
BS5. HVAC System	1	1
BS6. Communications & IT Equipment	1	0
BS7. Service Life of Components	2	2
BS8. Maintenance of Core Functions	1	1
BS9. Security	1	1
BS10. Fire Safety and Evacuation	3	2
BS11. Lifts	1	1
BS12. Escalator & Walkways	1	1
BS13. Earthquake Resistance	2	1
Section Score	*Before weighted* **71%**	*Weighted* **6%**
B4. Design Features (DF)	**12**	**10**
DF1. Energy Efficient Building Layout	2	2
DF2. Provision of Space	1	1
DF3. Maintenance Management	2	1
DF4. Spatial Flexibility	3	3
DF5. Spatial Margin	2	1
DF6. Floor Load Margin	1	1
DF7. Adaptability of Facilities	1	1
Section Score	*Before weighted* **83%**	*Weighted* **7%**

	Available credits	Credits achieved
E1. Resources Consumption (RC)	**44**	**27**
RC1. Land Use & Re-use	2	2
RC2. Land Use Efficiency	1	0
RC3. On-site Resources	1	1
RC4. Annual Water Consumption	4	2
RC5. Monitoring and Control	2	1
RC6. Water Efficient Irrigation	1	0
RC7. Water Harvesting and Recycling	3	3
RC8. Water Efficient Facilities & Appliances	1	1
RC9. Innovative Wastewater Technologies	1	1
RC-P1. Basic Energy Performance	Required	Achieved
RC10. Energy Use Reduction	18	9
RC11. Energy Use in Car Parks & Public Areas	2	1
RC12. Low or Zero Carbon Technologies	4	4
RC13. Clothes Drying Facilities	1	0
RC14. Energy Efficient Appliances	1	1
RC15. Metering and Monitoring	2	1
Section Score	*Before weighted* **61%**	*Weighted* **11%**
E2. Material Aspects (MA)	**20**	**15**
MA-P1. Timber Used for Temporary Works	Required	Achieved
MA1. Materials Specification	8	7
MA2. Certified Wood	1	1
MA3. Rapidly Renewable Materials	2	1
MA4. Recycled Content	2	2
MA5. Regional Materials	2	1
MA6. Building Reuse	1	0
MA7. Modular and Standardized Design	1	1
MA8. Prefabrication	1	0
MA9. Efficient Structure Design	1	1
MA10. Design for Robustness	1	1
Section Score	*Before weighted* **75%**	*Weighted* **6%**
E3. Environmental Loading (EL)	**32**	**24**
EL1. Construction/Demolition Waste	2	2
EL2. Recycled and Secondary Aggregates	1	1
EL3. Waste Recycle Facilities	1	1
EL4. Compactor/Baler	1	1
EL5. Compositing	1	1
EL6. Land Pollution	1	1
EL7. Refrigerant Use and Leakage	3	3
EL8. NOX Emissions	3	3
EL9. Water Pollution	1	1
EL10. Flood Risk	3	0
EL11. Noise Pollution	1	1
EL12. Light Pollution	1	1
EL13. Overshadowing and Views	1	0
EL14. Protection of Ecological Value	1	1
EL15. Mitigation of Ecological Impacts	2	0
EL16. Enhancement of Ecological Value	3	3
EL17. Long-term Impact on Bio-diversity	2	0
EL18. Surrounding Microclimate	4	4
Section Score	*Before weighted* **75%**	*Weighted* **11%**
E4. Social & Economic Aspects (SE)	**16**	**12**
SE1. Public Transport	3	3
SE2. Pedestrian and cyclist	3	1
SE3. Maximum Car Parking Capacity	1	1
SE4. Travel Plan	1	1
SE5. Neighborhood Amenities	1	1
SE6. Local Character	1	1
SE7. Historic Environment	1	0
SE8. Life Cycle Cost and Payback Time	2	2
SE9. Affordability of Rental/Cost Levels	1	1
SE10. Support of Local Economy	1	1
SE11. Mixed-use Development	1	0
Section Score	*Before weighted* **75%**	*Weighted* **7%**
Innovations (IN)	**16**	**3**
IN1. Innovative Strategies & Technologies	5	0
IN2. Exemplary Performance	11	3
Section Score	*Before weighted* **19%**	*Weighted* **2%**

TOTAL SCORE = 59%

Figure 7.16: Sample screenshot of the 'Result' tab – Issues summary

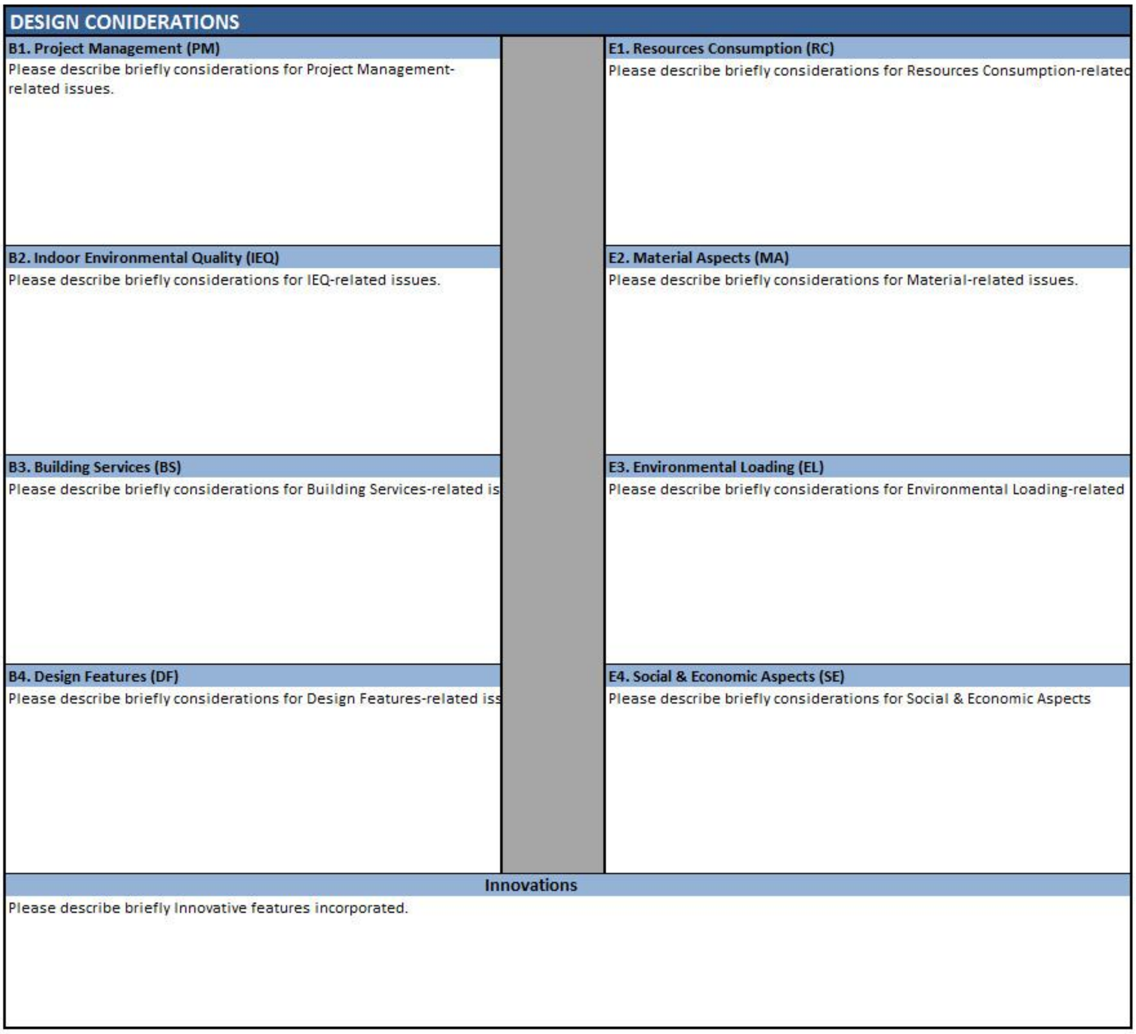


Figure 7.17: Sample screenshot of the 'Result' tab – Design considerations

7.9. TPSI ISSUES SUMMARY

Table 7.7 summaries all TPSI issues in the same order as presented in the TPSI Technical Manual 2012 Version and TPSI Calculator 2012 Version. Refer to Section 7.4 for the structure of TPSI's Categories and Sub-Categories.

Table 7.7: TPSI Issues' summary

Section	Issue	Issue summary	Possible credit(s)
B1. PROJECT MANAGEMENT (PM)			**29**
B1.1. Overall Management	PM1. Basic Principles	a) 1 credit if there is an Environmental Management System (EMS) to consider and assess the environmental aspects for each stage of the project. b) 1 credit if a member of the project team is identified as responsible for managing the environmental aspects of the project and is aware of the duties and responsibilities involved. c) 1 credit if environmental impacts, opportunities for environmental enhancements and associated social issues are: !Identified and clearly recorded for each stage, AND !Prioritised according to significance.	3
	PM2. Environmental Management	a) 1 credit if appropriate mechanisms are put in place to manage project's environmental issues, impacts and opportunities. 1 additional credit if regular checks are made to ensure that these mechanisms are implemented. 1 additional credit if there is a record of actions to be taken as a result of these checks. b) 1 credit if the results of the implementation of these mechanisms are assessed. c) 1 credit if there is a program of training on environmental and social issues relevant to the project delivered at an appropriate level for those engaged in the project.	5
B1.2. Design Process	PM3. Site Investigation	a) Maximum 2 credits for carrying out a Site Investigation at design stage. b) 1 credit for the incorporation of the sequenced site investigation activities during the project.	3
	PM4. Whole-life Approach	a) 1 credit if the design team adopts a whole-life approach to sustainable aspects of the project. b) 1 credit if the whole-life approach includes consideration of the potential effects of predicted climate change scenarios, leading to appropriate adaptation strategies.	2
	PM5. Site Design Appraisal	1 credit for a Site Design Appraisal report that demonstrates a proactive approach to achieve greater integration of site planning issues.	1
B1.3. Construction Issues	PM6. Choice of Construction Process	1 credit if the design team considers the environmental and social implications of different construction methods and technologies.	1
	PM7. Construction Site impacts Management	Maximum 4 credits if a Construction Impact Management Plan with specific targets are set during the design process for the environmental and social performance of the project *during construction* and progress toward the Plan is monitored.	4

	PM8. Construction Safety	a) 1 credit for adopting an Accident Prevention Scheme. b) 1 credit for providing a Safe Working Environment.	2
B1.4. Contractual and Commission Process	PM9. Contractual and Procurement Process	a) 1 credit if all parties directly engaged in the project are informed of the significant environment impacts and associated social issues of their part and/or stage of the project. b) 1 credit if the selection procedure for the following parties consider their past and potential environmental performance: - The principal designer - The main contractor - The key sub-contractor(s) c) 1 credit if the contract requirements for the designers and contractors expressly include achievement of specific environmental and social performance.	3
	PM10. Commissioning	Maximum 2 credits for fulfilling specific requirements in term of commissioning process.	2
B1.5. Operation	PM11. Operation Management Plan	1 credit if specific targets are set during the design process for the environmental and social performance of the project *during operation* or once in use, AND there is a monitoring program in place for the operational phase.	1
	PM12. Building User Guide	1 credit if a Building User Guide is developed which is relevant to the non-technical building users and stakeholder(s) that will occupy the building.	1
B1.6. Demolition	PM13. Demolition Management Plan	1 credit if a Demolition Management Plan is developed at the design stage with professional consultants(s).	1
B2. INDOOR ENVIRONMENTAL QUALITY (IEQ)			**36**
B2.1. Prerequisite	IEQ-P1. Minimum Ventilation Performance	Demonstrate compliance with the specific minimum requirements in respect of Outdoor Air Quality and Minimum Ventilation Rate.	Required
B2.2. Water Quality	IEQ1. Water Quality	1 credit if the quality of potable water meets the referenced drinking water quality standards at all points of use.	1
B2.3. Hygiene	IEQ2. Plumbing and Drainage	1 credit for designs that eliminate the potential for transmission of harmful bacteria viruses and odours.	1
	IEQ3. Biological Contamination	1 credit for complying with specific recommendations in respect of Legionnaires' disease prevention.	1
	IEQ4. Waste Disposal Facilities	1 credit for the provision of a hygienic refuse collection system.	1
B2.4. Indoor Air Quality (IAQ)	IEQ5. Environmental Tobacco Smoke (ETS) control	1 credit for complying with specific recommendations in respect of ETS Control.	1

	IEQ6. Construction IAQ Management	a) 1 credit for implementing a Construction IAQ Management Plan. b) 1 credit for undertaking a building ‘flush-out’ or ‘bake-out’ and replacement of all filters prior to occupancy.	2
	IEQ7. Outdoor Sources of Air Pollution	a) 1 credit for demonstrating compliance with appropriate criteria for Carbon monoxide (CO), Nitrogen dioxide (NO_2) and Ozone (O_3). b) 1 credit for demonstrating compliance with the appropriate criteria for Respirable Suspended Particle (PM_{10}).	2
	IEQ8. Indoor Sources of Air Pollution	a) 1 credit for demonstrating compliance with appropriate criteria for Volatile Organic Compounds (VOCs). b) 1 credit for demonstrating compliance with appropriate criteria for Formaldehyde (HCHO). c) 1 credit for demonstrating compliance with appropriate criteria for Radon (Rn).	3
	IEQ9. IAQ in Car Parks	1 credit for demonstrating compliance with the specific design requirements in respect of car parks air quality.	1
B2.5. Ventilation	IEQ10. Increased Ventilation Performance	1 credit for demonstrating an outdoor ventilation rate that exceeds the minimum ventilation performance requirements by at least 30%.	1
	IEQ11. Potential for Natural Ventilation	1 credit where it can be demonstrated that adequate ventilation can be achieved by natural means.	1
	IEQ12. Localised Ventilation	a) 1 credit for the provision of an adequate ventilation system for rooms/areas where significant indoor pollution sources are generated. b) 1 credit for the provision of a general exhaust system for future tenants.	2
	IEQ13. Ventilation in Common Areas	a) 1 credit for demonstrating that all enclosed common areas in a building are provided with adequate ventilation. b) 1 additional credit where the provision for ventilation is by natural means.	2
B2.6. Thermal Comfort	IEQ14. Thermal Comfort Design	Maximum 2 credits for delivering thermal comfort using specific design tools.	2
	IEQ15. Thermal Zoning	1 credit for the design of the heating/cooling system that allows flexible control of different areas within the building.	1
B2.7. Lighting and View	IEQ16. Natural Lighting and Glare Control	a) 1 credit if at least 80% of floor area in all normally occupied spaces is adequately lit with an average daylight factor (DF) of $\geq$ 2%. b) 1 credit for providing suitable daylight glare control and maintaining the average DF of 2%.	2

	IEQ17. Interior Lighting in Normally Occupied Areas	a) 1 credit where the prescribed lighting performance in each type of premises in respect of illuminance and lighting quality is achieved. The following requirements are compulsory: - Prescribed lighting performance in respect of maintained illuminance and illuminance variation is achieved, AND - The limiting unified glare rating is achieved and light sources have an appropriate colour rendering index. b) 1 additional credit for providing automatic control of artificial lighting such as daylight sensors at perimeter zone and/or occupancy sensor.	2
	IEQ18. Interior Lighting in Areas not Normally Occupied	1 credit if the prescribed lighting performance in each type of common or service space in respect of light output and lighting quality is achieved.	1
	IEQ19. High Frequency Lighting	1 credit if all fluorescent and compact fluorescent lamps are fitted with high frequency ballast.	1
	IEQ20. Lighting Zones and Control	1 credit if lighting is zoned to allow separate occupant control of different functional areas.	1
	IEQ21. View Out	1 credit for design that delivers adequate external views to the occupants.	1
B2.8. Acoustics and Noise	IEQ22. Room Acoustics	1 credit for demonstrating that internal noise levels are within the prescribed criteria and the mid-frequency reverberation time in applicable rooms meets the prescribed criteria for give types of premises.	1
	IEQ23. Noise Isolation	1 credit for demonstrating: - Airborne noise isolation between rooms, spaces and premises meets the prescribed criteria AND - Impact noise isolation between floors meets the prescribed criteria (for residential projects only).	1
	IEQ24. Background Noise	1 credit for demonstrating background noise levels are within the prescribed criteria.	1
B2.9. Other Issues	IEQ25. Indoor Vibration	1 credit for demonstrating that vibration levels do not exceed the prescribed criteria.	1
	IEQ26. Private Open Space	1 credit if at least 70% of dwelling units have private open space meeting or exceeding the minimum area criteria.	1
	IEQ27. Visual Privacy	1 credit if at least 70% of dwelling units have adequate visual privacy.	1
B3. BUILDING SERVICES (BS)			**17**
B3.1. Building Amenities	BS1. Access for Persons with Disability	1 credit for providing adequate and enhanced provisions for access for disabled persons.	1

	BS2. Amenity Features	1 credit for providing adequate and enhanced amenity features for the benefit of building users and for improved operation and maintenance of the building.	1
B3.2. Basic Building Equipment	BS3. Water Supply and Drainage System	1 credit for applying specific efforts to improve the performance of water supply and drainage system.	1
	BS4. Electrical Equipment	1 credit for applying specific efforts to improve the performance of electrical equipment.	1
	BS5. HVAC System	1 credit for applying specific efforts to improve the performance of HVAC system.	1
	BS6. Communications and IT Equipment	1 credit for applying specific efforts to improve the performance of communications and IT equipment.	1
	BS7. Service Life of Components	Maximum 2 credits for complying with specific refurbishment/renewal/replacement interval for building service components.	2
	BS8. Maintenance of Core Building Functions during Power Outages	1 credit if the building can continue to provide minimally acceptable service for at least 4 day under conditions of temperature, rainfall, power and fuel supply that fall outside of anticipated design conditions.	1
B3.3. Security and Safety	BS9. Security	1 credit for scoring at least 75% of the applicable security measures and facilities for the building.	1
	BS10. Fire Safety and Evacuation	a) 1 credit for design that complies with recognised Fire Safety and Evacuation standards. b) 1 credit for demonstrating design integration between fire services systems and non-fire services systems. c) 1 credit for the provision of a Fire Safety Manual based on a fire-risk assessment.	3
B3.4. Vertical Transportation	BS11. Lifts	1 credit for applying specific efforts to improve the performance of lifts system.	1
	BS12. Escalator and Travelling Walkways	1 credit for applying specific efforts to improve the performance of escalators and travelling walkways.	1
B3.5. Earthquake Resistance	BS13. Earthquake Resistance	a) 1 credit if the design meets or exceeds recognised earthquake resistance standards. Alternatively, damage control design has been used. b) 1 credit if a seismic isolation system or a vibration damping system is installed to prevent sway in time of strong wind or earthquake.	2
B4. DESIGN FEATURES (DF)			**12**
B4.1. Design for Energy Efficient	DF1. Energy Efficient Building Layout	Maximum 2 credits for incorporating specific design strategies in respect of energy efficient building layout.	2
B4.2. Design for Functionality and Usability	DF2. Provision of Space	1 credit for fulfilling the specific design standards in respect of provision of space.	1
	DF3. Maintenance Management	a) 1 credit for design that considers maintenance management. b) 1 additional credit for securing maintenance management functions.	2

B4.3. Design for Flexibility and Adaptability	DF4. Spatial Flexibility	a) 1 credit for providing spatial flexibility that can adapt spaces for different uses, and allows for expansion to permit additional spatial requirements to be accommodated. b) 1 credit for flexible design of services that can adapt to changes of layout and use. c) 1 credit for designs providing flexibility through the choice of building structural system that allows for change in future use, and which is coordinated with interior planning modules.	3
	DF5. Spatial Margin	a) 1 credit for meeting floor-to-floor height allowance. b) 1 credit for meeting wall length/area recommended ratio.	2
	DF6. Floor Load Margin	1 credit for meeting recommended floor load capacity.	1
	DF7. Adaptability of Facilities	1 credit for fulfilling the specific design standards in term of building facilities' adaptability.	1
E1. RESOURCES CONSUMPTION (RC)			**44**
E1.1. Land Use	RC1. Land Use and Re-use	a) 1 credit if at least 75% of the proposed development's footprint is on an area of land which has been *previously developed* for use by industrial, commercial or domestic purposes in the last 50 years. b) 1 credit if the site is deemed to be *significantly contaminated* and remediation strategies are carried out.	2
	RC2. Land Use Efficiency	1 credit if the land-take of different scheme designs, process designs and layouts of the planned works are calculated, AND these calculations influence the design process and the land use efficiency of the final design.	1
	RC3. On-site Resources	1 credit if the design and construction of the project take into consideration the conservation/use/reuse of topsoil, subsoil, minerals resources and other excavated materials as a result of the development.	1
E1.2. Water Use	RC4. Annual Water Consumption	1 to 4 credits for demonstrating that the use of water efficient devices leads to an estimated aggregate annual saving of 10%, 20%, 30% and 40% respectively.	4
	RC5. Monitoring and Control	a) 1 credit for installation of a water meter and sub-meter system. b) 1 credit for installation of a leak detection system.	2
	RC6. Water Efficient Irrigation	1 credit for adopting an irrigation system that does not require the use of municipal fresh water after a period of establishment is complete. ALTERNATELY, 1 credit for demonstrating highly efficient irrigation technology and/or the use of harvested rainwater and/or recycled grey water to reduce freshwater consumption for irrigation by 50% or more in comparison with conventional irrigation of water intensive planting.	1

	RC7. Water Harvesting and Recycling	a) 1 credit for harvesting of rainwater which will lead to a reduction of 5% or more in the consumption of fresh water b) 1 credit for the provision of plumbing and drainage system for separation of grey water from black water. 1 additional credit where recycled grey water will lead to a reduction of 10% or more in the building's annual consumption of fresh water.	3
	RC8. Water Efficient Facilities and Appliances	1 credit for installing water efficient facilities (pools, spas, fountains, etc.) and appliances that are at least 20% more efficient than otherwise.	1
	RC9. Innovative Wastewater Technologies	1 credit for reducing annual potable water use for building sewage conveyance by at least 50%. ALTERNATIVELY, 1 credit for treating at least 50% of wastewater on-site (annually) to tertiary standard (treated water must be infiltrated or used on-site).	1
E1.3. Energy Use	RC-P1. Basic Energy Performance	Demonstrating a minimum improvement in the building's energy performance compared with the Baseline Building performance rating.	Required
	RC10. Energy Use Reduction	a) Maximum 15 credits for demonstrating extra improvements in the building's energy performance compared with the Baseline Building performance rating. b) Maximum 3 credits for demonstrating reductions in the maximum electricity demand compared with the Baseline Building.	18
	RC11. Energy Use in Car Parks and Public Areas	a) 1 credit for ventilation systems that will consume less electricity than those meeting the zero-credit requirements (baseline) by 25% or more. b) 1 credit for fulfilling the specific requirements in respect of lighting for car parks and external public areas.	2
	RC12. Low or Zero Carbon Technologies	Maximum 4 credits for supplying the energy demand by low or zero carbon technologies (renewable energy).	4
	RC13. Clothes Drying Facilities	1 credit for providing suitable clothes drying facilities that utilise the natural environment for all residential units.	1
	RC14. Energy Efficient Appliances	1 credit if at least 70% of total rated power of appliances and equipment are certified energy efficient products.	1
	RC15. Metering and Monitoring	a) 1 credit for providing *separate accessible energy sub-meters* for different energy-consuming systems. b) 1 credit for providing accessible sub-meters covering the energy supply to all tenanted, or in the case of single occupancy buildings, relevant function areas or departments within the building/unit.	2

E2. MATERIAL ASPECTS (MA)			**21**
E2.1. Selection of Materials	MA-P1. Timber Used for Temporary Works	Demonstrate that virgin forest products are not used for temporary works during construction.	Required
	MA1. Materials Specification	Maximum 8 credits for using materials with low environmental impacts for building elements.	8
	MA2. Certified Wood	1 credit for demonstrating that at least 50% of all timber and composite timber products used in the project are from sustainable source/recycled timber.	1
	MA3. Rapidly Renewable Materials	Maximum 2 credits for using rapidly renewable materials.	2
	MA4. Recycled Content	Maximum 2 credits for using material with recycled contents.	2
	MA5. Regional Materials	Maximum 2 credits for using regionally manufactured materials.	2
E2.2. Efficient Use of Materials	MA6. Building Reuse	a) 1 credit for reusing existing building facades. b) 1 credit for reusing existing structures.	2
	MA7. Modular and Standardised Design	1 credit for the application of modular and standardised design.	1
	MA8. Prefabrication	1 credit where the manufacture of 40% of applicable building elements has been off-site.	1
	MA9. Efficient Structure Design	1 credit if the amount of steel used in the building structure is less than 28 psf (Pounds per Square Foot) or 136.7 kg/m^2.	1
	MA10. Design for Robustness	1 credit for applying specific efforts to provide adequate protection of vulnerable parts of the building and landscape.	1
E3. ENVIRONMENTAL LOADING (EL)			**32**
E3.1. Waste	EL1. Construction/ Demolition Waste Management	Maximum 2 credits for the implementation of a Construction/Demolition Waste Management Plan that provides for the sorting, recycling and proper disposal of construction and demolition materials.	2
	EL2. Recycled and Secondary Aggregates	1 credit for utilising recycled and/or secondary aggregates.	1
	EL3. Waste Recycle Facilities	1 credit for providing adequate facilities for the collection, sorting, storage and disposal of waste and recovered materials.	1
	EL4. Compactor/Baler	1 credit for providing a compactor/baler for the building.	1
	EL5. Compositing	1 credit for providing facilities that help reducing the volume of compostable organic waste during the building's operation.	1

E3.2. Pollution	EL6. Land Pollution	1 credit if there are measures, including monitoring of any containment or contaminant, in place to prevent any land pollution during the life of the building.	1
	EL7. Refrigerant Use and Leakage	a) 1 credit if there are no refrigerants specified for use in building services OR the refrigerants used have a global warming potential (GWP) of less than 5. b) 1 credit for installing a refrigerant leak detection system. c) 1 additional credit for installing a refrigerant recovery system.	3
	EL8. NO_X Emissions	Maximum 3 credits for using a heating system that has a low dry NO_X emission level.	3
	EL9. Water Pollution	1 credit for applying specific measures to reduce the potential for silt, heavy metals, chemicals or oil pollution to natural watercourses from surface water run-off from buildings and hard surfaces during the building's life cycle.	1
	EL10. Flood Risk	a) Maximum 2 credits if the building is located in a zone with low probability of flooding. b) 1 additional credit for applying attenuation measures to reduce the peak rate of water run-off.	3
	EL11. Noise Pollution	1 credit if the development cause no new source of noise which give rise to the likelihood of complaints from surrounding noise-sensitive receivers.	1
	EL12. Light Pollution	1 credit for demonstrating that the building's tallness/size/façade glazing/external light installations etc. cause no light pollution by complying with the specific criteria.	1
	EL13. Overshadowing and Views	1 credit for designs for which the access to daylight and views of neighbouring sensitive buildings is maintained to the prescribed level.	1
E3.3. Ecology and Microclimate	EL14. Protection of Ecological Value	1 credit for fulfilling specific requirements in order to protect the site's existing ecological value.	1
	EL15. Mitigation of Ecological Impacts	Maximum 2 credits for keeping the change in ecological value of the site to a minimum.	2
	EL16. Enhancement of Ecological Value	a) 1 credit for implementing professional recommendations/measures in order to protect and enhance the site's ecological value. b) 2 credits if these recommendations/measures result in an increase in the site's ecological value.	3
	EL17. Long-term Impact on Bio-diversity	Maximum 2 credits for implementing specific efforts to minimise the long term impact on the biodiversity of the site and surrounding area.	2
	EL18. Surrounding Microclimate	a) 1 credit for conducting an Air Ventilation Assessment (AVA) by wind tunnel or CFD[1]and demonstrating the optimal option is selected in comparing with different options. b) 1 credit for demonstrating that no pedestrian areas will be subject to excessive wind velocities caused by amplification due to the site layout and/or building design. c) 1 credit for applying adequate measures over non-roof areas to prevent heat island effect. d) 1 credit for applying adequate measures over roof areas to prevent heat island effect.	4

E4. SOCIAL AND ECONOMIC ASPECTS (SE)			**16**
E4.1. Social Aspects	SE1. Public Transport	3 credits if the building is located in proximity to public transport networks/nodes.	3
	SE2. Pedestrian and cyclist	a) 1 credit for providing adequate cycle storage spaces for building users. b) 1 credit for providing adequate supporting cyclists' facilities for building users. c) 1 credit for providing safe and secure pedestrian and cycle access routes on the development.	3
	SE3. Maximum Car Parking Capacity	1 credit if no more than 1 car parking space is provided for every 4 building users.	1
	SE4. Travel Plan	1 credit if a Travel Plan is available to building users which allows and encourages them to choose from a range of travel options instead of using private vehicles.	1
	SE5. Neighbourhood Amenities	1 credit if the building is located in proximity to adequate local amenities.	1
	SE6. Local Character	1 credit for the design that takes into consideration the surroundings and blends in with, or enhances, the local character.	1
	SE7. Historic Environment	1 credit if the building is not located on site of historic environment assets.	1
E4.2. Economic Aspects	SE8. Life Cycle Cost and Payback Time	a) 1 credit for demonstrating that efforts have been taken to minimise the Life Cycle Cost of the building. b) 1 credit for demonstrating that the expected payback time of the building is within 15 years.	2
	SE9. Affordability of Rental/Cost Levels	1 credit if the design team takes into account the total occupancy cost (rental cost or total carrying charges and upkeep of a purchased unit) and the average household income in the urban region.	1
	SE10. Support of Local Economy	1 credit if the amount of construction expenditure benefitting the economy of the urban region is ≥ 30% of total construction cost.	1
	SE11. Mixed-use Development	1 credit for the adoption of a mixed-use strategy based on a holistic investigation of local conditions and opportunities.	1
INNOVATION (IN)			**16**
	IN1. Innovative Strategies and Technologies	Maximum 5 credits for adopting procurement strategies, design features, management processes and/or technological development that innovate in the field of sustainability, beyond the scope of current TPSI issues.	5
	IN2. Exemplary Performance	Maximum 11 credits for exceeding the stated performance criteria under various TPSI issues.	11
TOTAL	**116 Issues + 3 Prerequisites**		**223 credits**

7.10. CHAPTER CONCLUSIONS

Chapter 6 and Chapter 7 – which represent 'Part B - Developing' stage of the research - have executively summarised the foundations for the development of TPSI and introduced the system itself. As the ultimate outcome of Part B, TPSI 2012 Version (comprises TPSI Technical Manual 2012 Version and TPSI Calculator 2012 Version) – the very first release of TPSI System – was fully functional after one and a half years since the commencement of the research.

The fact that developing a whole sustainability rating system is quite a major task for an individual PhD research is well aware by the candidate and his supervisor - Dr. Hasim Altan. In fact, some of the features and visions for the system that were planned in the beginning could not be incorporated into this first version due to the lack of human and financial resources. However, the current functions and features of TPSI – which are described in this chapter – are believed to be an improvement over existing rating systems, especially in term of sustainable tall-buildings evaluation.

In the next and final part ('Part C – Testing and Proving'), TPSI's advantages and performance will be tested in real-life. It is important to note that the development of TPSI is an interactive process during which TPSI is constantly improved based on many parties' opinions and criticism. In other words, although presented in the middle of this thesis, *the features of TPSI that were described in Part B already assumed all enhancements and perfections taken place during Part C of this research/thesis.*

CHAPTER 8: THE TRIAL PERIOD

8

8.1. CHAPTER INTRODUCTION

'Part C - Testing and Proving' is the final stage of the research which aims to verify the advantages of TPSI as well as the contributions of the research (see Figure 2.8 for the research framework). The main goals of Part C are:

- To test the utilisations of TPSI in real-life projects;
- To compare TPSI's performance with other existing rating systems;
- To prove TPSI's advantages over other existing rating systems when using in tall-building projects;
- To seek for validation of TPSI's advantages and reliance from trustworthy parties;
- To introduce TPSI to potential users;
- To build up the foundations to the future development of TPSI; and
- To validate the research's other contributions.

Part C is presented in two chapters:

- Chapter 8 summaries the Trial Period; during which, TPSI's performance, utilisation and advantageous are scrutinised from multiple viewpoints. TPSI is also updated and improved throughout this stage.
- Chapter 9 briefly introduces the development of TPSI rating scheme with the involvement of the University of Sheffield and some UK firms, as well as plans for the future growth of TPSI. This chapter is the proof of TPSI's technical contributions, practical values, and commercial potential.

8.2. SUMMARY OF THE TRIAL PERIOD

The Trial Period is divided into two phases: the Self-testing Phase and the External-testing Phase (or Interview Process).

The Self-testing Phase

By October 2010, the research was at the end of the 'Developing' stage and TPSI system was nearly ready to use. There were, however, some technical issues with the TPSI Calculator (mainly lay with Excel Macro-coding), which required expert helps/instructions. There were also difficulties of triggering the Trial Period. As planned, TPSI has to go through a Self-testing Phase first before engaging to the External-testing activities. During the Self-testing Phase, TPSI is supposed to be used by the candidate in several tall-buildings projects in the UK. A financial support was much needed for all of the expert helps and travelling fees.

From October 2010 to December 2010, the research received the Christopher Jones Studentship (administered by Dr. Chengzhi Peng of the University of Sheffield). The amount was quite limited (£700) but indeed a great help at the time. The scholarship was used to pay for travelling fees to several UK cities to test the utilisation of TPSI, and for some training sessions on the use of Excel Macros. Thanks to this support the fist version of TPSI was ready for the External-testing Phase (see Section 8.3).

The External-testing Phase (Interview Process)

The External-testing Phase was mainly carried out in form of interview sessions. This interview process lasted five months (from December 2011 to April 2011), which include three months in Vietnam (interval travelling to some South-East Asian countries were also involved – with financial supports by the Vietnamese Ministry of Construction) and two months in the UK.

A trial version of TPSI was provided to a number of individuals and organisations to test and verify its functions and advantages over other existing rating systems. The parties participated in this stage were chosen from the contacts of the candidate and his supervisors, and especially from the introduction and arrangement of the Vietnamese Ministry of Construction. There were over 50 individuals and organisations that made commitments to take part in the interview process (results of only 40 cases are chosen to analyse). Each participant had to use TPSI and some other rating systems with the same tall-building project.

A questionnaire was designed based on *the same screening criteria that were used to evaluate existing rating systems* (see Section 4.5 and Table 4.4) with some alterations. *The purpose is to compare the results gathered from external sources with the results of the Screening Analysis process*, which were presented throughout Chapter 4 of the thesis. Based on the feedback, TPSI' disadvantages and bugs were fixed or improved until a certain level of satisfaction was achieved within the participants. See Section 8.4 for the list of interviewees and case studies, questionnaire format, and results of the interview process.

8.3. SELF-TESTING PHASE

8.3.1. Christopher Jones Studentships and the Case Studies

The Christopher Jones Studentship were created in 1990 by the Reverend D Vernon Jones and Mrs Jones in memory of Christopher Jones, a student in the School of Architecture, University of Sheffield from 1985 to 1987. The purpose of the Studentships is to assist students in the School of Architecture who wish to carry out research in the area of computer aided design in Architecture.

The administration panel of the Christopher Jones Studentship has recognised the development of TPSI as a practical research, which would contribute a progressive tool to aid the design and management of tall-building projects. From October 2010 to December 2010, the research was supported by the Christopher Johns Studentship. Some contents of this section are extracted from the Scholarship Report (Nguyen, 2011).

The Christopher Johns Studentship came with a very good timing and really helped to kick-start the 'Testing and Proving' stage. A small amount of fund (£400) was spent for tutoring sessions on Microsoft Macros, which solved some technical issues of TPSI Calculator. The remains (£400) paid for travelling fees and other expenditures while visiting UK cities.

A number of buildings in the UK were chosen to test the performance of TPSI system in real-life projects. Six tall-buildings projects in Sheffield, Manchester, Birmingham, Newcastle, Liverpool and London were assessed. Due to the scope of this section, only one case study is presented below as a demonstration. The object is the Beetham Tower in Manchester city centre.

8.3.2. Featured Case Study: the Beetham Tower, Manchester

Project detail:

Location: 301 - 303 Deansgate, Manchester, UK.

Status: Complete (Constructed: 2004–2007).

Use: Mixed-use (hotel and residential).

Height: 168.87 metres (554 ft) - Floor count: 48.

Cost: £150 million.

Architect: Ian Simpson Architects.

Structural engineer: WSP Group Contractor Carillion.

Developer: Beetham Organisation.

Figure 8.1: The Beetham Tower – Manchester, UK

Figure 8.2: The core and steel frame structure of Beetham Tower

The Beetham Tower is a landmark 47-storey residential tall-building in Manchester city centre. Built in 2007, it is named after the developers, Beetham Organisation, was designed by Ian Simpson and was built by Carillion. It is the tallest skyscraper outside London, tallest building in Manchester, and overall the seventh tallest building in the UK. The skyscraper is visible from ten of the thirty-eight English counties on a clear day and is the tallest residential building in the country. It consists of a Hilton Hotel up to level 23 and apartments from level 25 up to the triplex penthouse on level 47. There are also two basement levels, which contain car parking for the residents of the apartments. It is also known as the Hilton Tower (Wikipedia, 2011c).

During the assessment, the TPSI Calculator and TPSI Technical Manual worked quite smoothly in collaboration with each other. The whole assessment took only about two days. The actual assessment time is likely to be longer because many of the documentations required are either ignored or couldn't be found, therefore a number of issues couldn't be appropriately assessed. Nevertheless this is a promising outcome.

The result of the assessment is shown below (see Figure 8.3, Figure 8.4, Figure 8.5, Table 8.1 and Figure 8.6).

TPSI

TALL-BUILDING PROJECTS SUSTAINABILITY INDICATOR

Manual: TPSI Technical Manual 2010 Version. Software: TPSI Calculator Vol1.

PROJECT INFO.

PROJECT SUMMARY			
Project name	*Beetham Tower*		*Please enter project name.*
Location	*Deansgate, Manchester, UK*		*Please enter location (e.g. street, city, etc.).*
Area / Zone	City-centers		*Please chose from Drop-down list.*
Climate Zone	Temperate		*Please chose from Drop-down list. (1)*
Building Type	Mixed-use		*Please select from Drop-down list the most suitable type to describe the building/project. (2)*
Completion Date	01/05/2007	Completed	*Please enter completion date (Completed or Scheduled).*
Site Area	n/a	m^2	
Construction Area	n/a	m^2	
Gross Floor Area (GFA)	50000	m^2	
Number of Floors	47	2	*Please enter the number of floors and number of basements.*
	Floors	*Basements*	
Height	168.87	168.87	*Please enter building height (with and without antena/spire).*
	Roof	*Antena or spire*	
Structure Type	Shear Wall / Hinged Frame		*Please select from Drop-down list the most suitable type to describe the building's structure system. (3)*
Occupancy	1000	Occupants (assumed)	
Annual Occupancy	n/a	hours/year (assumed)	
Architect/Project team	Ian Simpson Architects		
Client/Owner	Beetham Organization		

Figure 8.3: Beetham Tower's TPSI assessment – 'Project Info.' tab

B1. PROJECT MANAGEMENT

B1 SCORE= 59%

WEIGHTING FACTOR= 13%

SECTION SCORE (WEIGHTED)= 8%

SUB-CATEGORIES	ISSUE NO.	ISSUE NAME	AIM	ISSUE SUMMARY	AVAILABLE CREDIT(S)	CREDIT ACHIEVED	NOTE
	PM8	CONSTRUCTION SAFETY	To recognize and encourage the implementation of best practices in term of Construction Safety.	**a)** 1 credit for adopting an Accident Prevention Scheme. **b)** 1 credit for providing a Safe Working Environment.	**2**	2	*The projec requireme Refer to th criteria/pr*
B1.4. CONTRACTUAL AND COMMISSION PROCESS	PM9	CONTRACTUAL AND PROCUREMENT PROCESS	To encourage the awareness of sustainable issues of all parties engaged in the project.	**a)** 1 credit if all parties directly engaged in the project are informed of the significant environment impacts and associated social issues of their part and/or stage of the project. **b)** 1 credit if the selection procedure for the following parties consider their past and potential environmental performance: - The principal designer - The main contractor - The key sub-contractor(s) **c)** 1 credit if the contract requirements for the designers and contractors expressly include achievement of specific environmental and social performance.	**3**	1	*Refer to th criteria/pr*
	PM10	COMMISIONING	To recognize and encourage an appropriate level of building services commissioning that is carried out in a co-ordinated and comprehensive manner, thus ensuring optimum performance under actual occupancy conditions.	Maximum 2 credits for fulfilling specific requirements in term of commissioning process.	**2**	1	*The secon Refer to th criteria/pr*
B1.5. OPERATION	PM11	OPERATION MANAGEMENT PLAN	To recognize and encourage the sustainable operation of the building.	1 credit if specific targets are set during the design process for the environmental and social performance of the project during operation or once in use, AND there is a monitoring program in place for the operational phase.	**1**	1	*Refer to th criteria/pr*
	PM12	BUILDING USER GUIDE	To recognize and encourage the provision of guidance for the non-technical building users so they can understand and operate the building efficiently.	1 credit if a Building User Guide is developed which is relevant to the non-technical building users and stakeholder(s) that will occupy the building.	**1**	1	*The Buildi informatio Refer to th criteria/pr*
B1.6. DEMOLITION	PM13	DEMOLITION MANAGEMENT PLAN	To encourage the consideration of sustainable aspects of demolition activities right at the design stage.	1 credit if a Demolition Management Plan is developed at the design stage with professional consultants(s).	**1**	0	*The Demol issues in o Refer to th criteria/pr*
				TOTAL CREDITS:	29	17	

Figure 8.4: Beetham Tower's TPSI assessment – 'Project Management' tab

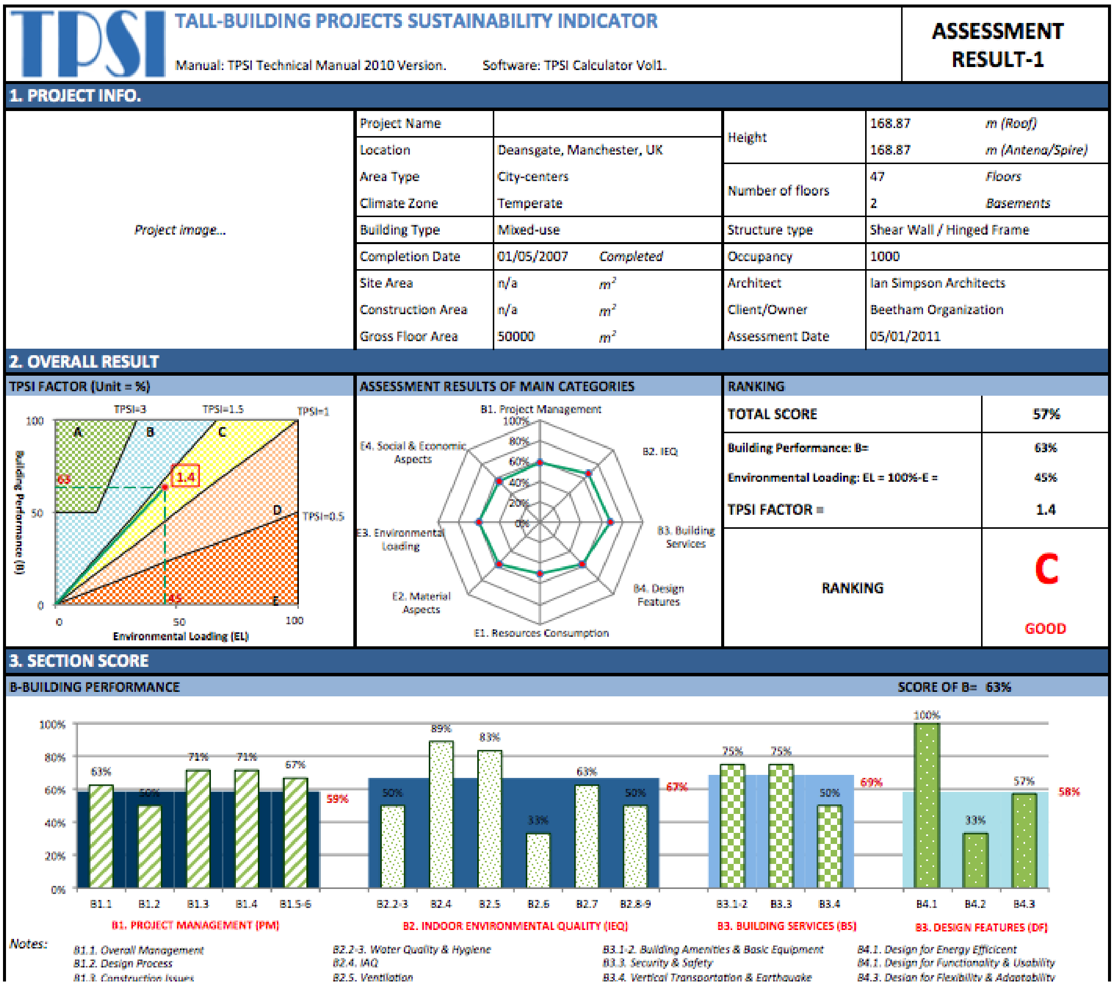


Figure 8.5: Beetham Tower's TPSI assessment – 'Result' tab

Table 8.1: Beetham Tower's TPSI assessment – Issues checklist

Issue	Available credits	Credits achieved	Notes	Bases for the assessment
B1. Project Management (PM)	**29**	**17**		
PM1. Basic Principles	3	2	Environmental Manager is not assigned.	An Environmental Management Report (EMR) is available which can substitute the EMS. However an Environmental Manager cannot be identified.
PM2. Environmental Management	5	3	Results of the implementation are not assessed. No training provided.	Assessment based on the EMR's contents. Appropriate management mechanisms available but no information regarding training activities and results monitoring.
PM3. Site Investigation	3	2	There are site investigations activities but not sufficient according to the Investigation Sequence of Events.	Reports and drawings showing the studies of: general topography, general geology, historical land use, underground services, foundation details and construction plans, laboratory geology test results, flood risk. However no activities after design stage.
PM4. Whole-life Approach	2	0	None.	No document to support the integrated design process.
PM5. Site Design Appraisal	1	1	All requirements are met.	Drawings showing the studies of different site scheme, which consider wider urban and land use issues.
PM6. Choice of Construction Process	1	1	All requirements are met.	Evaluation based on architect's recommendation that different constructions technologies were studied.
PM7. Construction Site impacts Management	4	2	Items 1, 2, 4, 7 are fulfilled.	Survey documents of CO_2 level and air pollution during construction. The EMR is available but no materials policy, no gas risk study, and no water pollution study.
PM8. Construction Safety	2	2	All requirements are met.	Evaluation based on architect's recommendation that contractor followed local safety procedure.
PM9. Contractual and Procurement Process	3	1	Credit b) and c) are not achieved.	Selection procedure doesn't consider potential environmental performance of parties. Contract requirements not available. No format of contract.
PM10. Commissioning	2	1	Credit b) is not achieved.	Evaluation based on the EMR. Requirements for commissioning of complex systems are not achieved.
PM11. Operation Management Plan	1	1	All requirements are met.	Operation Management Plan available

PM12. Building User Guide	1	1	All requirements are met.	Booklets for operation of building services are available which can substitute the Building User Guide. Detailed manuals to operating pre-fitted devices for tenants available online.
PM13. Demolition Management Plan	1	0	None.	No documents regarding demolition management.
B2. Indoor Environmental Quality (IEQ)	**36**	**24**		
IEQ-P1. Minimum Ventilation Performance	Required	✓	All requirements are met.	Local standard is adopted instead of ASHRAE 62.1-2007. Assessment based on architect's recommendation, no actual documental evidence.
IEQ1. Water Quality	1	1	All requirements are met.	Local standard is adopted instead of ISO. Water quality survey carried out every 2 years.
IEQ2. Plumbing and Drainage	1	0	Adopted standard is not qualified.	Plans of water supply and sewage systems do not show adequate contamination prevention mechanism.
IEQ3. Biological Contamination	1	0	Adopted standard is not qualified.	Plans of water supply and sewage systems do not show adequate Legionnaires disease prevention.
IEQ4. Waste Disposal Facilities	1	1	All requirements are met.	The development adopted the Waste Storage and Collection Guidance - Manchester City Council.
IEQ5. ETS control	1	1	All requirements are met.	Smoking is totally prohibited within the site.
IEQ6. Construction IAQ Management	2	1	Credit b) not achieved.	The EMR showed consideration pollution during construction but no evidence that the building 'flush-out' process was carried out.
IEQ7. Outdoor Sources of Air Pollution	2	2	All requirements are met.	Air quality survey showing no permanent outdoor or indoor sources of air pollution. Assessment also based on Beetham Tower's SAP Energy Performance Certificate. The building scored 86 (B) under SAP's Environment Impact (CO_2) Rating.
IEQ8. Indoor Sources of Air Pollution	3	3	All requirements are met.	
IEQ9. IAQ in Car Parks	1	1	Air quality in Car Park is met.	CO_2 monitoring devices are installed in car park.
IEQ10. Increased Ventilation Performance	1	0	None.	Required evidence of enhanced air quality sample not available.
IEQ11. Potential for Natural Ventilation	1	1	All requirements are met.	Building capable of functioning in 100% natural ventilation mode (through windows). Assessment based on floor plans.
IEQ12. Localised Ventilation	2	2	All requirements are met.	Assessment based on floor plans.

IEQ13. Ventilation in Common Areas	2	2	All requirements are met.	Enclosed common areas are adequately ventilated. Natural means available. Assessment based on floor plans.
IEQ14. Thermal Comfort Design	2	0	None.	Evidence not available.
IEQ15. Thermal Zoning	1	1	Thermal zoning available.	Separate occupant control of heating and cooling system available. Assessment based on architect’s recommendation.
IEQ16. Natural Lighting and Glare Control	2	2	Building utilises many devices to control natural lighting and glare.	High-end device such as flipping louvers on the south side, aluminium strips on the west and east side. Ultraviolet glass. Assessment based on façade details.
IEQ17. Interior Lighting in Normally Occupied Areas	2	2	All lighting standards are met.	Assessment based on sample lighting level measurement during site visit. Sensors to provide automatic control of artificial lighting.
IEQ18. Interior Lighting in Areas not Normally Occupied	1	1	All lighting standards are met.	Assessment based on sample lighting level measurement during site visit.
IEQ19. High Frequency Lighting	1	1	High frequency ballast available.	Assessment based on architect’s recommendation, no actual evidence available.
IEQ20. Lighting Zones and Control	1	0	Lighting zone available but not all functional areas.	No evidence for the lighting zone controlling of some communal areas such as restaurant, swimming pool, ballroom.
IEQ21. View Out	1	1	Adequate view out provided.	Calculations based on floor plans and elevations.
IEQ22. Room Acoustics	1	0	None.	Occupiers affected by loud noise generated by a thin glass blade at the top during strong winds. There is no sufficient noise isolation strategy available.
IEQ23. Noise Isolation	1	0	None.	
IEQ24. Background Noise	1	0	None.	
IEQ25. Indoor Vibration	1	1	Vibration level within prescribed criteria.	Survey carried out by Acoustic and Engineering Consultants Ltd (AEC) showed no noticeable vibration during strong winds.
IEQ26. Private Open Space	1	0	Only 40% dwelling units have adequate open spaces.	Calculations based on floor plans and sections of residential units.
IEQ27. Visual Privacy	1	0	Only 55% dwelling units have adequate visual privacy.	
B3. Building Service (BS)	**16**	**11**		
BS1. Access for Person with Disability	1	1	All requirements are met.	Local standard is adopted regarding provisions for access for disabled persons.
BS2. Amenity Features	1	1	6 out of 8 features available.	Assessment based on online tenants guide.
BS3. Water Supply and Drainage System	1	1	4 out of 6 items fulfilled.	Assessment based on design specs. There is no rainwater collection system. No use of well water and grey water.

BS4. Electrical Equipment	1	1	All 4 items fulfilled.	Assessment based on electric equipment operation and maintenance manual.
BS5. HVAC System	1	0	Only 1 item fulfilled.	Assessment based on HVAC operation and maintenance manual.
BS6. Communications and IT Equipment	1	1	All 3 items fulfilled.	Assessment based on photos during site visit.
BS7. Service Life of Components	2	0	None.	No evidence regarding the service life of building components.
BS8. Maintenance of Core Building Functions during Power Outages	1	1	All requirements are met.	Assessment based on electric equipment operation and maintenance manual. Building equipped with uninterruptible power source systems and emergency generator.
BS9. Security	1	1	All requirements are met.	Assessment based on online Security and Safety guide for tenants.
BS10. Fire Safety and Evacuation	3	2	Credit b) for design integration between services is not achieved.	
BS11. Lifts	1	1	All requirements are met.	Assessment based on lift catalogues.
BS12. Escalator and Travelling Walkways	Scoped out	-	None.	This issue does not apply to the building.
BS13. Earthquake Resistance	2	1	Credit b) is not achieved.	Building designed to withstand 1973 Greater Manchester Earthquake. Seismic isolation or vibration damping systems not available. Assessment based on architect's recommendation.
B4. Design Features (DF)	**12**	**7**		
DF1. Energy Efficient Building Layout	2	2	All 5 items fulfilled.	Design drawings and specifications showed the considerations of build form, building orientation, natural ventilation, passive solar design, shading devices, etc.
DF2. Provision of Space	1	1	Design standard is met.	Assessment based on floor areas calculation.
DF3. Maintenance Management	2	1	Credit b) is not achieved.	Design specification showed considerations to maintenance management but in reality building maintenance causes major disruptions to traffic and other safety issues for pedestrian.
DF4. Spatial Flexibility	3	2	Credit c) is not achieved.	Assessment based on floor plans.
DF5. Spatial Margin	2	1	Credit b) is not achieved.	Wall length/area ratio is not met. Assessment based on floor plans.
DF6. Floor Load Margin	1	0	None.	Evidence not available.
DF7. Adaptability of Facilities	1	0	Only 3 out of 6 items fulfilled.	Assessment based on operation and management manuals of building services and equipment.

E1. Resources Consumption (RC)	44	22		
RC1. Land Use and Re-use	2	1	The site is previously developed.	Assessment based on Site Appraisal and site planning schemes.
RC2. Land Use Efficiency	1	1	Different land use scenarios were studied	
RC3. On-site Resources	1	0	On-site resources are not utilised properly.	
RC4. Annual Water Consumption	4	2	Percentage reduction = 23%	Assessment based on architect's recommendation.
RC5. Monitoring and Control	2	1	Leak detection system not available.	Assessment based on water meters specification and catalogues. No evidence showing the installation of leaf detection system.
RC6. Water Efficient Irrigation	1	0	Irrigation uses > 50% fresh water.	Assessment based on plumbing and sewage system maps, online tenant guide, devices catalogues and maintenance logs. No evidence showing the utilisation of rainwater and grey water. Online tenant guide showed the installation of water saving devices in residential floors but no evidence showing the installation of water efficient facilities in pool and other public water features.
RC7. Water Harvesting and Recycling	3	0	The building uses entirely network water.	
RC8. Water Efficient Facilities and Appliances	1	0	Water efficient facilities are not installed for all of building premises.	
RC9. Innovative Wastewater Technologies	1	0	None.	No evidence available regarding building sewage conveyance and wastewater related technologies.
RC-P1. Basic Energy Performance	Required	✓	Local standard is adopted.	Assessment based on Beetham Tower's SAP Energy Performance Certificate and report. The building scored 83 (B) under SAP's Energy Efficiency Rating.
RC10. Energy Use Reduction	18	12	Minimum energy cost savings = 39%. Peak electricity demand reduction = 24%.	
RC11. Energy Use in Car Parks and Public Areas	2	2	All requirements are met.	Assessment based on site visit. Car park's ventilation and lighting systems are controlled by sensors.
RC12. Low or Zero Carbon Technologies	4	0	No renewable technologies available.	It has been established that wind energy is highly suitable for the site but could not be integrated eventually.
RC13. Clothes Drying Facilities	1	0	No clothes drying facilities.	Assessment based on floor plans.
RC14. Energy Efficient Appliances	1	1	> 80% of appliances are certified efficient products	Assessment based on appliances catalogues.
RC15. Metering and Monitoring	2	2	All requirements are met.	Assessment based on maintenance guide of metering systems.

E2. Material Aspects (MA)	**21**	**12**		
MA-P1. Timber Used for Temporary Works	Required	✓	No virgin forest products are used during construction.	The material supply chain of the main contractor, Carillion, underwent WWF Forest and Trade Network audit process. Assessment was based on these claims although no certificates of legality for materials could be achieved.
MA1. Materials Specification	8	6	Green Guide Rating requirements for 6 elements are met.	
MA2. Certified Wood	1	1	None.	
MA3. Rapidly Renewable Materials	2	0	Percentage of rapidly renewable materials < 2.5%	
MA4. Recycled Content	2	0	Percentage of recycled content < 10%	
MA5. Regional Materials	2	2	Percentage of regional materials > 35%.	
MA6. Building Reuse	2	0	None.	No evidence regarding the reuse of facades and structure.
MA7. Modular and Standardised Design	1	1	Standardised design is applied.	The main building mass was prefabricated and supplied by Carillion. Assessment based on British Precast's report – Precast Concrete in Buildings <sustainableprecast.com>.
MA8. Prefabrication	1	1	About 70% of applicable building elements are manufactured off-site.	
MA9. Efficient Structure Design	1	1	Amount of structural steel is < 28 psf.	Calculations based on BIM models.
MA10. Design for Robustness	1	1	All 2 items fulfilled.	Assessment based on British Precast's report – Precast Concrete in Buildings <sustainableprecast.com>
E3. Environmental Loading (EL)	**32**	**19**		
EL1. Construction/Demolition Waste Management	2	0	None.	No evidence of a Construction/Demolition Waste Management Plan.
EL2. Recycled & Secondary Aggregates	1	0	None.	No evidence regarding the utilisation of recycled and/or secondary aggregates.
EL3. Waste Recycle Facilities	1	1	All 2 items fulfilled.	Drawings showing the adequate provisions of facilities for the collection, sorting, storage and disposal of waste and recovered materials.

EL4. Compactor/Baler	1	0	No compactor/baler provided.	Assessment based on site visit.
EL5. Compositing	1	0	None.	Floor plans show no composting facilities for individual kitchens.
EL6. Land Pollution	1	1	No land pollution threat presented.	Assessment based on the EMR and Site Appraisal.
EL7. Refrigerant Use and Leakage	3	3	No refrigerant used.	Assessment based on manufacturer catalogues.
EL8. NOX Emissions	3	3	Heating system has low NOX emission.	
EL9. Water Pollution	1	1	No water pollution threat presented.	Site plan demonstrated that there are no external areas that present a pollution risk, no plan supported on the roof.
EL10. Flood Risk	3	3	No flood risk presented.	Site located in zone with low probability of flooding. Site design follows the guidance of 'Strategic Flood Risk Assessment for Greater Manchester.'
EL11. Noise Pollution	1	0	None.	The design causes serious 'howling' issues during strong winds, which has received complains from neighbouring residents.
EL12. Light Pollution	1	1	No light pollution presented.	The curtain wall structure is clad in glass and elements were added to counter excessive light. Assessment based on design specs.
EL13. Overshadowing and Views	1	1	Building causes no obstruction to daylight and views access.	Assessment based on site visit of surrounding areas at different times during the day.
EL14. Protection of Ecological Value	1	0	None.	Project did not qualify for this credit. Assessment based on the use of Checklist 6.
EL15. Mitigation of Ecological Impacts	2	0	None.	Project did not qualify for this credit. Assessment based on the use of Appendix 10.
EL16. Enhancement of Ecological Value	3	0	None.	
EL17. Long-term Impact on Bio-diversity	2	0	Not all mandatory criteria are achieved.	No ecologist is appointed during the early stages.
EL18. Surrounding Microclimate	4	2	Credit a) and b) are not achieved.	No CFD test during design stage, which lead to a series of issues during strong winds. Pedestrian safety is affected during glass maintenance in the past. Site design showing adequate means to prevent heat islands.

E4. Social and Economic Aspects (SE)	**16**	**9**		
SE1. Public Transport	3	3	Adequate public transportation network nodes available.	Assessment based on Google Maps studying of surrounding pubic transportation.
SE2. Pedestrian and cyclist	3	1	None.	Cycle storage spaces and supporting cyclists' facilities not available. Assessment based on site visit.
SE3. Maximum Car Parking Capacity	1	0	None.	Car parking capacity calculation show inadequate results to achieve this credit.
SE4. Travel Plan	1	0	None.	Travel Plan not available.
SE5. Neighbourhood Amenities	1	1	The building is located in proximity to local amenities.	Assessment based on Google Maps studying of neighbourhood amenities.
SE6. Local Character	1	0	Aspects not all addressed.	Building maintenance causes repeated disruptions to traffic. Assessment based on local highway chiefs announcements.
SE7. Historic Environment	1	1	The building is not located on site of historic environmental assets.	Greater Manchester Historic Environment Record was studied during design stage although there is no baseline historic environmental survey carried out as evidence.
SE8. Life Cycle Cost and Payback Time	2	0	None.	Evidence not available regarding Life Cycle cost and payback time calculation.
SE9. Affordability of Rental/Cost Levels	1	0	None.	No evidence showing the considerations of affordability of rental cost. Architect's recommendation not sufficient enough.
SE10. Support of Local Economy	1	1	All requirements are met.	The main contractor is local based.
SE11. Mixed-use Development	1	1	All requirements are met.	The project adopted a mixed-use development strategy.
Innovations (IN)	**16**	**5**		
IN1. Innovative Strategies and Technologies	5	0	None.	No evidence available.
IN2. Exemplary Performance	11	3	None.	Exceeded the stated performance under issues: IEQ16, MA5, EL8.
TOTAL	**222**	**121**		

Total Score = 56.7 %

B = 59/93 = 63%. E = 59/113 = 52% EL = 100% - E = 100% - 52% = 48 %

TPSI Factor = 63/48 = 1.3

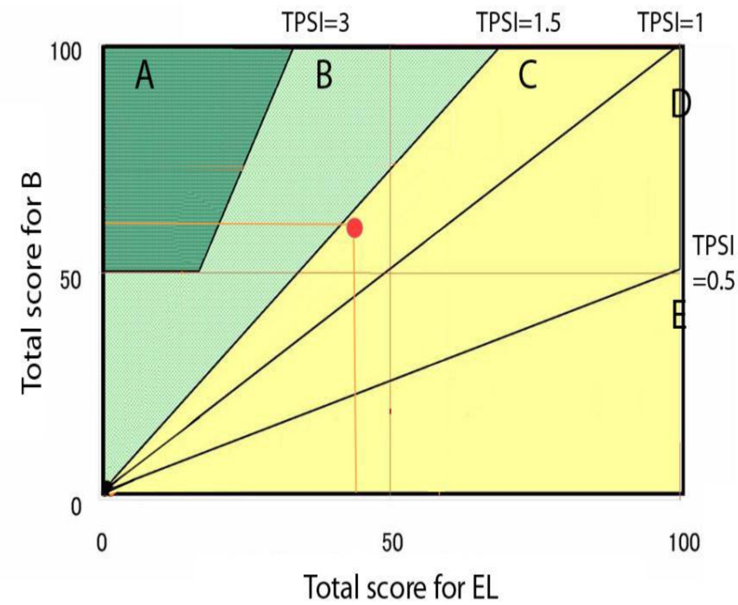


Figure 8.6: Beetham Tower's TPSI assessment – TPSI Factor calculation

➔ **TPSI Ranking: C (Good)**

8.3.3. Self-testing Phase Conclusions

The Beetham Tower in Manchester is a very interesting project that revealed many aspects of TPSI during the assessment. The design scheme has won many awards including the RIBA Housing Excellence Award 2008 and the Civic Trust Award 2008. On the other hand it is a very controversial project in term of sustainability. The building suffers from serious noise problems caused by a thin glass blade on the top during strong winds, which causes complains from tenants and neighbouring residents. Its glass panels maintenance also cause repeated traffic issues and safety risks. There were also many disputes between the main contractor – Carillion – and the Environmental Investigation Agency (EIA) regarding the supply chain of materials used in this project. The EIA even claimed Carillion used illegally-logged and endangered timber from New Guinea, although their documentations showed otherwise. Overall, TPSI thoroughly covered all of these matters, as well as other tall-building specific concerns of this project, from the effect on surrounding microclimate (issue EL18), the overshadowing issue (EL13), the prefabrication aspects (MA7 and MA8), to the earthquake standard adopted (BS13).

The most important outcome of the Self-testing Phase is that it gave the candidate the chance to look at TPSI from a different, more practical angle. Although all the visions and foundations were carefully established for the development of TPSI (see Section 5.4.3 and Chapter 6), there were always factors and issues that could not be foreseen.

The most prominent issue is the contents of the assessment criteria. There are disparities between the evaluation methods proposed in the TPSI Issues and their application in real-life projects. In order to build an accurate rating tool, efforts were made to establish the mechanisms to quantify the contents of the standards into measurable values. Some of these mechanisms do not work in reality, and only through the Self-testing Phase that these drawbacks were recognised. Difficulties were seen when assessing issues under 'E1. Resources Consumption' category (especially issue RC-P1 and issue RC10) and issues that require sampling measurements under 'B2. Indoor Environmental Quality' category. The main reason for this is the difference in codes of practice adopted, which lead to the difficulty when comparing the project with the baseline building/standard.

The assessment criteria's requirements in term of documentary evidences posed another issue. There were many documents (required by TPSI) that could not be acquired or were not often available during certain stages of a project. The referencing to external standards sometime slowed down and complicated the assessment process. Many issues had to be assessed based on the architect's recommendations and assumptions because required evidences could not be presented although it was certain that the project is qualified for that particular issue.

The arrangement of the TPSI Issues and their weight toward overall result was also a problem. Some Issues tended to be ignored because its importance toward overall sustainability was not stated strongly enough. The allocation of credits might also raise some issues. For example Beetham Tower is known for its series of issues during strong winds (excessive noise, safety issues of pedestrian, traffic disruption) but the issues

EL11 and EL18 that deals with this problems only contribute 5 credits toward overall result. This does not justify the affects of this tower to traffic and pedestrian safety.

The Self-testing Phase, on the other hand, showed many positive signals. Overall, TPSI System worked fluently and effectively. The Technical Manual's arrangement well served the reference activities and its link with the TPSI Calculator proved to be very smooth. The design and features of TPSI Calculator show their appropriateness and efficacy when being applied during different project stages, especially the graphs and charts. The time to complete a TPSI assessment is roughly two days for a detailed evaluation – quite short compared to existing rating systems. Quick assessment without the examining of required evidences can be done in three to four hours with easiness and notable accuracy. Many particular features of tall-building case studies are covered sufficiently by TPSI criteria.

At the end of Self-testing Phase, the first trial version of TPSI System was fully functional and was put through the External-testing Phase (see Section 8.4).

8.4. EXTERNAL-TESTING PHASE (INTERVIEW PROCESS)

Up until the External-testing Phase, the development of TPSI has basically been an internal process without direct contribution from outside. This is normal for a PhD research. However, the final outcome of this research is a practical rating tool. This turns the research directly toward users, who decide the success of the tool and the research itself. The External-testing Phase is, therefore, of significant importance.

The main goals of this phase, besides seeking for validation of TPSI's advantages and reliance from trustworthy parties, also include the comparison between the performance of TPSI and other existing rating systems. This comparison must be thorough and objective, at the same time has to be synchronised with the criteria established during the 'Reviewing' stage (see Chapter 4). Furthermore, this phase will build the bases for future development of TPSI rating scheme (introduce TPSI to the market and potential users, building up users base, etc.). This phase also incorporates repeated modifying and perfecting intervals of TPSI System, which based on the feedbacks of participants.

8.4.1. List of Interviewees and Case Studies

Interviews (with questionnaire) combined with case studies are chosen as the strategy to carry out the External-testing Phase. The main challenge was finding the participants. The participants not only should be committed to the task, but also must be varied, which is very important to fully examine TPSI's utilisation when being used by different types of users. The variation is based on:

- Participant's experience of using sustainability rating systems;
- Participant's background;
- Participant's experience within the Built Environment;
- The countries where participant is active;
- Participant's involvement in major sustainable/high-performance projects (general projects and tall-building projects);
- Participant's major, speciality and position.

Participants' access to case studies (tall-building projects) is also important. These case studies, again, have to be diverse in term of:

- Location (climate zone, urban area);
- Stage of project;
- Building type;
- Building technical information (structure type, height, floor count).

By December 2010, there were over 50 individuals and organisations make commitments to take part in the interview process. For technical reasons only 40 results were chosen to be reviewed and are presented in this chapter. The list of participants and associated case studies are shown in Table 8.2.

Table 8.2: List of Interviewees and Case Studies

No.	Name	Organisation	Active in Countries	Position	Case Studies
1	Dr. Le Quan	Hanoi Architecture University	Vietnam	Dean of Architecture Department	Trung Hoa Nhan Chinh Tower, Vietnam
2	Prof. Nguyen Hong Thuc	Hanoi Architecture University	Vietnam	Dean of Post-Graduate School	Keangnam Hanoi Landmark Tower, Vietnam
3	Prof. Nguyen Duc Thang	Hanoi Architecture University	Vietnam	Dean of Urban Design Department - HAU	Building A, Hanoi Architectural University,
4	Dr. Nguyen Tien Thuan	Hanoi Architecture University	Vietnam	Architecture Department - HAU	Ocean Park Building, Vietnam
5	Mr. Nguyen Manh Ha	Housing and Real Estate Market Department, Ministry of Construction	Vietnam	Director of the Housing and Real Estate Market Department, Ministry of Construction, Vietnam	Tall- buildings in Vietnam in general
6	MA. Ameya Rahardjo	DP Architect	Singapore, Indonesia, UK	Designer, Researcher	Wisma 46, Indonesia
7	MA. Juri Yoshimi	University of Sheffield	UK	Designer, Researcher	n/a
8	MA. Truong Vu Tuan	Vinaconex Corp.	UK, Vietnam	Designer, Researcher, Technician	Vietinbank Twins Tower
9	MA. Cao Thi To Tram	RSP Architect	Singapore, UK, Vietnam	Designer, Manager, Researcher	Mulberry Lane, Ha Dong, Vietnam
10	MA. Akanksha Mehra	CPG Consultants	Singapore, UK	Designer, Manager, Inspector	The Sail @ Marina Bay, Singapore
11	MA. Piyush Khandelwal	University of Sheffield	UK, India	Designer, Researcher, Technician	n/a
12	MA. Wang Ting	Mohen Design International	UK, China	Designer, Researcher	One Lujiazui, Shanghai, China
13	Mr. Nguyen T. Quang	HUD-CIC - HUD Group	Vietnam	Inspector, Director of HUDCIC	Park Lane Ciputra, Hanoi, Vietnam
14	Mr. Nguyen T. Hiep	HUD4 - HUD Group	Vietnam	Manager, Constructor, inspector	New Skyline Building, Hanoi, Vietnam
15	MA. Phan Ba Dung	AA School	UK	Designer, Researcher	Euston Tower, London, UK
16	Mr. Michael Loc Pham	CL3 Architect Ltd.	HongKong	Designer, Manager, Inspector	HSBC Building, Wanchai, Hong Kong
17	Ms. Bi Hong	Propnex Real Estate	Singapore	Manager	One Shenton Way, Singapore
18	Mrs. Le Thu Hang	Vincom Jsc.	Malaysia, Vietnam	Real Estate Manager	Vincom City Towers, Hanoi, Vietnam
19	MA. Truc Nguyen	Vincom Jsc.	UK, Vietnam	Real Estate Manager, Project Manager	The Arts Tower, Sheffield, UK
20	Dr. Garuth Chalfont	Chalfont Design	U.S, UK	Landscape Architect	n/a

21	Mr. Richard Geller	Khwang Bang Chan Khet Khlong Samwa, Bangkok	Thailand, U.S	Project Manager, Designer	Italthai Tower, Bangkok, Thailand
22	Mr. Darren O'Dea	Vietnam Green Building Council	US, Vietnam	LOTUS Rating Tool Manager	Tall-buildings in Vietnam and the US in general
23	Mr. Xavier Leulliette	Vietnam Green Building Council	France, Vietnam	Technical Advisor	Tall-buildings in France and Vietnam in general
24	Mr. Jalel Sager	Vietnam Green Building Council	US, Vietnam	Advisor, Inspector	Marquis Residences, Miami, US
25	Mr. Olivier Jacquet	VGBC, Schneider Electric	US, Vietnam	Tool Developer	Tall-buildings in general
26	Mr. Thomas R. Miller	Green Cities Fund - Miller & Ngo	US, Singapore, Vietnam	Former VGBC Executive Director	Tall-buildings in general
27	Mrs. Kathrin Moore	San Francisco Planning Commission	US, Vietnam	Honorary Vice-Chair of VGBC	Tall-buildings in general
28	Mr. Nguyen Huu Dung	Hanoi Architecture University, VGBC	Vietnam	Chairperson of VGBC	Fico Tower, Ho Chi Minh City, Vietnam
29	Mrs. Thao Griffiths	Climate Change Program, US-Vietnam Trade Council	US, Vietnam	Vice Chairperson of VGBC	Saigon M&C, Ho Chi Minh City, Vietnam
30	Mr. Nguyen Quang	UN Habitat	UN, Vietnam, US	Board Member of VGBC, member of UN Habitat	Lotte Centre, Hanoi. Vietnam
31	Mr. Yannick Millet	Vietnam Green Building Council	US, Vietnam	VGBC Executive Director	Tall-buildings in general
32	Mr. Huang Tai Tong	Surbana Corporation Pte Ltd	Singapore, U.S	Project Manager	Caltex House, Singpapore
33	Miss. Trang Huyen Vu	CB Richard Ellis Vietnam	UK, Vietnam	Project Manager, Real Estate Agent	Coastal Area Condo – Azura, Vietnam
34	Mr. Thomas Pang	Green Building Council Australia	Australia, Vietnam	Inspector, Manager, Designer	Santos Place, Queensland, Australia
35	Mr. Tran Phuc Toan	TPTA	Vietnam	Architect, Project Manager	n/a
36	MA. Masaaki Kaneshiro	Vinaconex Corp.	Japan, Vietnam	Architect, Project Manager, Advisor	Keio Plaza Hotel North Tower, Tokyo, Japan
37	Dr. Dong Nguyen	F.O.B.A	Japan, Vietnam	Architect, Project Manager	Nagoya Lucent Tower, Nagoya, Japan
38	Mr. How Ta Tuang	PrimeWorld Development Corporation	Singapore, UK, Hong Kong, Australia, Vietnam	Chairman of PrimeWorld, Manager, Bussiness & Project Investment Advisor	Tall-buildings in general
39	Mr. Vu Tran	Kobe University	Japan	Master in Architecture Student, Kobe University	Kobe Sannomiya Tower Mansion Project, Kobe, Japan
40	Ms. Rachel Nguyen	Freelance architect	Australia, Vietnam	Manager, Designer	1 Bligh Streeet, Sydney, Australia

The participants were chosen from the following sources:

- Contacts of the candidate and his supervisor – Dr. Hasim Altan;
- The arrangement and introduction of the Department of Human Resources - Vietnamese Ministry of Construction;
- The researchers and staffs at the Department of Housing and Real Estate Market - Vietnamese Ministry of Construction;
- Vietnam Green Building Council (VGBC);
- Singapore Green Building Council (SGBC);
- The professors and colleagues at the Hanoi Architectural University - Vietnam.

The interviewees widely ranged across the Built Environment. Their backgrounds and majors were deliberately varied, including architects, designers, project managers, advisors, inspectors, tool developers, real-estate agents, team-leaders, firm-leaders, members of national green building councils and international organisations, researchers and lecturers at universities, and governors. Many of them hold important position and have established renowned credibility, which promises a reliable result of the Interview Process.

The Interview Process lasted five months with interviews took place in UK, Vietnam, Malaysia, Indonesia and Hong Kong. Online communications and interviews were also made to participants in Australia, Japan, the US, and Thailand. Travelling fees and other types of support were kindly provided by the Department of Housing and Real Estate Market – Vietnam Ministry of Construction.

Agreements were made, according to which, a trial version of TPSI was provided to participants and organisations and they were entitled to use it for free for three months. Additional terms were applied with particular parties. Basically, the participants were asked to use two or three rating systems (one of them is TPSI) with their chosen case studies. After that they had to fill out a questionnaire - the original format of which can be found in Section 8.4.2.

Some participants preferred to fill out the questionnaire with general tall-buildings in mind, not just a particular case – they were often managers and directors who deal with housing issues in a major scale; trained inspector who work with many buildings at the same time; or developer of rating systems themselves. Some of the participants did not have a case study - that's because they are new users who use sustainability rating systems for the first time. It is important to understand the experiences of all types of users and this variation is valuable to the interview process.

8.4.2. Questionnaire Format

The Questionnaire was developed based on the following criteria:

- Concise and user-friendly;
- Thoroughly reflect the variation of users and caste studies, as outlined in Section 8.4.1;
- Allow the thorough evaluation of TPSI's features;
- Allow the comparison between TPSI and other rating systems;
- Guarantee the synchronisation of the Questionnaire's assessment criteria and the criteria established during the 'Reviewing' stage (see Section 3.5.3 and Chapter 5); therefore enable the comparison of external-testing and self-testing results.

Refer to Table 8.3 for the original format of the Questionnaire. A sample filled questionnaire and other survey documents are shown in Appendix D. The results collected and analysed from the Questionnaires are presented in Section 8.4.3.

Table 8.3: Questionnaire format

DETAILS		
Participant's Name:		Organisation:
Address:		Email: Phone:
Project Associated with the Review:		
Location:		Area/Zone: Climate Zone:
Completion Date:		Stage:
Site Area:		Construction Area:
Gross Floor Area (GFA):		Building Type:
Number of floors:		Basement:
Height:		Structure Type:
BACKGROUND		
1	Do you often (i.e. at least once a year) get involved in major sustainable/high-performance projects? ☐ YES ☐ NO Do you often (i.e. at least once a year) get involved in sustainable tall-building projects? ☐ YES ☐ NO *Note: Within this research, a 'sustainable tall-building' is defined as: "one in which the design team have struck a balance between environmental, economic and social issues at all stages – design, construction, operation and change of use/end of life".*	
2	In what position do you often get involved in such projects? Manager ☐ Designer ☐ Constructor ☐ Inspector ☐ Engineer ☐ Technician ☐ Other ☐	
3	Do you often use sustainable rating/assessment tools during your projects? ☐ YES ☐ NO If YES name the systems you often use:…………………………………………………… *If YES answer question 4.1, if NO answer question 4.2*	
4	4.1. Do you have to use them because of some reasons (e.g. requirements of customer, etc.) or do you feel the need to use them? ☐ I have to use them althought I don't want to ☐ I feel the need to use them 4.2. Would you/your organisation be interested in having access to a sustainable rating/assessment tool to guide you through the projects and improve the sustainability of your projects? ☐ YES ☐ NO	
5	During your projects, when dealing with sustainable issues, what do you often need? ☐ A *design tool* to help you making decisions, comparing design schemes, etc. ☐ An *assessment tool* to help you evaluate the performance of the projects ☐ Something to rely on, like a *checklist*, to help you manage sustainable issues ☐ All of the above ☐ None, I can tottaly deal with everything by myself	
6	At what stage of the projects that you need such supports mentioned in (5)? Pre-Design ☐ Design ☐ Construction ☐ Contractual & Commission ☐ Operation ☐ Demolition ☐	

1. AVAILABILITY

Give your opinion about TPSI and other sustainability rating systems that you used according to the following criteria:

- Easy to Access: Is it convenient to have full-possession of the system (i.e. easy to find and acquire/subscribe it)?
- System's Format: In what format and language is the system available? Is it convenient for use and transfer between parties?
- Cost of System: Do you think the cost of the system is acceptable?
- Availability of Information: Is it easy to find information/literature about the system?
- System's Openness: Is it easy to gather information on the rating system membership, represented organisations, and development process?

Give a '✓' if you think the criterion is met, give a '-' if otherwise.

	TPSI		
Easy to Access			
System's Format			
Cost of System			
Availability of Information			
System's Openness			

2. METHODOLOGY

Give your opinion about TPSI and other sustainability rating systems that you used according to the following criteria:

- Rating Levels: How many rating levels does the tool offer? Is it sufficient enough for your purposes?
- Quantitative criteria: Are the quantitative criteria (number, content, requirement, etc.) sufficient enough for the assessment?*
- Qualitative criteria: Are the qualitative criteria (design descriptions, illustrations, etc.) sufficient enough for the assessment?*
- Complexity: Assessment method's sophistication (Sophisticated – Average - Basic?)
- Efficiency: The level of efficiency of assessment method (Very High - High - Average - Low - Very Low?)

Give a '✓' if you think the criterion is met, give a '-' if otherwise

	TPSI		
Rating Levels			
Quantitative Criteria			
Qualitative Criteria			
Complexity			
Efficiency			

Note:

** Sustainable performance assessment, especially when dealing with energy and mass flows issues, requires criteria that are described in quantitative terms. On the other hand, the wider range of performance issues necessary within an assessment of 'green' performance currently cannot avoid using more qualitative metrics to evaluate a building comprehensively. A good rating tool therefore needs to be a harmonic combination of quantitative and qualitative criteria.*

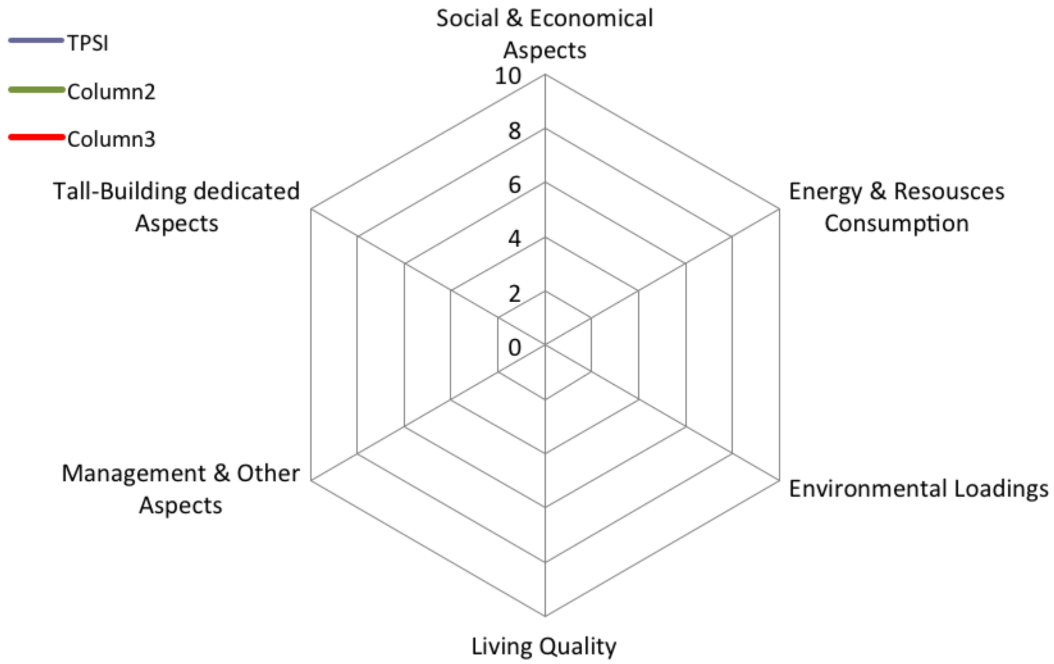
3. APPLICABILITY	
3.1	When using assessment tool(s) in tall-building projects (excluding TPSI), do you think there are certain sustainable aspects that are not covered by those tools? ☐ YES ☐ NO And these aspects are: ☐ Sustainable aspects in general ☐ Particular aspects which are associated with tall-building projects only *Ignore this question if you have no experience of using sustainability assessment tools in tall-building projects.*
3.2	Do you think there should be separate tools for low-rise buildings and high-rise buildings (in order to improve the accuracy of the assessments)? ☐ Yes, there should be separate tools such as TPSI ☐ I prefer a tool for both low-rise and high-rise buildings
3.3	Give a '✓' for each project stage that you think is well-covered by TPSI and other sustainability rating systems that you used:
3.4	On a scale from 1-10 (10 being the highest performance), give your opinion on how well a certain sustainable aspect is covered by TPSI and other sustainability rating systems that you used:

3.3 table:

Stages of building life cycle	TPSI		
Pre-Design/ Planning/ Site Selection			
Design/ Procurement			
Construction/Post Construction Review			
Management/Operations/Maintenance			
Tenant Fit-Out/ Refurbishment			
Demolition			

3.4 table:

Sustainable Aspects	TPSI		
Social and Economical Aspects			
Energy and Resources Consumption			
Environmental Loadings			
Living Quality			
Management and Other Aspects			
Tall-Building dedicated Aspects			



Note: This diagram is the illustration of the points you give for TPSI and other systems. It is for the principal researcher to calculate and finish. You do not have to finish it.

4. DATA COLLECTING

Give your opinion about TPSI and other sustainability rating systems that you used according to the following criteria:

- Data Collecting Method: Identify the method used to input data. Is that method sufficient?
- Evidence:* What type of evidence needed for the assessment? Is it easy to gather those documents?
- Measurability: Does the tool use measurable method to collect data?
- Convenience: Is it easy and quick to gather data? Is it possible to finish data inputting process without the need of excessive technical knowledge?

Give a '✓' if you think the criterion is met, give a '-' if otherwise

	TPSI		
Data Collecting Method			
Documentation			
Measurability			
Convenience			

Note:
** Evidence: sustainability rating systems often requires evidence or proofs to confirm that a certain criterion is fulfilled. Evidences are often in form of design descriptions, reports, contracts, and other types of documents.*

5. ACCURACY

On a 3-level-scale (High – Medium – Low), give your opinion on the accuracy of TPSI and other sustainability rating systems that you used, according to the following assessment stages:

Assessment Stages	TPSI		
Accuracy of Data Inputting Stage			
Accuracy of Data Processing Stage			
Accuracy of Data Outputting Stage			

6. USER-FRIENDLINESS	
6.1	During your projects, when dealing with sustainable issues, what do you often need? ☐ A *simple, user-friendly* tool which can produce quick results (to compare your design schemes, etc.) ☐ An *sophisticate, technical-driven* tool which can produce highly accurate assessment ☐ Both ☐ Something in between ☐ Neither
6.2	On a scale from 1-5, give your opinion on the User-Friendliness/Handiness/Convenience of TPSI and other sustainability rating systems that you used:

	TPSI		
User-Friendliness/ Handiness/Convenience			

7. RESULTS PRESENTATION

Give your opinion about TPSI and other sustainability rating systems that you used according to the following criteria:

- Presentation Method: End products of assessment process, ratings, result product. Do you think the tool's method of presenting assessment result is sufficient enough?
- Clarity: Well-defined, easily communicated, and clearly understood among multiple parties?
- Comparability: The ability of comparing different design schemes and/or different projects using the results produced by the tool.
- Result Usability: Usability of result documentations for communicating the accomplishments of the building.

Give a '✓' if you think the criterion is met, give a '-' if otherwise

	TPSI		
Presentation Method			
Clarity			
Comparability			
Result Usability			

8. STANDARD COMPARISION

Complete the standard comparison below between TPSI and other sustainability rating systems that you used:

Roughly put the systems' ratings on the 'sustainable scale' like the examples given for BREEAM and LEED below (please feel free to modify them). The more rigorous standards are placed toward to the top of the scale.

BREEAM (Example)	LEED (Example)	TPSI		
Excellent	Platinum			
Very good				
Good	Gold			
Pass	Silver			
	Certified			

9. BUILDING'S PERFORMANCE IMPROVEMENT

On a 3-level-scale (Significant – Medium – Low), give your opinion on the buildings' performance improvement after using TPSI and other sustainability rating systems that you are familiar with, according to the following aspects:

Sustainable Aspects	TPSI		
Social and Economical Aspects			
Energy and Resources Consumption			
Environmental Loadings			
Living Quality			
Management and Other Aspects			
Tall-Building dedicated Aspects			

NOTES

8.4.3. Results of the Interview Process

1. Number of interviewees: 40 people.

Rating systems used by interviewees: BREEAM, LEED, CASBEE, HK-BEAM, LOTUS (Vietnam's rating tool, Green Mark (Singapore's rating tool), Green Star (Australia's rating tool).

2. Position of people participated:

Managers	31
Inspectors	10
Designers	27
Technicians	12
Constructors	3
Other *	11

* Other positions include: Researchers, Real Estate Agents, Landscape Architects, Rating tool Developing Managers, Technical Advisors, Tool Developers, Lecturers, Students, Advisors, and Investors.

3. Number of people involved in major sustainable/high-performance projects: 40.

Number of people involved in sustainable tall-building projects: 34.

4. Number of people who used sustainability rating tool(s) before: 27 (68%).

Of all the people who used rating tool(s) before:

- 13 (48%) of them had to use them although didn't want to.
- 14 (52%) of them felt the need to use them.

Number of people who never used any rating tool before: 13 (32%).

Of all people who never used any rating tool before, 92% of them show interest in a new design/rating tool.

Of all people (both already used and never used sustainability rating tools), 95% of them show interest in a new design/rating tool.

5. Answering the question: 'During your projects, when dealing with sustainable issues, what do you often need?'

A design tool	12	30%
An assessment tool	12	30%
Something to rely on, like a checklist	10	25%
All of the above	5	12.5%
None	1	2.5%

6. Answering the question: 'At what stage of the projects that you need such support?'

Pre-Design	29	72.5%
Design	37	92.5%
Construction	34	85%
Contractual and Commission	29	72.5%
Operation	31	77.5%
Demolition	20	50%

7. Answering the question: 'Do you think there should be separate tools for low-rise buildings and high-rise buildings (in order to improve the accuracy of the assessments)?'

- Yes, there should be separate tools such as TPSI: 29 (72.5%).
- I prefer a tool for both low-rise and high-rise buildings: 11 (27.5%).

8. 92% of all people who used sustainable tools think that there are certain aspects that are not covered by these tools when using them in tall-building projects. Among them:

- 35% think they are sustainable aspects in general.
- 75% think they are tall-building-associated issues.

9. Answering the question: 'During your projects, when dealing with sustainable issues, what do you often need?'

A *simple, user-friendly* tool which can produce quick results	17	42.5%
An *sophisticate, technical-driven* tool which can produce highly accurate assessment	8	20%
Both	6	15%
Something in between	16	40%
Neither	3	7.5%

10. Comparing TPSI with other rating systems.

The assessment criteria of the Interview Process (see Table 8.4) are based on the same model set-up at the early stage of the research. The purpose is to make a comparative review based on external opinions in addition to the self-assessment presented in Part A of the research – see Chapter 4 (Section 4.5 in particular) and Chapter 5.

Table 8.4: Assessment criteria of the Interview Process

Criteria	Points (/100)
Availability	**10**
- Easy to Access: Is it convenient to have full-possession of the system?	2
- System's Format: In what format and language is the system available? Is it convenient?	2
- Cost of System: Do you think the cost of the system is acceptable?	2
- Availability of Information: Is it easy to find information/literature?	2
- System's Openness	2
Methodology	**15**
- Rating Levels: How many rating levels does the tool offer? Is it sufficient enough for your purposes?	3
- Quantitative criteria: Are the quantitative criteria (number, content, requirement, etc.) sufficient enough for the assessment?	3
- Qualitative criteria: Are the qualitative criteria (number, content, requirement, etc.) sufficient enough for the assessment?	3
- Complexity: Sophistication of methodology (Sophisticated – Average - Basic?)	3
- Efficiency: The level of efficiency of assessment method (Very High - High - Average - Low - Very Low?)	3
Applicability	**20**
Stages of building life cycle influenced?	10
Technical contents: How well a certain sustainable aspect is covered?	10
Data Collecting	**8**
- Data Collecting Method: Identify the method used to input data. Is it sufficient?	2
- Documentation: What type of documents needed for the assessment? Is it easy to gather those documents?	2
- Measurability: Does the tool use measurable method to collect data?	2
- Convenience: Is it easy and quick to gather data? Is it possible to finish data inputting process without the need of excessive technical knowledge?	2
Accuracy	**12**
- Accuracy of Data Inputting Stage: High – Medium – Low?	4
- Accuracy of Data Processing Stage: High – Medium – Low?	4
- Accuracy of Data Outputting Stage: High – Medium – Low?	4
User-friendliness	**5**
Results Presentation	**8**
- Presentation Method: End products of assessment process, ratings, result product. Is the tool's method of presenting assessment result is sufficient enough?	2
- Clarity: Well-defined, easily communicated, and clearly understood among parties?	2
- Comparability: The ability of comparing different design schemes and/or different projects using the results produced by the tool.	2
- Result Usability: Usability of result documentations for communicating the accomplishments of the building.	2
Standard Level	**10**
Points are given for the higher sustainable standards that the system raises.	
Building Performance Improvement	**12**
On a 3-level-scale (Significant – Medium - Low), give your opinion on the buildings' performance improvement after using the systems, according to the following aspects:	
· Social and Economical Aspects;	2
· Energy and Resources Consumption;	2
· Environmental Loadings;	2
· Living Quality;	2
· Management and Other Aspects;	2
· Tall-Building dedicated Aspects.	2

Table 8.5 shows the points achieved by rating systems as the result of the Interview Process. Table 8.6 compares this outcome with the result of the Intensive Screening Analysis (presented in Table 4.5 and Table 4.6).

Table 8.5: Points achieved by rating systems as the result of the Interview Process

	TPSI	BREEAM	LEED	CASBEE	HK-BEAM	LOTUS	Green Mark	Green Star
Availability (/10)	8	9	9	7	8	8	7	7
Methodology (/15)	12	11	11	12	10	10	11	11
Applicability (/20)	17	15	15	14	13	11	12	12
Data Collecting (/8)	6	5	7	5	6	6	6	6
Accuracy (/12)	10	10	10	11	9	8	8	8
User-friendliness (/5)	5	4	5	3	4	4	4	5
Results Presentation (/8)	8	6	7	7	6	6	6	6
Standard Level (/10)	8	8	8	8	8	7	7	7
Performance Improvement (/12)	11	9	8	7	7	6	8	7
Total (/100)	**85**	**77**	**80**	**74**	**72**	**66**	**69**	**69**

Table 8.6: Comparison of Intensive Screening Analysis result and Interview Process result

No.	Tools	Intensive Screening Analysis result (/100)	Interview Process result (/100)
1	TPSI (Universal)	-	85
2	BREEAM (UK)	76	77
3	LEED (US)	75	80
4	CASBEE (Japan)	70.5	74
5	HK BEAM (Hong Kong)	66	72
6	Green Star (Australia)	65	69
7	SBTool/GBTool (International)	64	-
8	Green Globes(US, Canada, UK)	64	-
9	SBAT (Africa)	63	-
10	SPeAR (UK)	63	-
11	Green Mark (Singapore)	61	69
12	NABERS (Australia)	61	-
13	CEEQUAL (UK)	60	-
14	EEWH (Taiwan)	60	-
15	Green Leaf Eco-Rating Program (US, Canada)	59	-
16	Living Building Challenge (US)	59	-
17	MSBG (US)	59	-
18	CEPAS (Hong Kong)	58	-
19	Design Quality Indicator (UK)	57	-
20	BEES (US)	57	-
21	SPiRiT (US)	57	-
22	SE Checklist (UK)	56	-
23	TERI GRIHA (India)	55	-
24	Envest 2 (UK)	50	-
25	HQE (France)	46	-
26	M4i (UK)	46	-
27	Green Building Certification System (Korea)	45	-
28	Scottsdale's Green Building Program (US)	45	-
29	'Quality of Life Counts' Indicator (UK)	44	-
30	Earth Advantage (US)	42	-
31	LOTUS (Vietnam)	-	66

8.5. CHAPTER CONCLUSIONS

The Trial Period was divided into 2 phases: the Self-testing Phase and the External-testing phase (or the Interview Process). During the Self-testing Phase, with the acknowledgement and support from Christopher Jones Studentship, technical issues of

TPSI were solved; and the first complete version of TPSI was ready to use. In the External-testing Phase, various aspects of TPSI were scrutinised and evaluated by multiple parties; and, based on the participants' feedbacks, TPSI was continuously perfected.

TPSI was thoroughly reviewed during the Interview Process by a criteria system of nine categories (see Table 8.5). The Interview Process produced a reliable comparison between TPSI and other rating systems (especially the Top Five rating systems) when being used in the case studies (tall-building projects). This process is similar to the Intensive Screening Analysis in term of assessment criteria. This allows a justification of both processes' consistency.

As the final result of the Interview Process, the performances of the Top Five rating systems when assessing tall-buildings were marked (see Table 8.6). LEED scored the highest (80/100 points), followed by BREEAM, CASBEE, HK-BEAM, Green Star. This order is similar to the result generated by the Intensive Screening Analysis (see Table .5 and Table 4.6) except for the positions of BREEAM and LEED. LEED's simplicity (reflected in the ease of the 'Data Collecting' process, the user-friendliness and the results presentation) was better received than BREAAM in reality. The scores of CASBEE, HK-BEAM and Green Star also fluctuated from the Intensive Screening Analysis scores, partly reflecting the alteration of assessment criteria.

Based on the opinions of the participants, TPSI's performance in the case studies was rated highest (85 points). This result is considered to be reliable considering the class and credibility of the interviewees as well as the number of case studies. The 'Applicability' of TPSI was very well appreciated (scored 17/20 points compared to 15 points of both BREEAM and LEED), which proved the suitability and effectiveness of the assessment criteria system. Its 'Methodology' point was also higher than that of BREEAM and LEED (12/15 compared to 11/15), which means the assessment process functioned smoothly. The design of TPSI Calculator earned it the highest score in the 'Results Presentations' criterion (8/8). Most importantly, tall-building projects that utilised TPSI had improved their sustainability aspects more than all other rating systems, expressed by the 'Performance Improvement' point of 11/12, compared to 9/12, 8/12 and 7/12 of BREEAM, LEED and CASBEE respectively.

The Interview Process also revealed TPSI's drawbacks. While TPSI's 'Availability' can only be improved after it becomes available to general users, other features can be enhanced. The 'Data Inputting' process, at the moment, is over scored by LEED (6/8 compared to 7/8). This has been foreseen as a limitation of the research, since the human resources are not enough to build up some of assessment mechanisms, resulting in the fact that users have to refer to external standards while working in several TPSI issues. Also, the standard level of TPSI was not rated higher than that of BREEAM and LEED although it was one of the initial goals. This feature has been improved by the modification of TPSI Issues' requirements.

To conclude, the Trial Period indicated TPSI's advantages and disadvantages when being used in reality, which in turn helped perfecting the rating system. It has successfully confirmed TPSI's values as well as the contributions of the research. Opportunities also arose during this period, which realised into further development of the research and extra validation of TPSI rating system (see Chapter 9).

CHAPTER 9: TPSI IN PRACTICE

9

9.1. CHAPTER INTRODUCTION

After the Interview Process, the potentials of TPSI were recognised and confirmed by various individuals and organisations. These potentials include:

- The advanced performance over other rating systems in tall-buildings projects;
- The innovative features and user-friendliness;
- The dissemination and influence across the Built Environment; and
- The commercial prospects.

During the 3 months (From December 2010 to February 2011) when the Interview Process took place in Vietnam and some other South-East Asian countries, the research caught the attentions of the Vietnamese Government and Vietnam Green Building Council (VGBC). A collaboration was established between the candidate and the Department of Housing and Real Estate Market - Vietnamese Ministry of Construction. Financial supports (mostly travelling and accommodation expenses) and human resources (participants in the interviews) were provided by the Department of Housing and Real Estate Market to aid the Interview Process. The VGBC also offered staffs to take part in the interviews and case studies. The VGBC is currently developing and introducing LOTUS – a sustainability rating tool of Vietnam and the establishment showed serious interest in a rating tool for tall-buildings in Vietnam. There are opportunities for cooperation between TPSI and these organisations.

In March 2011, the research received a £50,000 EPSRC funding from the University of Sheffield's Knowledge Transfer Account (KTA) to develop TPSI further into a commercial online rating tool. A KTA Proof of Concept project was established, which named 'TPSI Project,' and now is under development. The TPSI Project is introduced in Section 9.2.

Also around this period, some major firms in UK and Vietnam (namely Hilson Moran – UK, Mott McDonald, Arup – UK, HUD Group – Vietnam, and Vinaconex – Vietnam) also showed their interests in the future of the research and TPSI Project. Agreements are being made, according to which, TPSI will be utilised in these firms' high-rise projects. Validation from high-status firms would be a strong authentication of TPSI's capabilities. This will be discussed in Section 9.3.

9.2. THE PROOF OF CONCEPT FUNDED TPSI PROJECT

9.2.1. EPSRC Knowledge Transfer Accounts and the Proof of Concept Fund

The Engineering and Physical Sciences Research Council (EPSRC) is the largest research council in the UK, investing millions of pounds into research and training each year. EPSRC has awarded twelve Knowledge Transfer Accounts (KTAs) to UK Universities. KTAs aim to overcome barriers to collaboration between universities and other public and private sector organisations, and to ensure that the outputs of EPSRC research deliver the maximum economic and societal benefit to the UK. The University of Sheffield has secured a £5.7M EPSRC Knowledge Transfer Account, and has developed a number of innovative KTA activities which stimulate collaborative working and partnerships between the University and industry, including Proof of Concept Projects.

The University of Sheffield's Proof of Concept Fund invests in academic areas with early stage commercial opportunities. The fund was established in 2004 under the second Higher Education Innovation Fund (HEIF-2), and was continued into HEIF-3 and now HEIF-4. Up to February 2011, £603K has been invested in 64 projects across all Faculties. The purpose of the fund is to provide financial support at early stage of turning research into a business proposition. The financial support is intended to:

- Enable the exploration of academic research's commercial potential;
- Assist projects to reach a point at which the research is commercially viable.

9.2.2. Outline of TPSI Project

Time Frame

In March 2011, the research received £50,000 from the Proof of Concept Fund. The TPSI Project was established in conjunction with the research, which is divided into two main stages (see below). The funding will be finish in March-April 2012 although there are opportunities for extension and further funding from different sources.

Purposes and Stages

The core of the project is the development of TPSI into a Web-based Design/Rating Tool (under the new name – 'GreenLight'). The online tool will allow the users to:

- Log in and register their high-rise projects;
- Use the online system to assess the sustainability of their projects;
- Use the online system as a design tool or a checklist to follow up and manage their projects throughout its' stages;
- View other rated projects, compare them with their own projects, learn from the others;
- Communicate with other users;

The online tool would eventually become a huge library of tall-building projects. The system is not simply a rating tool anymore. It will collect all information about a project when it is registered (design, technical information, sustainable strategies, etc.) and make them valuable to other users.

The second stage is to develop a social-network for individuals and organisations that work in the Built Environment worldwide, which named 'Sustainable Network.' The network will create an online community, an all-in-one stop for anyone involved in the Built Environment.

The People

The candidate's supervisor – Dr. Hasim Altan, is the manager of the TPSI Project. The main developers are the candidate and Dr. Darren Roberts – senior software engineer and website developer. Other personnel, experts and consultants are also involved in different stages of the project.

9.2.3. Market Research

Potential markets

At the start of TPSI Project, two experts were commissioned to carry out thorough market research for TPSI Project, namely Prof. Lorna Walker of Lorna Walker Consulting Ltd[37] and MA. Pascale Scheurer of Surface to Air Architects.[38]

[37] Prof. Lorna Walker – Head of Lorna Walker Consulting Ltd, Visiting Professor in the Department of Engineering at the University of Sheffield – Market research report see (Walker, 2011).

[38] MA. Pascale Scheurer – Director of Surface to Air Architects - Market research report see (Scheurer, 2011).

The market research gave comprehensive insights into the following aspects:

- Detailed review of TPSI, including SWOT analysis (Strengths, Weaknesses, Opportunities and Threats).
- Market Analysis: customers, competitors and market opportunities.
- Revenue and Pricing: strategies for primary and secondary revenue streams, with case studies of competitors' pricing models.
- Marketing Strategy: clear, sequential strategy for engaging key advisors and potential customers, and for marketing once the rating scheme is launched.
- Next developments of TPSI.

This systematic and professional market investigation has confirmed many potentials of TPSI rating system. As concluded by Scheurer (2011): "Sustainable Tall-buildings are an established and popular typology, which offers a clear business opportunity. The existing TPSI tool will enter a maturing but not saturated market. TPSI has potential to be developed commercially in several different ways to meet growing demand, and to find its own place alongside existing and upcoming commercial offers."

The market research also confirmed the potential influences of TPSI in particular and the research in general, both in term of academic contributions and practical utilisations. Walker (2011) has identified two main potential markets for TPSI: Commercial and Academia (see Figure 9.1).

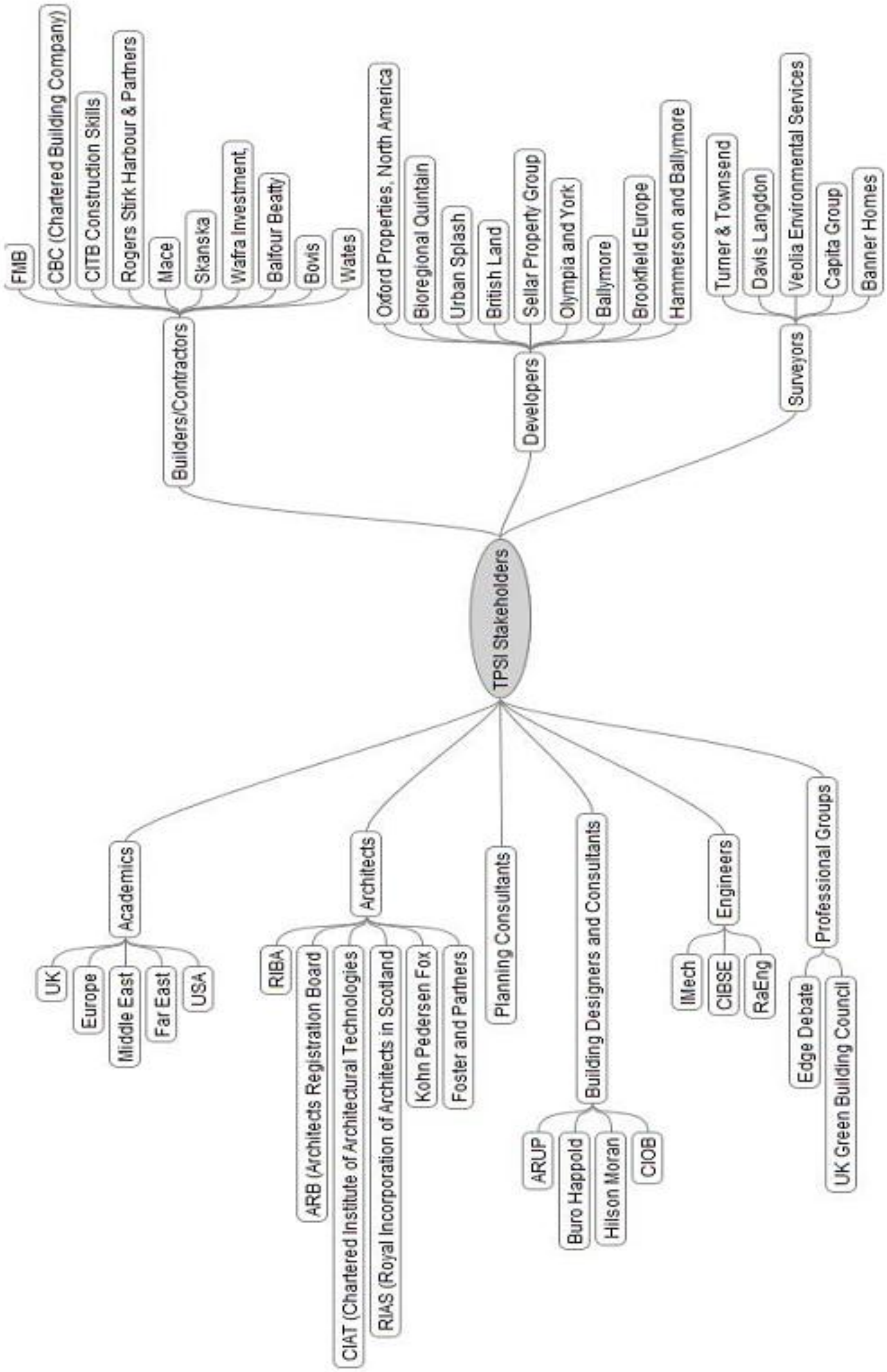


Figure 9.1: Potential markets for TPSI

Source: (Walker, 2011)

Approach Strategies

a. The Commercial Sector

The two main selling points that will be emphasised are that the online tool can be used throughout the design to inform and direct the process thus ensuring that sustainability issues are addressed, but also to make savings in both the construction and operation of the buildings. The cost savings in terms of resource efficiency, supply chain and procurement, both in savings of time and money, will be emphasised. Secondly, the graphical output and the clear results summary provide information that is simple, easy to understand and implement. It is also most useful when working in a multidisciplinary team so that all are engaged. In addition, the reputational enhancement of all involved, particularly the client, will also be promoted.

Contact will be made with designers and developers of tall-buildings in order to engage possible clients and validate the TPSI Project. It may be possible to approach these organisations individually, or approach organisations that represent such people such as the UK Green Building Council.[39] This cascade approach, along with individual approaches may lead to greater reach and efficiency of time. Often, a champion may be found who will encourage others. Another organisation that would be considered is the Edge Debate.[40] This is a think tank set up some years ago to encourage collaboration between engineers and architects. Apart from having a wide constituency in the sector they have the advantage of intellectual weight and rigor (Walker, 2011).

The strategy for marketing the TPSI Project consists of the following:

- Presentations to all the major professionals and consultants in UK.
- Launch a publicity campaign using placed articles and adverts in the main trade magazines in form of hard copies and on-line articles.
- Meetings with architect, designers at selected consultancies will lead to information on suitable projects and should lead to wider usage of this tool on future projects.

[39] **UK Green Building Council**: <http://www.ukgbc.org>.

[40] **The Edge Debate**: <http://www.edgedebate.com>.

- Meetings with contractors, particularly those with a reputation for environmental excellence.

b. The Academic Sector

It is becoming more important for students to have a broader view of sustainability within their degree. SPeAR has been used for several years in a 4th year Civil Engineering module at the University of Sheffield. This module is now multidisciplinary with students from other departments such as Mechanical Engineering and Architecture. The course has proved very useful in demonstrating a more holistic view of sustainability and allowing students to work in groups with others of different disciplines. It is believed that TSPI could contribute greatly in the teaching of sustainability (Walker, 2011). In addition, this tool could be used for research projects within higher education institutions to test various hypotheses.

c. Literature: Brochure and Leaflet

The first step will be creating a brochure that will describe the tool and emphasise its attributes. In addition, a leaflet of A5 size with a short description of the tool and contact details to give to people at various events and conferences would be a useful addition to the literature. Similar marketing approach should be considered to market this tool worldwide (Walker, 2011).

d. Website/Blog – Creating a *Communit*y

The Project's website is not only the online tool itself but also a Directory of tall-building projects, a forum, a network, and above all a community of everybody who is involved or interested in high-rise structures. Creating such a community will help in advertising this tool to wider audience and create possible links through other websites. For example the website for the Council on Tall Buildings and Urban Habitat is dedicated to tall-buildings and contains substantial information, reports and studies. In current era of the Internet, more professionals are interested in blogs and getting all information via computer, creating the blog will increase the possible client base. It will also help in reaching professionals internationally. The blog can be integrated into the main website so the logged-in accounts and guests can interact with the community.

The website and the online tool will be very interactive in order to transform the experience of users when they work with tall-building projects.

e. Professional Institutes and Associations

Maintain a database of professionals in the UK, and contact them via email, postal mail and telephone. Moreover, another route to market is to obtain industry backing for this tool, for example by obtaining support for the product from the Royal Institute of British Architects (RIBA), and the Chartered Institute of Building Services Engineers (CIBSE). Most of the professional institutions and associations have a regular journal or publication, as well as an online presence and in the case of RIBA, an online Product Selector that enables architects and others to choose the right tool for their project. Placing feature articles, case studies and success stories about this tool will help to build industry-wide exposure. Institution journals are often more trusted sources of information than the general trade media so carry more technical weight. Institutions that might be worth contacting to disseminate the tool include (Walker, 2011):

- RIBA (Royal Institute of British Architects);
- CIBSE (Chartered Institute of Building Services Engineers);
- AECB (Association of Environmentally Conscious Builders);
- ICE (Institute of Civil Engineers);
- IMechE (Institute of Mechanical Engineers);
- IET (Institute for Environmental Technology);
- Home Builders Federation;
- British Property Federation.

There are a number of professional/green networks which offer journals, website and events to their readers. Participants tend to be more aware of green alternatives and the environmental message than few years ago and are searching for new tools to improve their buildings. These networks have a smaller reach than institutions but are populated by people who are more likely to be receptive to the environmental benefits of this tool.

Many other outcomes were produced during the market research, which helped building up bases and setting forth strategies for further developments of TPSI and the research.

9.2.4. The GreenLight Online Rating System

Up until March 2012, the first stage of TPSI Project was running toward completion. The online rating tool, now under the new name 'GreenLight,' was fully functional. The structure and assessment mechanisms of GreenLight are principally the same as TPSI. All the prominent advantages of TPSI were preserved with some notable improvements and additions of new features. The GreenLight Tool is now entering the Beta test stage with the involvement of external parties.

One of the important features is the ability to manage different projects. Users who setup a private account can save, load and manage their projects handily. At later stage of the project, they will also be able to publish their assessment result to a public Project Directory, which can be accessed by members of the Sustainable Network.

Many processes are automatised and simplified; especially the data input process is much more convenient compared to the Excel tool (TPSI Calculator). Users can also produce result reports (pdf or jpg format) for reference and distribution purposes. Assessment outcomes are generated simultaneously as users working and result reports can be produced at anytime during a project, making it very convenient to compare different design schemes or check out the performance improvement of a project. Graphics and results presentations are thoroughly improved. GreenLight tool also allows users to upload associated project images and uses them in the result report.

Overall, GreenLight offers a more interactive experience than the TPSI Calculator. Figure 9.2 shows the main page of GreenLight online tool. Figure 9.3 shows the 'Project Info.' Tab, where users input their project's data. Figure 9.4 shows the 'Assessment Criteria' tab, where the assessment process takes place. Figure 9.5 and Figure 9.6 show screenshots of the 'Results' tab, where users view assessment presentations and produce result reports. Figure 9.7 and Figure 9.8 show the assessment results of two sample projects.

Figure 9.2: GreenLight tool – Main page

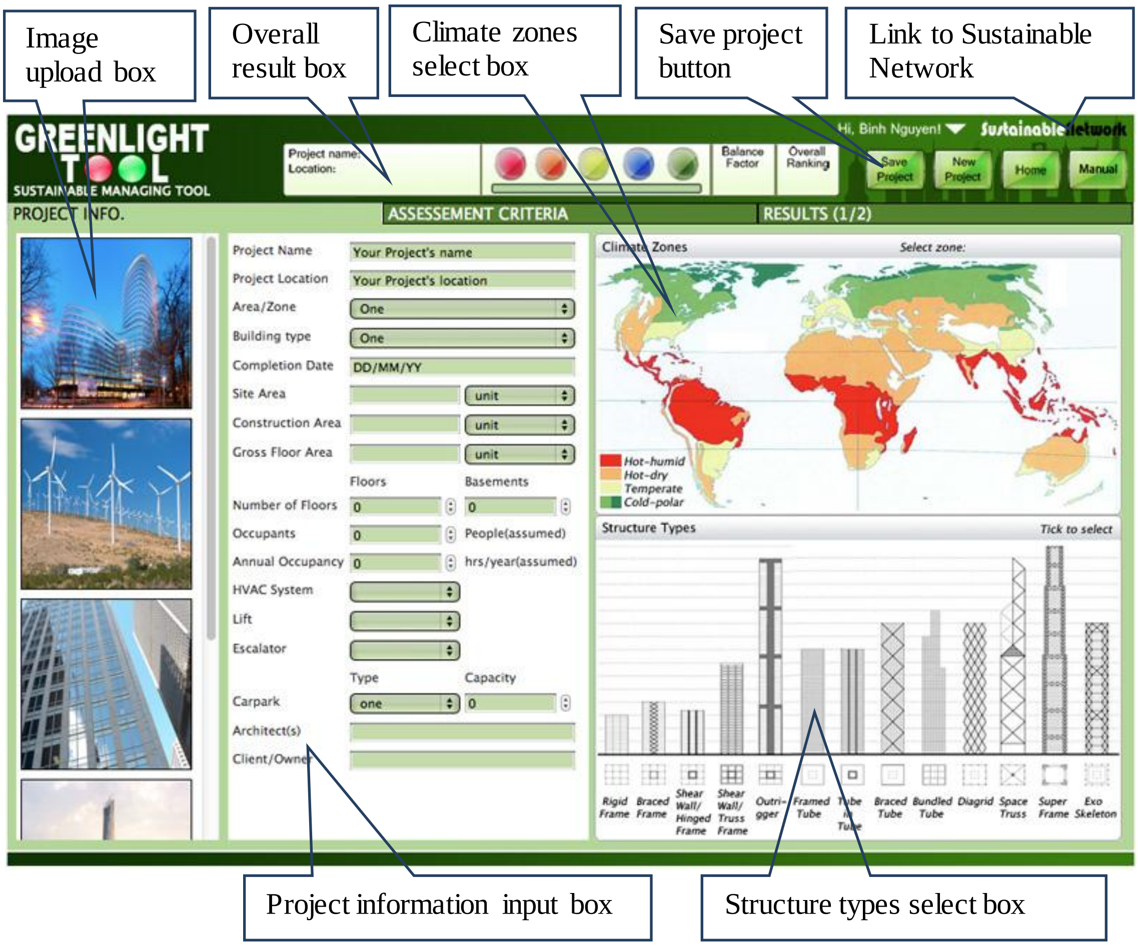


Figure 9.3: GreenLight tool – 'Project Info.' tab

Figure 9.4: GreenLight tool – 'Assessment Criteria' tab

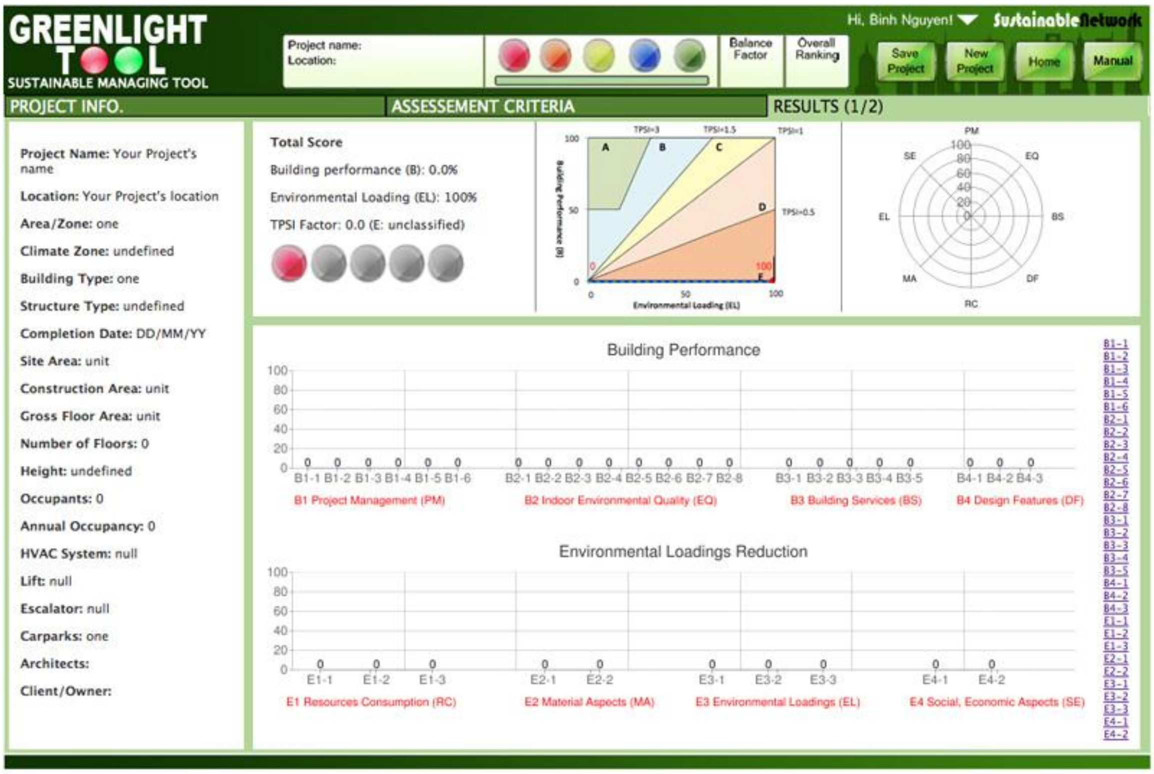


Figure 9.5: GreenLight tool – 'Results' tab 1

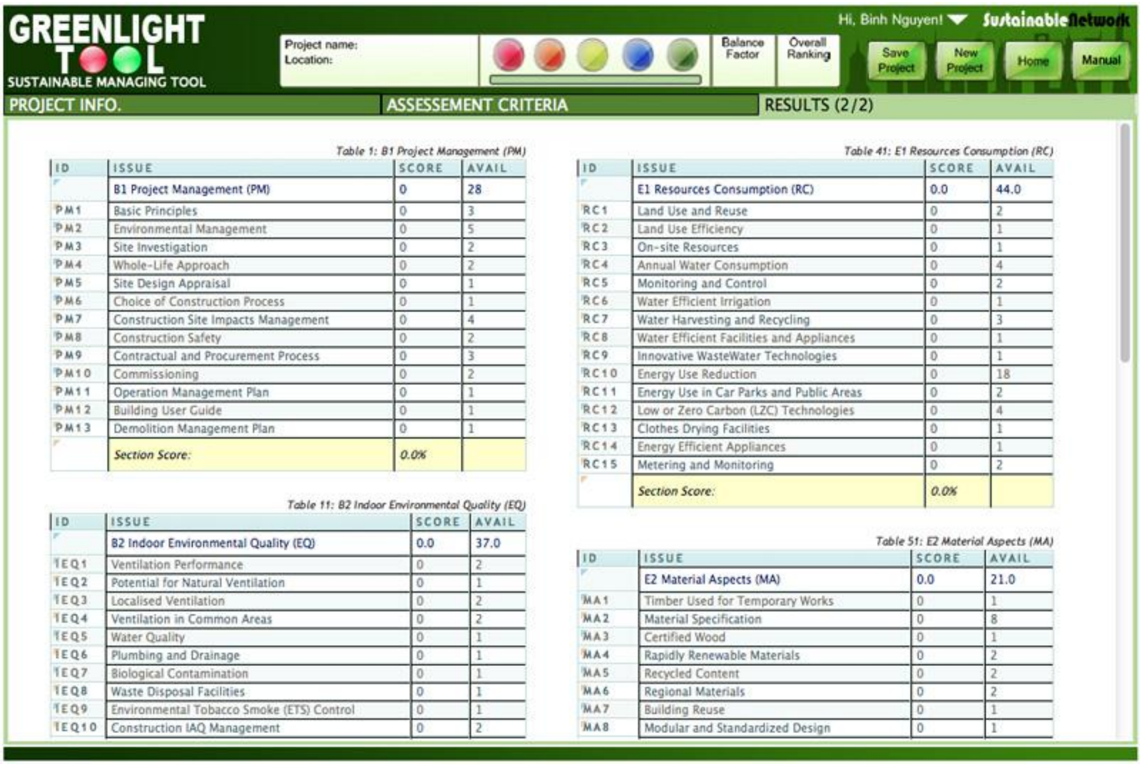


Figure 9.6: GreenLight tool – 'Results' tab 2

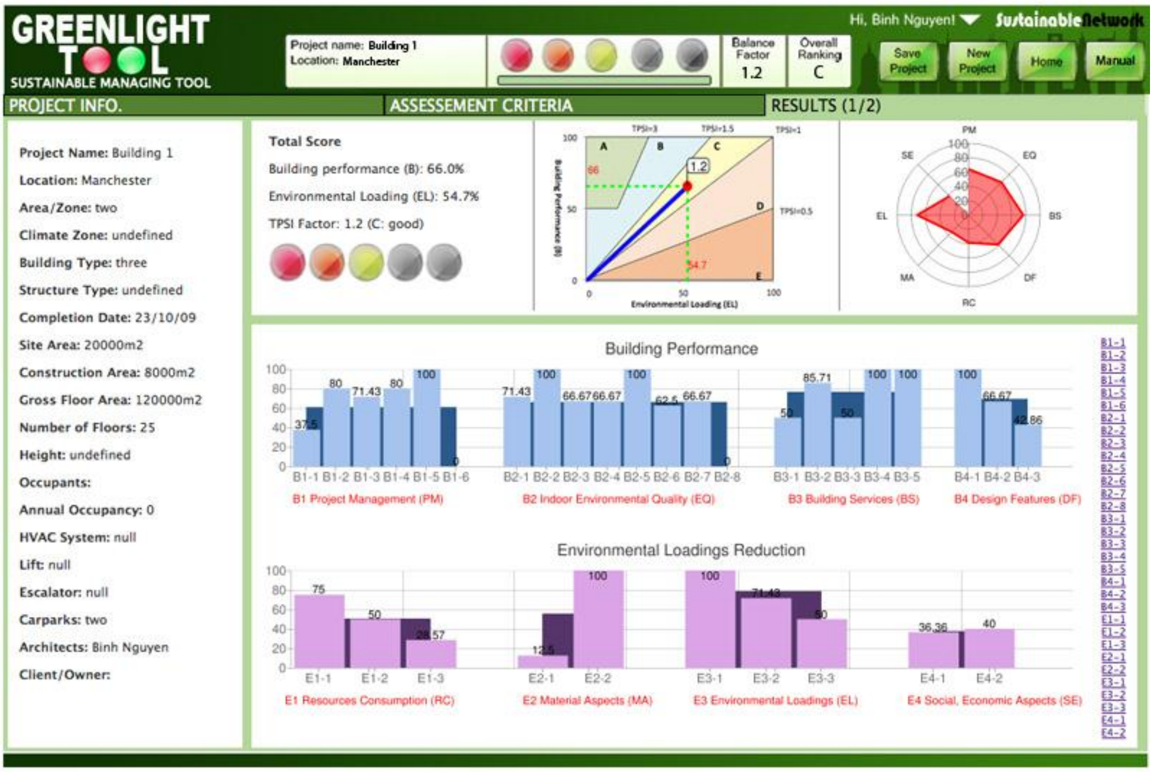


Figure 9.7: GreenLight tool – Sample building assessment 1

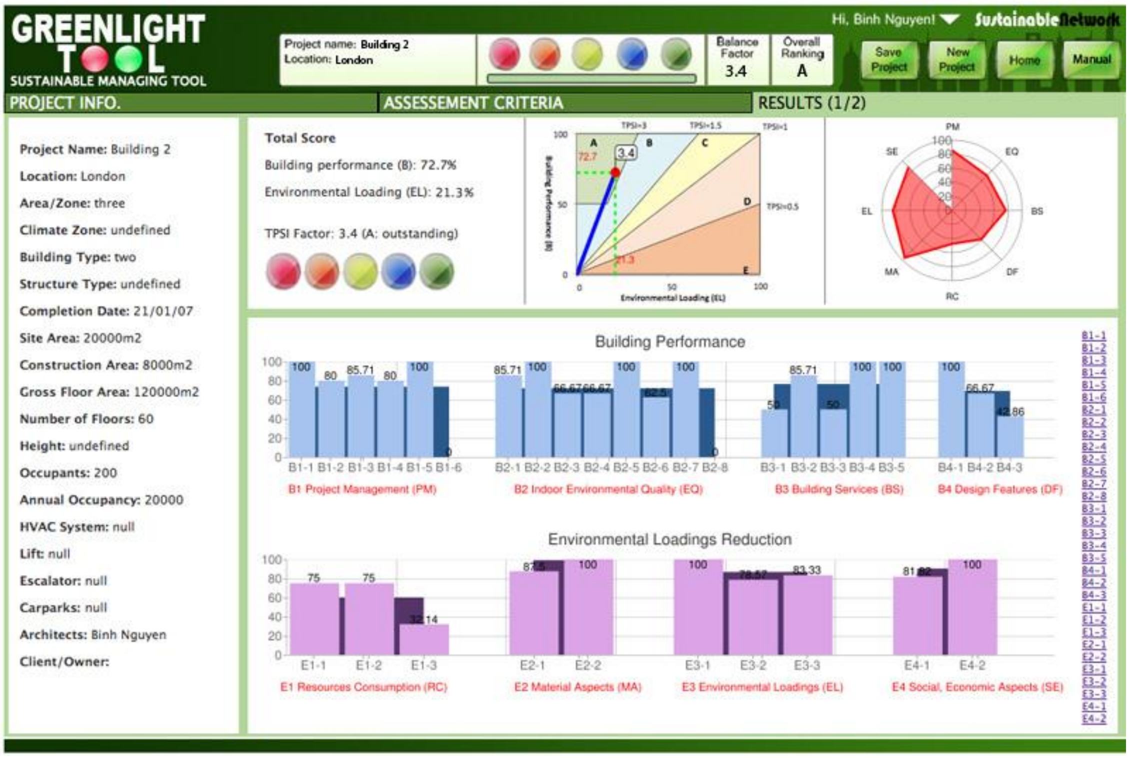


Figure 9.8: GreenLight tool – Sample building assessment 2

The GreenLight online tool is not yet open to public because some other important features are still under development, such as the user administration system and the connection with the Sustainable Network (users must be a member of Sustainable Network in order to access the GreenLight tool).

9.2.5. The Sustainable Network

The development of the Sustainable Network (stage 2 of the project) is currently in progress. Users will have access to an open and interactive community that filled with opportunities. The network will also be equipped with interactive design and management applications. A free Projects Library will also be opened to public where users can get information about Sustainable Projects worldwide. Users themselves will help developing this library. TPSI and other third-party applications will be available on this network, making it the perfect platform to promote and publicise TPSI rating scheme. This is what has been missing from other rating schemes, and what will make this project unique, apart from the tool itself. Figure 9.9 and Figure 9.10 show the screenshots of the under-development login pages. Figure 9.11 and Figure 9.12 shows the main user interface and user profile panel. Figure 9.13 shows the Online Project

Directory. The Sustainable Network and GreenLight Tool are expected to be open to public access in August 2012; at <http://sustainable-network.org/>.

Figure 9.9: Sustainable Network – Login page 1

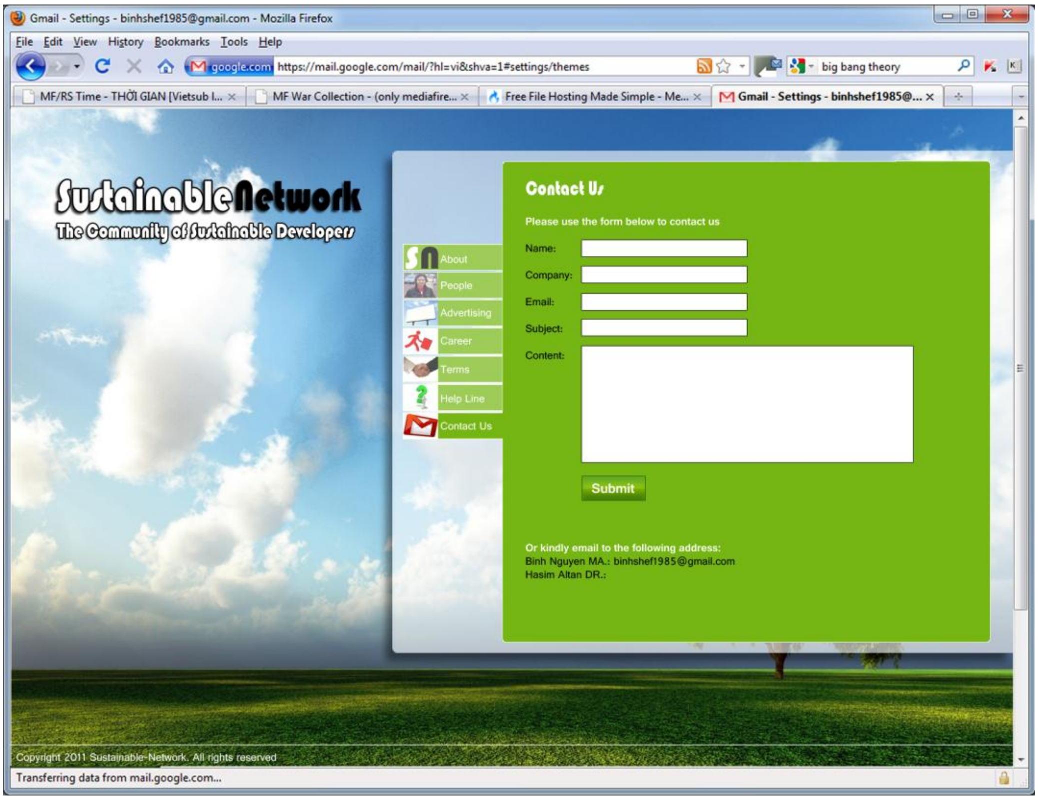


Figure 9.10: Sustainable Network – Login page 2

Figure 9.11: Sustainable Network – Main interface

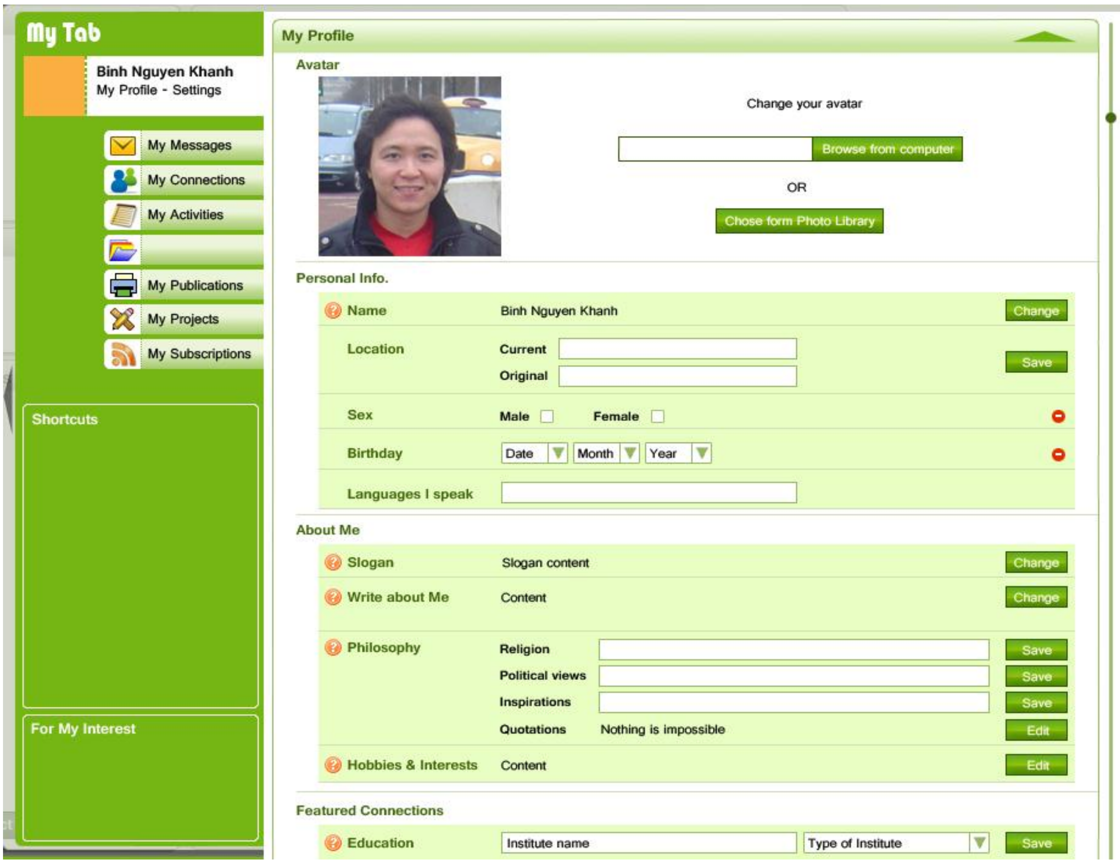


Figure 9.12: Sustainable Network – User profile panel

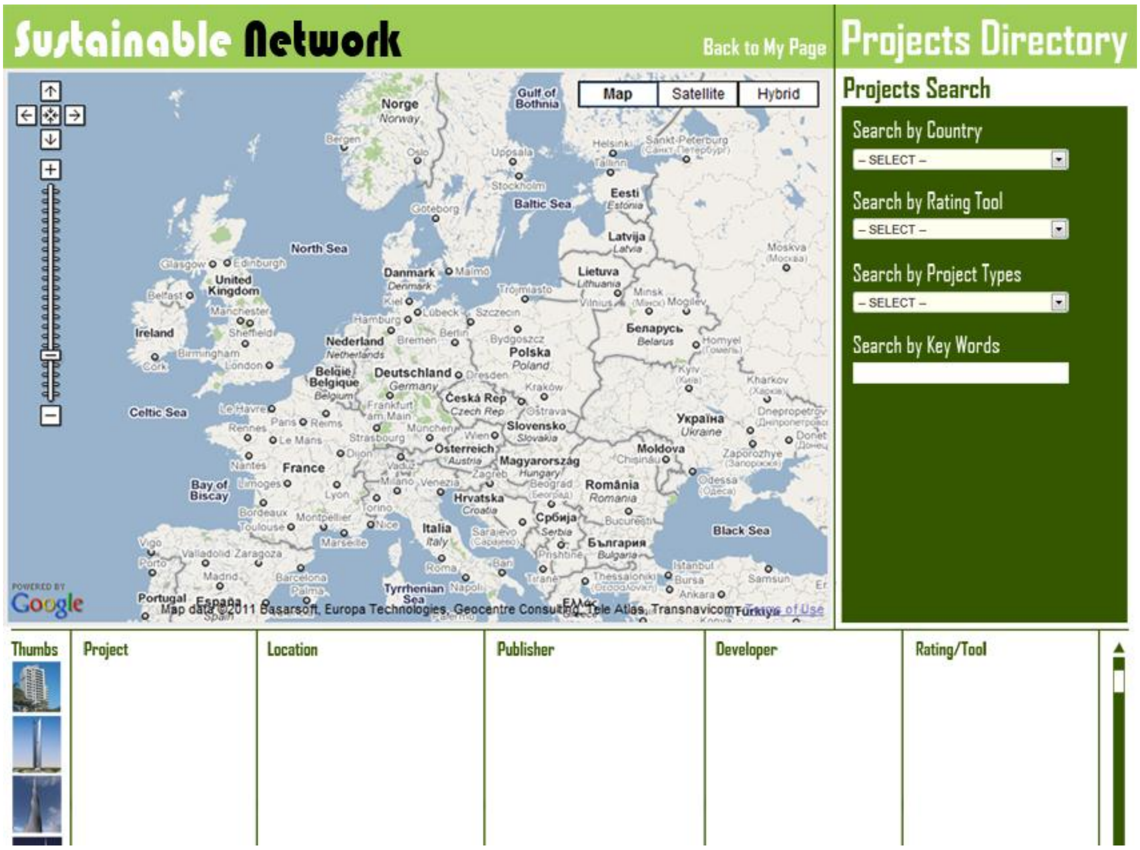


Figure 9.13: Sustainable Network – Project Directory

9.2.6. The Role of TPSI Project in the Research

TPSI Project, although being an independent funded project, has direct connections to the research. In fact, it is considered the most important phase during 'Part C – Testing and Proving' stage. Thanks to this project, the development of TPSI rating system is not an internal process anymore, but an interdisciplinary research. The highest contributions of a research are the practical ones, which can benefit the related field thoroughly. The TPSI Project displays great potentials of TPSI rating system in reality. It is a big step toward bringing TPSI system to general users, thus paving the way for its dissemination in the near future.

9.3. COOPERATION WITH MAJOR FIRMS

Beside the University of Sheffield, the potential and performance of TPSI rating system as well as the online GreenLight tool are also recognised by some major firms in the

Built Environment. There is an expression of interest for supporting the TPSI rating system from three industry leading consulting firms in the UK, which also have international presents:

- Arup:[41] a global professional services firm headquartered in London, United Kingdom which provides engineering, design, planning, project management and consulting services for all aspects of the built environment. The firm is present in Africa, the Americas, Australasia, East Asia, Europe and the Middle East, and has over 10,000 staff based in 92 offices in 37 countries. Arup has participated in projects in over 160 countries.
- The Mott McDonald Group:[42] is an employee-owned company management, engineering and development consultancy serving the public and private sectors worldwide. The firm employs more than 14,000 staff and works in 140 countries.
- Hilson Moran:[43] is a leading multi-disciplinary engineering consultancy for the built environment. A member of the Altran Group, the European leaders in innovative consulting, Hilson Moran has over 250 staff working from offices in London, Farnborough, Manchester, Paris, Milan and Abu Dhabi. They provide services in other countries in conjunction with a network of strategic partners.

There is a great potential that a corporation will be established between the University of Sheffield and these firms. The general idea is, these companies will use TPSI in their tall-building projects worldwide. This would lead to the official adoption of TPSI in these companies' work procedure, as well as other interesting opportunities. Especially, Hilson Moran has confirmed their interest in supporting the TPSI project and other further developments of TPSI rating system. Hilson Moran has signed a non-disclosure contract with the University of Sheffield and currently is using the GreenLight online tool in one of their tall-building projects in central London (the 100 Bishopsgate project – see Figure 9.14 and Figure 9.15).

[41] **Arup:** <http://www.arup.com/>.

[42] **The Mott McDonald Group**: <http://www.mottmac.com/>.

[43] **Hilson Moran**: <http://www.hilsonmoran.com>.

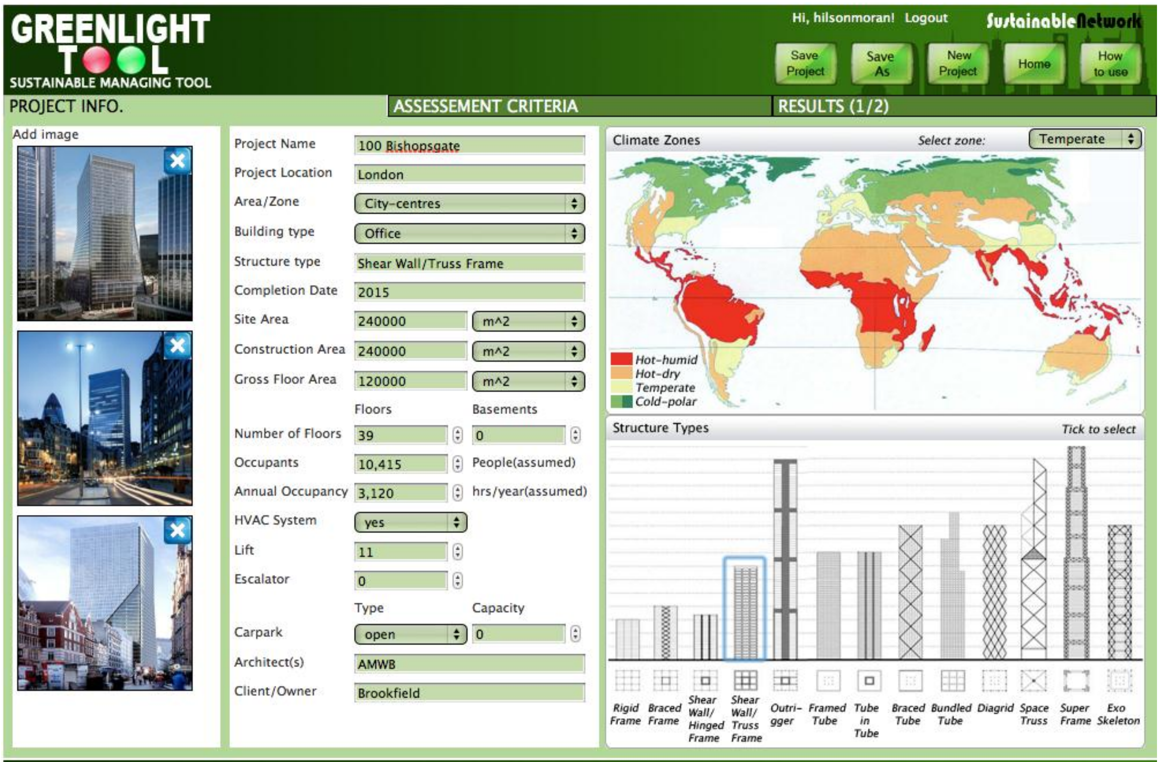


Figure 9.14: The 101 Bishopsgate building being assessed by GreenLight tool – Project Info. tab

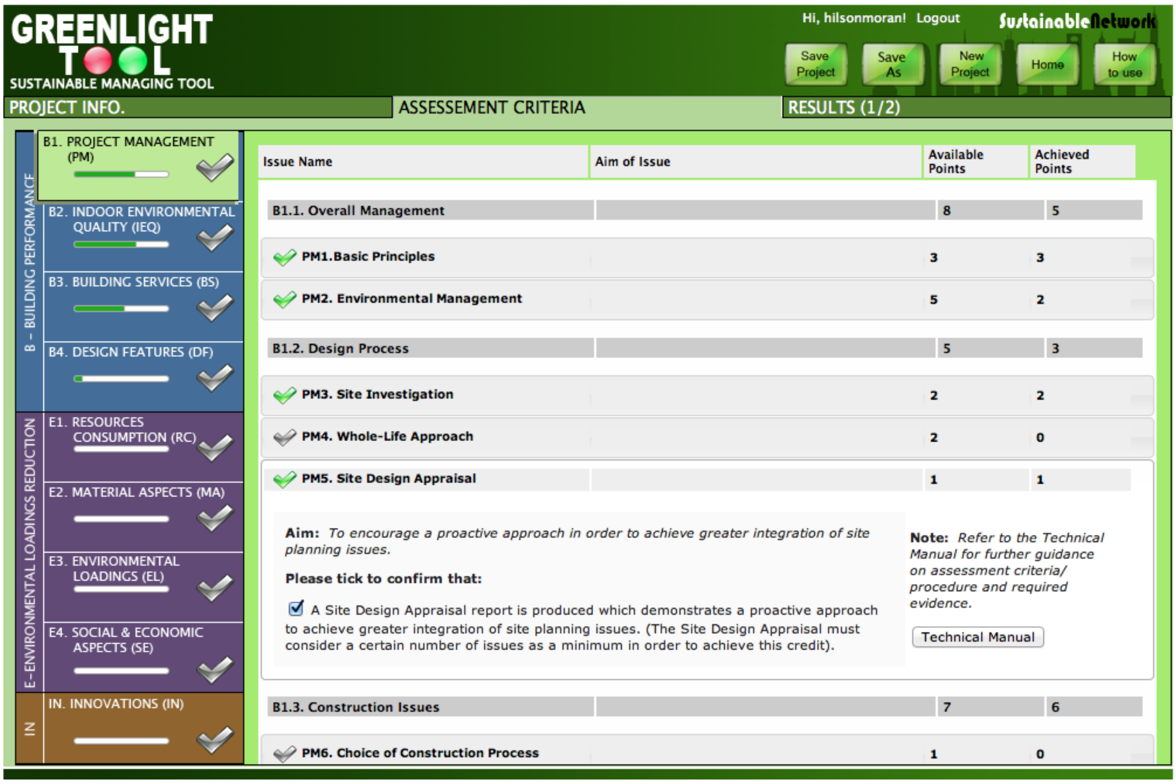


Figure 9.15: The 101 Bishopsgate building being assessed by GreenLight tool – Assessment Criteria tab

The initial responds of Hilson Moran are very promising, which basically indicate that GreenLight tool is working smoothly in their workflow. Hilson Moran will keep participating in the TPSI Project to help improving the GreenLight tool and probably disseminating the online system and the Sustainable Network in the near future.

TPSI Project also received attentions outside of the UK. In Vietnam, there are two firms among the 'Big Four' organisations in the Vietnamese Built Environment that show their interest, namely:

- Vietnam Housing and Urban Development Group (HUD);[44]
- Vinaconex Corporation.[45]

These two companies had already provided some of their staffs to participate in the Interview Process (see Section 8.4). During this process, they have realised the values of TPSI rating system as well as the GreenLight online tool. They are willing to implement GreenLight into their quality management system.

9.4. CHAPTER CONCLUSIONS

The TPSI project, especially the market research process carried out by two renowned consulting firms, confirmed the potentials of TPSI rating system - both academically and commercially. It offers a fresh, hands-on, comprehensive insight into the actual outcomes of the research, and also the prospective downsides and obstacles. It has been established that there are clearly unsaturated markets for TPSI rating system and suggests the detailed strategies to approach these markets. It also examines multiple aspects of TPSI rating system and reveals the probabilities for further research. The initial results of TPSI project (up to March 2012) are very encouraging. The online tool works sufficiently and the network are being developed to support the dissemination of TPSI/GreenLight. TPSI's criteria system and assessment mechanism show their effectiveness and reliability. The features adopted from the TPSI Calculator also prove

[44] **Vietnam Housing and Urban Development Group (HUD)**: <http://www.hud.com.vn>.

[45] **Vinaconex Corporation**: <http://www.vinaconex.com.vn/>.

their advantages. The outcomes generated from case-study buildings show a remarkable consistency. Overall, TPSI displays a big improvement over other existing rating systems, in many aspects. The attentions and potential cooperation with major firms are also strong proofs of the research's values and contributions.

CHAPTER 10: CONCLUSIONS

10

10.1. EXECUTIVE SUMMARY

This research revolves around the development of a sustainability rating system named 'TPSI – Tall-building Projects Sustainability Indicator,' which can be implement throughout the life cycle of a tall-building project. The essence of the research is to create a practical tool that is actually beneficial in reality and would lead to an extensive distribution, while guarantee the originality and contributions of an academic research. As the final outcome, the research has successfully produced the first complete version of TPSI - TPSI 2012 Version, which is available in form of an Excel Tool and a Technical Manual. TPSI has been tested in many tall-building projects both inside and outside of the UK. Currently, the research is receiving supports to develop TPSI further into an online rating scheme. Plans are also in place to bring TPSI to general users as well as to exploit the research's other contributions.

10.2. MAIN CONTRIBUTIONS OF THE RESEARCH

The Creation of TPSI Rating System: TPSI is the first rating system that is specialised for tall-building projects. Academically, TPSI introduces a new, enhanced system of assessment criteria, as well as an innovation assessment methodology. It also introduces many assessment mechanisms/methods (presented within TPSI Issues), which helps improving the interactivity and effectiveness of the assessments and enhances the plain, featureless experience when using traditional rating systems. TPSI is suitable to implement right from the start of a project, and remain useful throughout the project's life cycle. TPSI flexibly offers the options to carry out quick, holistic evaluations using just the TPSI Calculator; as well as detailed, robust examinations when incorporating the Technical Manual.

The Development Model: this research presents a detailed framework for similar developments to that of TPSI, which embraces all aspects of creating a rating system. It also suggests strategies to solve potential issues where appropriate. Overall, the development of TPSI is an inheritable process, during which, the best features of existing tools are adopted and combined with newly developed features to form an enhanced system with specialised qualities. This research strategy is appropriate for individual research with limited resources, which aims to create specialised tools/systems for a particular country or region, for a specific type of projects, or for a certain area of sustainability.

The Enhanced Set of Standards for Sustainable Tall-buildings: this research introduces a complete, detailed set of standards for high-performance high-rise buildings, with actual bars and thresholds. This set of standards is represented by TPSI's assessment criteria system itself. It can function as an independent 'checklist,' which in turn can be used for many purposes other than as a component of a rating tool.

Educational Benefits: TPSI offers an effective and easy-to-use tool, which is suitable for teaching and learning activities at undergraduate and post-graduate levels. TPSI can help 1st and 2nd year students to get used to sustainability issues via an interactive design tool, as well as delivering a powerful system for technical-driven studies - which would be helpful to post-graduate students and researchers. There are plans to introduce TPSI into the MArch course at the University of Sheffield in the next school year.

Technical Contents: TPSI Technical Manual offers many important and original contributions in term of technical contents, at different levels:

- At the highest level, TPSI introduces a new structure of sustainability issues, which includes two main groups, eight categories (excluding the 'Innovation' category), and sub-categories. This structure represents a new strategic approach to sustainability aspects. It offers new opportunities to exploit sustainability assessment criteria such as the TPSI Factor.
- At the Issues level, TPSI introduces a range of new sustainability assessment criteria, especially tall-building specialised criteria. They help enhancing the accuracy and overall quality of the evaluations, as well as other benefits.
- At the issue contents level, efforts are made to enhance the quality of the adopted assessment criteria, as well as inventing new evaluation mechanisms for the original criteria. The main goal is to make sure the TPSI assessment criteria are measurable, quantifiable, applicable, and recognisable worldwide.

Valuable Reference Source: the results of Part A provide a deep insight into the aspects and issues of these systems. Throughout three chapters of Part A, all the pros and cons of exiting rating systems are revealed as well as related information and data. It would be a valuable database for various reference purposes.

Commercial Benefits and Added Values: 'Part C – Testing and Proving' reveals many additional values and potentials of TPSI rating system. The market research, which is carried out by two renowned consulting firms, specifically indicates the sectors that can benefit from TPSI. The candidate and his supervisor have received official approaches from many organisations to further develop and exploit TPSI's potentials. Currently, the TPSI Team is working closely with the University of Sheffield's Commercialisation Team toward the marketing and dissemination of GreenLight online rating scheme as well as expanding the Sustainable Network.

10.3. ADVANTAGES AND DISADVANTAGES OF TPSI

The Interview Process has verifies that TPSI has many advantages over current rating systems when applying to tall-building projects. This is demonstrated by the overall score of 85/100 in comparison to 80/100, 77/100 and 74/100 of LEED, BREEAM and CASBEE correspondingly (see Table 8.5, Section 8.4.3). However, there are some aspects that can still be further improved.

10.3.1. Advantages

Targeting the untapped area: according to the participants' opinions, current rating systems are generally not satisfying their needs. 95% of the participants are interested in a new design and/or rating tool that support them better during their high-rise projects' life cycles. The survey process also reveals that there is a great need for a specialised tool for tall-buildings in order to improve the assessment quality. 72.5% of the participants prefer a separate tool for tall-building projects, compared to just 27.5% who want a combined tool for both low-rise and high-rise buildings. These data prove that the development of TPSI is very timely and would be welcomed by general users.

A combined assessment and design system: when being asked the question: 'During your projects, when dealing with sustainable issues, what do you often need?' answers reveal that the need for a design tool and the need for an assessment tool are equally great (see Section 8.4.3). This suggests that TPSI's move towards more integration with the design process is a right strategy. As one of the survey results, the early stages of a project are the times when users need the support of sustainability rating systems the most. 92.5% of participants said that they need supports when dealing with sustainability issues at the Design stage.

User-friendly tool which can also provide detailed assessment: TPSI is rated among the most user-friendly systems by the interviewees (scores 5/5 under the 'User-friendliness' criterion, as high as LEED and Green Star). At the same time TPSI's accuracy is also well appreciated (scores 10/12 under the 'Accuracy' criterion, second to only the extremely sophisticated CASBEE).

Improved applicability and technical contents: 92% of participants who used sustainable rating systems before think that there are certain aspects that are not covered by these systems; among them, 75% think they are tall-building associated issues (see Section 8.4.3). The 'Applicability' criterion (which takes into account two factors: the stages of tall-building life cycle influenced by the tool, and the technical contents) witnesses the highest score of TPSI (17/20) compared to 15/20 of BREEAM and LEED, and 14/20 of CASBEE (see Table 8.5).

Improved assessment methodology and result presentations: under the 'Methodology' criterion, TPSI scores the highest alongside with CASBEE (both 12/15 – see Table 8.5). TPSI's criteria structure, rating rules, TPSI Factor, and dynamic weighting system allow it to make the most out of user inputs. Subsequently, TPSI offers a great interactivity with users and can produce accurate evaluations in different contexts. The improved assessment methodology also naturally results in the high quality result presentations: TPSI reaches the highest possible score under the 'Result Presentation' criterion (8/8 - see Table 8.5).

Performance improvement: the improvement in a project's overall performance after implementing a rating tool is the most practical and reliable measurement of that tool's quality. During the Interview Process, participants are asked to mark their case studies' performance improvement after using the rating systems. TPSI scores highest under this criterion with 11/12 points, following up are BREEAM, LEED and CASBEE with 9/12, 8/12 and 7/12 points respectively (see Table 8.5).

10.3.2. Disadvantages

Data collecting process: currently, TPSI is over scored by LEED under the 'Data Collecting' criterion (6/8 compared to 7/8 – see Table 8.5). This is due to the fact that TPSI is based on external standards and existing systems. This could substantially lengthen the data inputting process when it comes to detailed evaluations. Solution to this matter lies in the future research where there are involvements of multiple parties as well as additional human and financial resources.

Limitations of Microsoft Excel format: while this is a good choice because of the popularity and capacity of Excel, there are still inconveniences when it comes to saving and loading projects. There is no function to automatically reset all the data boxes (i.e. cells) to the default values. Using Excel format also makes it difficult to exchange assessment results between parties. Because there is no function to export *.jpg files or PDF reports, currently users have to capture their screen or send the entire Excel tool to the person with whom they want to communicate. These inconveniences will be totally removed in the GreenLight online tool (see Section 9.2).

Limitations of the Technical Manual: while the tool-booklet format is a good combination that has been successfully adopted by many rating systems, there are always rooms for improvement. Merging the Assessment Software and the Technical Manual into a single system is one of the online tool's purposes. In the online tool, each TPSI issue will have a button which, when clicked, will 'pop-up' the corresponding contents in the Technical Manual (built right into the system).

10.4. FURTHER RESEARCH

TPSI Project: Carrying on with the TPSI Project would be the immediate next research activity. There are plans in place to tackle the remaining issues and enhance the features of TPSI. The online tool will have more interactivity and accuracy. More graphical presentations will be implemented to better assist the design process. The dynamic weighting system will be studied further to include more factors into the calculation. More parties will be involved in the research. Financial supports will be sought to implement a team of sustainability experts to enhance the Data Collecting process. More testing and validating activities will be carried out and the system will be constantly improved.

Developing other versions for other project types: Dr. Darren Roberts – the current software engineer of GreenLight tool has developed a system that allows easy alterations of TPSI's issues structure and contents without affecting the system's functioning. Initially, this mechanism serves the purpose of producing successive versions of the TPSI online tool. However, it also offers an advantageous method to generate others rating systems for other project types based on TPSI. Simply by modifying the issues structure and contents, there would be a version for another project types (e.g. office buildings) with specialised assessment criteria; and at the same time inherit all the assessment mechanisms and features of TPSI.

Other research directions: the first research direction is to answer theoretical questions arise during the research. For example, there is a question of *quantifying the actual increase in a project's environmental performance* after implementing a rating system. This does not apply only to TPSI or tall-building projects. Another research directions, which is more practical, is to develop other types of systems and software to support different types of users, at different project stages. Intensive research into a certain area of tall-building sustainability is also a potential research direction, which would inherit strong research foundations from TPSI's development. The corporations with major organisations and governments would reveal many exciting research opportunities, and also get practical use out of this research's outcomes.

"While we are free to choose our actions, we are not free to choose the consequences of our actions."

Stephen R. Cove

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A

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APPENDICES

APPENDIX A: REVIEW OF 29 APPLICABLE RATING SYSTEMS

This Appendix reviews the features of 29 applicable tools excluding the Top Five rating systems, which are reviewed in Chapter 5 (i.e. BREEAM, LEED, CASBEE, Green Star, and HK-BEAM). The 29 applicable tools are presented in alphabetical order.

The contents of each rating system are summarised into four headings:

- Overview: Overall review of the tool.
- Assessment criteria: The aspects that are assessed in a project/building.
- Assessment method: Evaluation process and result presentation.
- Source: Where to find the tool?

A.1. BEES (Building for Environment and Economic Sustainability) (U.S.)

Overview:

Over the last decade, the Building and Fire Research Laboratory of the National Institute of Standards and Technology (U.S.) has developed and automated an approach for measuring the life cycle environmental and economic performance of building products. Known as BEES (Building for Environmental and Economic Sustainability), the tool is based on consensus standards and designed to be practical, flexible, and transparent. BEES reduces complex, science-based technical content (e.g., over 400 material and energy flows from raw material extraction through product disposal) to decision-enabling results and delivers them in a visually intuitive graphical format (WBDG, 2011).

Assessment criteria:

User may set relative importance weights for (Lippiatt, 2007):

- Synthesising up to 12 environmental impact scores (global warming, acid rain, eutrophication, fossil fuel depletion, indoor air quality, habitat alteration, ozone depletion, smog, human health, ecological toxicity, criteria air pollutants, and water intake) into an environmental performance score.
- Discounting future costs to their equivalent present value.
- Combining environmental and economic performance scores into an overall performance score, weighting is optional.

Assessment method:

Summary graphs depicting life cycle environmental and economic performance scores for competing building product alternatives. Detailed graphs are also available depicting physical flow quantities for each environmental impact (e.g., grams of carbon dioxide for the global warming impact), embodied energy, and first and future costs.

Source:

The tool is available at: <http://www.wbdg.org/tools/bees.php>.

A.2. BREEAM (UK)

breeam

(See Chapter 5, Section 5.2.1).

A.3. CASBEE (Japan)

CASBEE® 建築環境総合性能評価システム

Comprehensive Assessment System for Built Environment Efficiency

(See Chapter 5, Section 5.2.3).

A.4. CEEQUAL (The Civil Engineering Environmental Quality and Assessment Scheme) (UK)

Overview:

CEEQUAL is the assessment and awards scheme for improving sustainability in civil engineering and public realm projects. It is being promoted by the ICE,[46] CIRIA[47] and a group of committed industry organisations such as CECA[48] and ACE.[49] Its objective is to encourage the attainment of environmental excellence in civil engineering, and thus to deliver improved environmental and social performance in project specification, design and construction (CEEQUAL, 2008).

Assessment criteria:

Basically, a project will be assessed according to 12 categories. The credits received in each category will then be multiplied by that category's weight to come up with the final 'Grade.' Categories and their weights are as in Table A.1.

Table A.1: CEEQUAL's assessment criteria summary

Category	Weight	Category	Weight
Project Management	10.9%	Energy and Carbon	9.5%
Land use	7.9%	Material Use	9.4%
Landscape	7.4 %	Waste Management	8.4%
Ecology and Biodiversity	8.8%	Transport	8.1%
Historic Environment	6.7%	Effects on Neighbours	7.0%
Water resources and the Water Environment	8.5%	Relations with Local Community and other Stake Holders	7.4%

Data source: (CEEQUAL, 2008)

[46] **ICE (Institution of Civil Engineers)** is an independent professional association based in central London, representing civil engineering. <http://www.ice.org.uk>.

[47] **CIRIA** is a member-based research and information organisation dedicated to improvement in all aspects of the construction industry. <http://www.ciria.org>.

[48] **CECA**: Civil Engineering Contractor Association. <http://www.ceca.co.uk>.

[49] **ACE (Association for Consultancy and Engineering)** is a British business association in the field of consultancy and engineering. <http://www.acenet.co.uk>.

Assessment method:

Users who want their project to be assessed have to register for one of the following schemes:

- *Whole Project Award:* applied jointly by the client, designer and principal conductor(s).
- *Client and Design Award*: applied jointly by the client and designer.
- *Design Award*: applied by the principal designer(s) only.
- *Construction-Only Award*: applied by the main (or principal) contractor(s).
- *Design and Build Award*: applied by Design and Build and other partnership contracts.

The CEEQUAL official assessment process is quite costly (the minimum fee is £2,995 for projects up to £2 million). Alternatively, a free CEEQUAL Manual can be used to assess the sustainability of a project non-officially. There are four types of Final Grade: Pass, Good, Very Good, and Excellent (CEEQUAL, 2008).

Source:

Free CEEQUAL Manual and other related materials can be downloaded at:

<http://www.ceequal.co.uk>.

A.5. CEPAS (Comprehensive Environmental Performance Assessment Scheme for Buildings) (Hong Kong)

Overview:

CEPAS is a holistic assessment tool for various building types in Hong Kong with clear demarcation of the entire building life cycle, which covers the pre-design, design, construction and demolition and operation stages. The element of sustainability has been built into this assessment scheme. Issues of broader sense of sustainability as well as extending environmental sustainability to social and economic aspects are also integrated into all CEPAS categories and indicators (CEPAS, 2006a).

Assessment criteria:

There are eight performance categories (i.e. Resource Use, Loadings, Site Impacts, Neighbourhood Impacts, Neighbourhood Amenities, Site Amenities, Building Amenities, and Indoor Environmental Quality) to be accessed in each of four stages of the building's life cycle (i.e. Pre-design stage, Design stage, Construction stage, and Operation stage) (see Figure A.1).

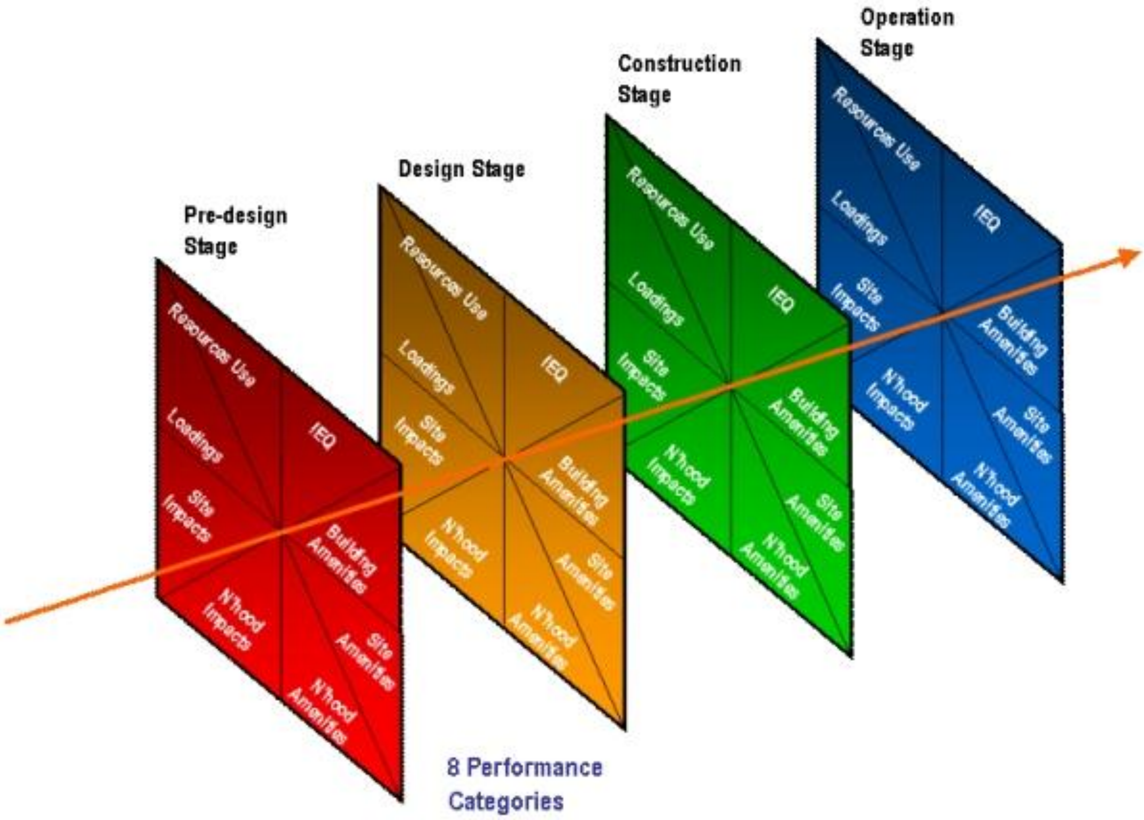
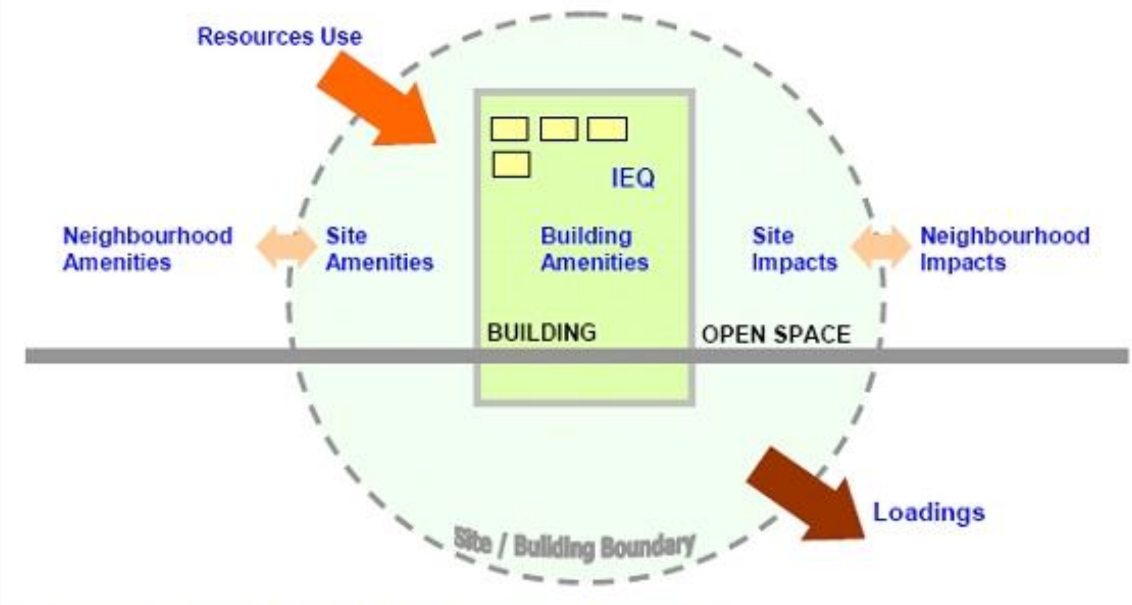


Figure A.1: CEPAS's assessment criteria system

Source: (CEPAS, 2006a)

Assessment method:

CEPAS's assessment method is very simple. Projects are given points for fulfilling sustainable requirements. The obtained score over the overall score demonstrates the sustainability of the project. There is no Grade or Award or Scheme given (see Figure A.2).



Physical Relations of CEPAS Performance Categories

Figure A.2: CEPAS's assessment method

Source: (CEPAS, 2006b)

Source:

The four tools for four stages of a building's life cycle are available at: <http://www.bd.gov.hk/english/documents/index_CEPAS.html>.

A.6. DQI (Design Quality Indicator) (UK)

DQI
DESIGNQUALITYINDICATOR

Overview:

DQI (Design Quality Indicator) is a pioneering process for evaluating design quality of buildings in the UK. It can be used by everyone involved in development processes and activities that contribute to the improvement of the Built Environment's quality. DQI is a generic toolkit that can be used with all types of building. There is also a version specifically aimed at school buildings - the DQI for Schools. DQI encompasses issues that are relevant at all stages in the development of a building and the tool should be used throughout the life of the project. DQI collects views from respondents about building's functionality, build quality and impact (CIC, 2008).

Assessment criteria:

DQI assess a building by using a range of indicators under three main headings (see Table A.2).

Table A.2: DQI's assessment criteria summary

Build Quality: relates to the engineering performance of a building, which includes structural stability and the integration and robustness of the systems, finishes and fittings. Sub-headings: - Use; - Access; - Space.	**Functionality**: is concerned with the arrangement, quality and inter-relationship of space, and the way in which the building is designed to be useful. Sub-headings: - Performance; - Engineering.	**Impact**: refers to the building's ability to create a sense of place, and to have a positive effect on the local community and environment. Sub-headings: - Form and Materials; - Internal Environment; - Urban and Social Integration; - Character and Innovation.

Data source: (CIC, 2008)

Assessment method:

The DQI assessment uses a short, generic questionnaire that takes about 20-30 minutes to complete. There are four versions of DQI relevant to different phases of the project that is being assessed:

- *The brief version:* is used to help a group of key stakeholders to form a consensus about priorities and ambitions for the design brief by defining what aspects are fundamental, what would add value, and what would achieve excellence in the completed building.
- *Mid-design version:* allows the client and design teams to check whether early aspirations have been met and make adjustments accordingly in focus and quality, and can be used throughout the design phase when things are not too late to change.
- *Ready for occupation version:* is used to check whether the brief/original intent has been achieved immediately at occupation.
- *In-use version:* is used in order to receive feedback from the project team and the building users to help make improvements for this project and the next.

Source:

Information and references can be found at: <http://www.dqi.org.uk>.

A.7. Earth Advantage (Commercial Buildings) (U.S.)

Overview:

Earth Advantage Commercial is one of the sustainability assessment tools that are developed by EAI (Earth Advantage Institute – Oregon, U.S.). EAI is a non-profit organisation working with the building industry to help implementing sustainable building practices. Offering a suite of green building certification programs, including new home, remodel, community and commercial standards, Earth Advantage Institute is one of the leading resources for green building knowledge in the U.S. While Earth Advantage Tools for New Homes and Community are not very suitable for tall-buildings, the version for commercial buildings is sometime used to assess tall-buildings in the U.S., especially in Oregon and nearby locations (EIA, 2010).

Assessment criteria:

The structure of measurement criteria of Earth Advantage Tool is quite different from other sustainability assessment tools. There are many strategies to apply to buildings to achieve sustainability and they are divided into five broad groups: Energy, Water, Health, Land, and Material. In each group, these strategies serve four different sustainable targets as in Table A.3:

Table A.3: Earth Advantage's assessment criteria summary

Energy Save Energy System Performance Measure and Manage Other	**Water** People Plants Storm water Other	**Health** Pollution Source Control Toxic Reduction Occupant Comfort Other
Land Site Ecology Transport Connectivity and Place Making Other	**Material** Environment preferable Materials Materials Minimisation and Durability Waste Reduction Other	

Data source: (EIA, 2010)

Assessment method:

The Earth Advantage Commercial provides three levels of certification: Silver, Gold and Platinum. At the Silver level, a customer who may not be familiar with green building practices would be able to navigate the requirements with minimal technical assistance. At the Gold and Platinum levels of certification, the program requirements not only become more rigorous but also increase the customers' level of responsibility in the design, monitoring, and verification of environmental benefits exhibited by their project. Developers have to acquire the lower level before reaching for the higher ones (EIA, 2010).

Source:

More information and the tool itself can be downloaded at:
<http://www.earthadvantage.org>.

A.8. EEWH (Taiwan)

Overview:

EEWH (Ecology, Energy saving, Waste reduction and Health) results from The Green Building Certification Program - a voluntary program but is mandatory for any new public building construction project in Taiwan which is funded by the government with an amount of more than about $1.5 million U.S. (approximately £935,000) (STSIPA, 2011). Interestingly, Taiwan government was the first in Asia, and fourth in the World, to adopt a set of sustainable building standards (Crook, 2007). In 1999, the Taiwan's Architecture Research Institute of the Ministry of the Interior developed a Green Building Evaluation System, called EEWH and Evaluation Manual for Green Buildings in Taiwan that, according to some experts, has been very successful. EEWH was built largely based on LEED.

Assessment criteria:

EEWH encompasses nine indicators, which are then categorised into four areas (see Table A.4).

Table A.4: EEWH's assessment criteria summary

Category	Indicators	Contents
Ecology	1. Bio-diversity Indicator	Including community-based green network system, topsoil preservation technology, eco-pool, eco-waterfront, ecological slope / eco-fence design and porous environment.
	2. Greenery Indicator	Including eco-greenery, green wall, green wall irrigation, artificial sites greenery technology, greenery waterproof and drainage technology, and greenery windproof technology.
	3. Soil Water Content Indicator	Including permeable paving, landscape infiltration and retention pond, retention and infiltration space, infiltration wells and the infiltration pipe, and retention in artificial site.
Energy Savings	4. Energy Savings Indicator	Including Energy-related technology, the use of wind direction and air currents, the use of air conditioning and cooling systems, management of energy and lighting, the use of solar energy
Waste Reduction	5. CO2 Emission Reduction Indicator	Including simple building shape and interior furnishing, appropriate structural system, lightweight structure and timber structure.
	6. Construction Waste Reduction Indicator	The use of recycled building materials, earthwork balance, construction automation, dry-construction partition, unit bathroom, and air pollution prevention during construction.
Health	7. Water Resource Indicator	Including water-efficient fixtures, grey-water recovery plan, rainwater recovery and water-efficient plant irrigation.
	8. Garbage and Sewage Improvements	Including diversion of rainwater and sewage, improvement of garbage field, ecological wetland wastewater treatment and kitchen waste composting.
	9. Indoor Environmental Quality Indicator	Including indoor pollution control, indoor air purifying, ecological building materials, wall condensation/efflorescence prevention, damp-proofing, moisture-adjusting, noise and vibration prevention.

Data source: (STSIPA, 2011)

Assessment method:

EEWH offers five rating levels: Certified, Bronze, Silver, Gold, and Diamond. As of May 2008, one building (the Beitou Public Library) had been rated at Diamond level, and one at Gold level. EEWH's assessment method is roughly equivalent to LEED, CASBEE, and HQE (Wikipedia, 2010b).

Source:

More information can be found at: <http://gsp.stsipa.gov.tw/eng/main03_2.html>.

A.9. Envest 2 (UK)

Overview:

Envest 2 is a tool developed by BRE that simplifies the otherwise very complex process of designing buildings with low environmental impact and whole life costs. Envest 2 allows both environmental and financial trade-offs to be made explicit in the design process, allowing the client to optimise the concept of best value according to their own priorities (BRE, 2011).

Assessment criteria:

Environmental data may be presented as a range of 12 impacts, from climate change to toxicity, as well as a single Ecopoint score, for ease of communication, especially in comparison with costs (Thistlethwaite, 2008).

Assessment method:

Designers input their building designs (height, number of stories, window area,) and choices of elements (external wall, roof covering,). Envest 2 identifies those elements with the most influence on the building's environmental impact and whole life cost and shows the effects of selecting different materials. It also predicts the environmental and cost impact of various strategies for heating, cooling and operating a building. Having made comparisons between different buildings and specifications, designers can graphically demonstrate the environmental and financial credentials of different designs to clients. Envest 2 produces detailed and summarised information that is readily transferred to the users’ own template to create a bespoke environmental report for a building (Thistlethwaite, 2008).

Envest 2 is web based, allowing large design companies to store and share information in a controlled way, enabling in-house benchmarking and design comparison. Two versions of the tools are available:

- *Envest 2 estimator:* uses default environmental and financial data about the whole life performance of the building. It is intended for use by design teams who are particularly interested in the environmental performance of a building but also find it useful to provide an estimate of relative whole life costs for different designs.
- *Envest 2 calculator:* provides default environmental data but allows the user to enter their own capital and lifetime financial cost information. It provides a powerful tool for design teams for whom the whole life costs are of prime importance.

Source:

Information and the tool itself are available at: <http://envestv2.bre.co.uk/>.

The tool is not free, however users can have access to a free demo version of the tool on the official website.

A.10. Green Building Certification System (GBCS) (Korea)

Overview:

Green Building Certification System (GBCS) is an assessment tool equivalent to LEED, BREEAM, CASBEE, HQE, developed by the Korea Green Building Council (KGBC) - a non-profit organisation authorised by the Korean government to promote the development of the allied industries through the development and dissemination of green building technologies. From 2000, KGBC has been developing sustainable building standards in Korea.

The standards now cover four types of buildings/projects: Multi-Unit Residential building, Mixed-Used dwellings, Office buildings and Schools. The Office buildings scheme is most suitable to assess tall-buildings (Yongchan, 2008).

Assessment criteria:

The list of criteria and their potential contribution to the overall score (under GBCS Office buildings scheme) is shown in Table A.5:

Table A.5: GBCS's assessment criteria summary

Category	Criteria	Score (Total 136)
Land development	Ecological value Land development Impacts on the site and adjacent properties	7
Commuting transportation	Reduction of commuting transport loads	5
Energy	Energy consumption Energy conservation	23
Materials and resources	Resources conservation Resource Recycling	21
Water Resources	Establishment of water circulating system Conservation of water resources	14
Atmosphere pollution	Prevention from global warming	6
Management	Systematic on- site construction management	10
Ecological environment	Creation of green space in the site Creation of biological habitat	19
Indoor Environmental Quality	IAQ Thermal environment Noise and acoustics Creation of comfort indoor environment Consideration for the old and the weak person	31

Data source: (Kim, 2009)

Assessment method:

The assessment method of GBCS is very simple. Buildings/projects score points for fulfilling criteria. Title will be given for number of points achieved. For example, buildings that score ≥ 65 points will be graded 'Excellent,' buildings that score ≥ 85 points will be graded 'Best,'

Source:

The tool is available at: <http://www.greenbuilding.or.kr>.

A.11. Green Globes (U.S., Canada, UK)

Green Globes

Overview:

The Green Globes system is a revolutionary building environmental design and management tool. It delivers an online assessment protocol, rating system and guidance for green building design, operation and management. The system was built largely based on BREEAM. Versions of Green Globes are available in the U.S., Canada and even the UK. There are five tools available; two of them have been using to assess sustainable tall-buildings (GBI, 2010), which are:

- Design of New Buildings or Significant Renovation;
- Management and Operation of Existing Buildings.

Assessment criteria:

Green Globes' assessment criteria are divided into seven main categories as shown in Table A.6.

Table A.6: Green Globes' assessment criteria summary

Assessment Category	Points (1000)	Description
Energy	360	Performance, efficiency, demand reduction, energy efficient features, use of renewable energy, transportation.
Indoor Environment	200	Ventilation, lighting, thermal and acoustical comfort.
Site	140	Ecological impact, development area, watershed features, enhancement.
Resources	100	Low impact materials, re-use, demolition, durability, recycling
Water	100	Performance, conservation, treatment
Emission and Effluents	50	Air emissions (boilers), ozone depletion, water and sewer protection, pollution controls
Project Management	50	Design process, environmental purchasing, commissioning

Data source: (GBI, 2010)

Assessment method:

Users start by filling in an online questionnaire. Building performance will be assessed on a 1000 point score in seven different categories. A graphical view of summary performance in each environmental assessment category will then be delivered, clarifies building strengths and weaknesses (see Figure A.3). An overall score and detailed summary of environmental/sustainable features will also be available (GBI, 2011).

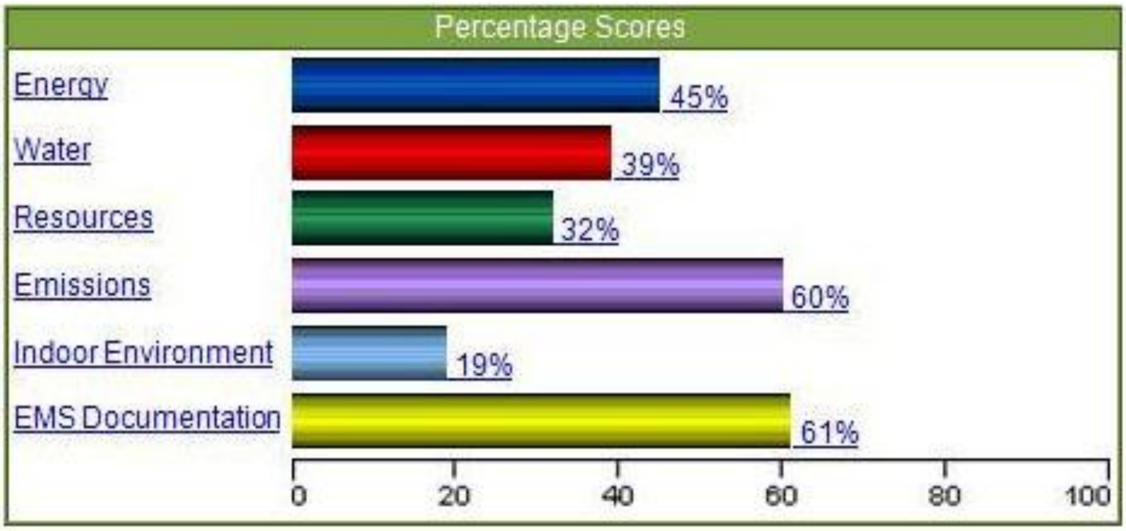


Figure A.3: Green Globes section scores example

Source: Google Images

Source:

All versions of Green Globes can be found at: <http://www.greenglobes.com/>.

A.12. Green Leaf Eco-Rating program (U.S., Canada)

Overview:

Green Leaf Eco-Rating Program (or Audubon Green Leaf Eco-Rating Program) is well known in US and Canada. It provides the assurance that audited lodging facilities have met environmental best practice standards. The program began in 1998 to meet the lodging industry's desire to provide quality guest services, while minimising their impact on the environment. Through a comprehensive and credible method for assessing the extent of the environmental measures undertaken, participating facilities can reduce environmentally related costs and gain a marketing advantage. Green Leaf covers most type of lodging facilities including (Audubon International, 2010):

- Hotels;
- Motels;
- Resort;
- Inns;
- Bed and Breakfasts;
- Conference Centres;
- Tourist Destinations.

Assessment criteria:

Green Leaf's assessment criteria are categorised into four groups as shown in Table A.7

Table A.7: Green Leaf's assessment criteria summary

Energy Efficiency Energy Efficient Equipment Energy Efficient Operations Preventative Maintenance Building Upkeep Advanced Energy Practices	**Resource Conservation** Water Conservation Decreasing Waste
Pollution Prevention Hazardous Materials Management Use and Disposal of Hazardous Materials Environmental Air Quality	**Environmental Management** Policy Development Goal Setting and Planning Employee Training and Communication Guest Communications and Outreach Eco-Purchasing Outdoor Habitat Management

Data source: (Audubon International, 2009)

Assessment method:

The tool is available in form of a questionnaire/survey about detailed environmental profile of all functional areas of a hotel. It is easy to follow and has questions requiring simple responses. By providing users with a list of well-established 'best environmental practices,' developed with industry and outside stakeholder input, users can tell where and how they have been using eco-efficiency. The Survey's four main sections (see Table A.7) cover issues ranging from energy efficient equipment to indoor air quality to water conservation to environmental policies and communication. It takes about four hours to complete. It can be completed in hardcopy or by filling out a PDF form online.

Source:

The questionnaire can be downloaded at: <http://greenleaf.audubonintemational.org/>.

A.13. Green Mark (Singapore)

Overview:

The Green Mark (or BCA Green Mark Scheme) was launched in January 2005 as an initiative to drive Singapore's construction industry towards more environment-friendly buildings. In order to have a building officially assessed under Green Mark Scheme, users have to submit an application form to BCA (Building and Construction Authority of Singapore). However, Green Mark documents and a Score Calculator are free to download for users to assess their projects themselves. One of the unique features of Green Mark is that the differences between Air-conditioned and non-air-conditioned buildings are given especial attention (due to Singapore’s housing policy).

There are seven schemes of Green Mark for various types of projects (BCA, 2011):

- *Non-Residential New Buildings:* for new buildings such as offices, commercial, industrial and institutional buildings with or without air-conditioning systems.
- *Residential New buildings*: for new private and public residential developments.
- *Existing Buildings*: for existing commercial, industrial and institutional buildings under operation.
- *Office Interior*: applicable for tenant renovation and maintenance practices.
- *Landed Houses:* for landed housing projects.
- *Infrastructure*: for infrastructure projects e.g. as barrages, roads, bridges.
- *District:* for district projects.

Assessment criteria:

Green Mark’s assessment criteria are divided into five sections as summarised in Table A.8.

Table A.8: Green Mark's assessment criteria summary

Energy Efficiency	**Water Efficiency**	**Indoor Environmental Quality**
Building Envelope	Water Efficient Fittings	Thermal Comfort
Air-Conditioning System	Water Usage and Leak Detection	Noise Level
Building Envelope	Irrigation System	Indoor Air Pollutants
Natural Ventilation	Cooling Tower	High Frequency Ballasts
Artificial Lighting	**Environmental Protection**	**Other Green Features and** Innovation
Ventilation in Car parks	Sustainable Construction	Green Features and Innovations
Ventilation in Common Areas	Greenery	
Lifts and Escalators	Environmental Management	
Energy Efficiency	Public Transport Accessibility	
Renewable Energy	Refrigerants	

Data source: (BCA, 2010a; 2010b)

Assessment method:

Depending on the overall assessment and point scoring, the building will be certified to have met the BCA Green Mark Platinum, Gold Plus, Gold or Certified rating.

Source:

The tool, documents and more information can be found at:
<http://greenmark.sg/> or
<http://www.bca.gov.sg/GreenMark/green_mark_buildings.html>.

A.14. Green Star (Australia)

(See Chapter 5, Section 5.2.4).

A.15. HK BEAM (Hong Kong)

(See Chapter 5, Section 5.2.5).

A.16. HQE (France)

Overview:

The Haute Qualité Environnementale or HQE (High Quality Environmental standard) is a standard for green building in France, which is controlled by the Paris based *Association pour la Haute Qualité Environnementale (ASSOHQE).* The HQE process puts the emphasis on the early stages of the project. It proposes 14 targets that the project owners should prioritise according to the project objectives, local context and environmental requirements.

Assessment criteria:

There are 14 targets, which are classified under two areas and four categories (see Table A.9).

Table A.9: HQE's assessment criteria summary

First Area: Environment preservation	Second Area: User's health
1. Eco construction - Harmonious relation between buildings and their close environment - Integrated choice of construction processes and products - Building site with low nuisance	*3. Comfort* - Heat comfort - Acoustic comfort - Visual comfort - Olfactory comfort
2. Eco management - Energy management - Water management - Waste management - Maintenance management	*4. Health* - Health quality of the areas - Health quality of water - Health quality of air

Data source: (Bidou, 2006)

Assessment method:

Each target is directly linked with requirements that correspond to a set of operational indicators (qualitative or quantitative). An original feature of the HQE process comes from the fact that it is not required to have the best performance for the 14 targets. It is asked to choose the main important targets on which special attention and efforts will be carried out. The purpose is not to achieve a medium mark on a set of criteria but to be really good on the most sensible criteria.

Source:

The tool, documents and more information can be found at: <http://www.assohqe.org>.

A.17. LEED (U.S.)

(See Chapter 5, Section 5.2.2).

A.18. Living Building Challenge (U.S.)

Overview:

Living Building Challenge (LBC) is not actually a rating tool but a very strict standard developed based on LEED by Cascadia Region Green Building Council and International Living Building Institute. LBC's developers believe that buildings which achieve LBC certificate even exceed LEED Platinum standard and begin to re-imagine how the Built Environment can better co-exist with the natural World. There is only one LBC standard for all type of buildings and projects. LBC is based on actual, rather than modelled or anticipated, performance. Therefore, projects must be operational for at least 12 consecutive months prior to the evaluation. The latest version of LBC (by April 2010) is LBC 2.0 (McLennan & Bukman, 2010).

Assessment criteria:

LBC's assessment criteria are divided into seven categories as shown in Table A.10.

Table A.10: LBC's assessment criteria summary

Site Limits to Growth Urban Agriculture Habitat Exchange Car Free Living	**Materials** Red List Embodied Carbon Footprint Responsible Industry Appropriate Sourcing Conservation + Reuse	**Beauty** Beauty + Spirit Inspiration + Education	**Health** Civilised Environment Healthy Air Biophilia
Water Net Zero Water Ecological Water Flow	**Equity** Human Scale + Humane Places Democracy + Social Justice Rights to Nature	**Energy** Net Zero Energy	

Data source: (McLennan & Bukman, 2010)

Assessment method:

LBC divides up buildings and projects into four ‘Typologies’ and users have to decide what typology their project is. The compilation of ‘Imperatives’ (i.e. requirements or criteria) can be applied to almost every conceivable Typology, be it a building (both renovation of an existing structure, or new construction), infrastructure, landscape or community development. Naturally, strategies to create Living Buildings, Sites or Communities will vary widely by occupancy, use, construction type and location, but the fundamental considerations remain the same. Some Typologies have fewer than 20 Imperatives. Although not a measurement tool, LBC is still a valuable reference for the development of TPSI while it is attempting to raise the bar of sustainability.

Source:

LBC 2.0 and references can be downloaded at: <http://ilbi.org/>.

A.19. MSBG (U.S.)

Overview:

In 2000, The Minnesota Legislature required the Departments of Administration and Commerce to develop sustainable building design guidelines mandatory for all new buildings and major renovation. Consequently, the MSBG (The State of Minnesota Sustainable Building Guidelines) was built. The guidelines are designed to be clear, simple and easily monitored with explicit documentation that will record progress. They are designed to be compatible with the U.S.’s national guidelines such as LEED™ while maintaining regional values, priorities and requirements. The latest version of MSBG is MSBG 2.1 or B3-MSBG 2.1 (B3 = Buildings, Benchmarks and Beyond) (MSBG, 2010a).

Assessment criteria:

MSBG’s assessment criteria system consists of five main categories as demonstrated in Table A.11.

Table A.11: MSBG's assessment criteria summary

Performance management Guideline Management General Project Data Planning for Conservation Integrated Design Process Design and Construction Commissioning Operations Commissioning Lowest Life Cycle Cost	**Energy and Atmosphere** Energy Efficiency Renewable Energy Efficient Equipment and Appliances Atmospheric Protection
Site and Water Identification and Avoidance of Critical Sites Storm water Management Soil Management Sustainable Vegetation Design Light Pollution Reduction Erosion and Sedimentation Control During Construction Landscape Water Efficiency Building Water Efficiency Appropriate Location and Development Pattern Brownfield Redevelopment Heat Island Reduction Transportation Impacts Reduction Wastewater Management	**Indoor environmental quality** Restrict Environmental Tobacco Smoke Specify Low-emitting Materials Moisture Control Ventilation Design Thermal Comfort Quality Lighting Effective Acoustics and Positive Soundscapes Reduce Vibration in Buildings Daylight View Space and Window Access Personal Control of IEQ Conditions and Impacts Encourage Healthful Physical Activity
Materials and waste Life Cycle Assessment of Materials Environmentally Preferable Materials Waste Reduction and Management	

Data source: (MSBG, 2010b)

Assessment method:

As MSBG is not strictly a valuation tool, there is no credit given to the buildings/projects for each section and there is no final assessment too. In each section, there will be clear and concise instruction on intent of the guideline, required criteria to fulfil the guideline and recommended criteria for further developments (MSBG, 2011).

Source:

The guidelines are available for free at: <http://www.msbg.umn.edu/>.

A.20. M4i (UK)

Overview:

M4i is a self-completion tool for sustainable construction using indicators and monitoring. The tool is project based in line with other forms of Key Performance Indicators. The indicators' purposes are (Constructing Excellent, 2009):

- To measure the project performance against a set of sustainability issues.
- To provide project managers with a steer towards what makes a project more sustainable.
- To help project managers ask the right questions of themselves and others in the running of the project.
- To help project managers with a measure of what is being done in sustainability terms; and provide a route to continuous improvement.

Assessment method:

The M4i assessment tool provides benchmarks to allow a project to be compared with others. The benchmarks were based on the analysis of 30 projects during 1999/2000 (PETUS, 2010). The tool is designed for use by the project manager. Since the project manager will be knowledgeable about the project, the tool could produce fairly quick results (preliminary assessments take about an hour). Research or measures to improve a project score might however increase the time. The tool is divided into two parts:

- *Project profile*: collates details about the project such as type of project and site and location.
- *Projects performance*: measures against a set of sustainability issues, while steering the project towards sustainability. Should be completed on a quarterly basis and considers issues such as water saving measures incorporated, material chosen on best value.

The results are tabulated, displayed on graphs or on spider web charts. When used on the web the indicators scores were calculated on the user's behalf. The results are quantitative and are tabulated or in graphs.

Source:

The tool is available for use online, but can also be printed and used on paper: <http://www.m4i.org.uk/>.

A.21. NABERS (Australia)

Overview:

The National Australian Built Environment Rating System (NABERS) is one of the most well known two tools in Australia (the other one is Green Star – see Section 5.2.4). NABERS is a collection of separate tools, each of which calculates and rates the performance of an *existing building* (or part of one) on a particular environmental indicator as at a certain point in time. Thus it differs crucially from Green Star, which rates design rather than performance. On a simplistic level, the difference is that Green Star asks, among other things, "Does your building have separate light switches for each zone?” being a design feature that can help reduce electricity use; whereas NABERS asks, "How much electricity did you use last year?" NABERS has been developed for offices, hotels residential buildings, and are currently being developed for retail buildings (Mitchell, 2009). The NABERS Office rating tool is often used to assess high-rise projects.

Assessment criteria:

NABERS’ assessment criteria system consists of four main categories as shown in Table A.12.

Table A.12: NABERS’ assessment criteria summary

Energy	Looking at the amount of each type of energy (electricity, gas, coal, oil…) consumed on the premises in a year, and how much of it is supplied from renewable energy sources
Water	Looking at the amount of water used on the premises in a year, and how much of this is externally-supplied recycled water
Indoor Environment	Looking at internal environmental quality: thermal comfort, air quality, acoustic comfort, lighting and office layout..
Waste	Looking at the total materials used (e.g. paper) per person per day, and the amount of those materials that are recycled or reused.

Data source: (Bose, 2010)

Assessment method:

Ratings for each component are expressed in ‘Stars,’ as with Green Star, but the maximum number of NABERS stars is five (rather than six for Green Star), with five stars being the top performance. Half-stars are available, allowing greater discrimination on performance than the whole stars used in Green Star (see Table A.13). Although NABERS is energy-biased and neglect many design-related features of buildings as well as other sustainable features; its unique characteristics make it a competitive tool in Australia, especially when it comes to office buildings. The simplicity and cost-effectiveness of the tool is widely recommended.

Table A.13: NABERS ratings

Rating	Comments	Emissions (kg CO2/ m2)
1 Star	Poor – poor energy management or out-of-dated systems	199
2 Star	Average building performance	167
3 Star	Very good – current market best practice	135
4 Star	Excellent – strong performance	103
5 Star	Exceptional – best building performance	71

Data source: (Mitchell, 2009)

Source:

The tool and related materials can be accessed at: <http://www.nabers.com.au>.

A.22. 'Quality of Life Counts' Indicators (UK)

Overview:

In December 1999, the UK Government published the 'Quality of Life Counts' (or 'QoLC 1999') – indicators for a strategy for sustainable development for the United Kingdom to provide a baseline assessment from which progress might be judged. A key feature of these indicators was the 15 headline indicators of sustainable development. Making up a 'quality of life barometer' of issues (such as employment, education, health, crime, air quality, road traffic and waste), these indicators were intended *"to provide a high level overview of progress, and be a powerful tool for simplifying and communicating the main messages for the public"* (DEFRA, 2004). Since 1999, QoLC has become a model and resource for a considerable number of other indicator initiatives at local, regional, national and international levels, and the indicators have been adopted in many other indicator sets.

Assessment criteria:

The indicators are structured within six 'themes' and 19 'families.' In addition there are further 16 indicators providing further analysis of the relationship between economic, social and environmental issues. The structure of 19 main families is presented in Table A.14.

Table A.14: DEFRA's 'Quality of Life Counts' Indicators

1. Assessing overall progress and priorities	H - Headline Indicators
2. A sustainable economy	A - Doing more with less: improving resource efficiency B - Economic stability and competitiveness C - Developing skills and rewarding work D - Sustainable production and consumption
3. Building sustainable communities	E - Promoting economic vitality and employment F - Better health for all G - Travel J - Access K - Shaping our surroundings L - Involvement and stronger institutions
4. Managing the environment and resources	M - An integrated approach N - Climate change and energy supply P - Air and atmosphere Q - Freshwater R - Seas, oceans and coasts S - Landscape and wildlife
5. Sending the right signals	T - Sending the right signals
6. International co-operation and development	U - International co-operation and development

Data source: (DEFRA, 2004)

Assessment method:

QoLC is not an actual assessment tool; each indicator has a different methodology.

Source:

Related information can be found at: <http://www.defra.gov.uk>.

A.23. SBTooL/GBTooL (International)

Overview:

The SBTool (formerly GBTool) is a rating framework or *'toolbox,'* designed to allow countries to design their own locally relevant rating systems. SBTool is developed to include consideration of regional conditions and values, in local languages and standards, but the calibration to local conditions does not destroy the value of a common structure and terminology. SBTool produces both relative and absolute results. The system is therefore a very useful international benchmarking tool. This system was developed under the guidance of 19 national teams participating in the Green Building Challenge, an on-going international project to develop and test a new method of assessing the performance of buildings (Larsson, 2007).

Assessment criteria:

SBTool's assessment criteria system consists of seven main categories as in Table A.15.

Table A.15: SBTool's assessment criteria summary

A. Site Selection, Project Planning and Development A. Site selection A2. Project planning A.3. Urban Design and Site Development	**B. Energy and Resource Consumption** B1. Total Life Cycle Non-Renewable Energy B2. Electrical peak demand for facility operations B3. Renewable energy B4. Materials B5. Potable water
C. Environmental Loadings C1. Greenhouse Gas Emissions C2. Other atmospheric emissions C3. Solid wastes C4. Rainwater, storm water and wastewater C5. Impact on site C6. Other local and regional impacts	**D. Indoor Environmental Quality** D1. Indoor air quality D2. Ventilation D3. Air temperature and relative humidity D4. Daylighting and illumination D5. Noise and acoustics
E. Service Quality E1. Safety and security during operations E2. Functionality and efficiency E3. Controllability E4. Flexibility and adaptability E5. Commissioning of facility systems E6. Maintenance of operating performance	**F. Social and Economic aspects** F1. Social aspects F2. Cost and economics **G. Cultural and Perceptual Aspects** G1. Culture and heritage G2. Perceptual

Data source: (Shari *et al.*, 2007)

Assessment method:

The system contains three levels of parameters that nest within each other: Issues, Categories and Criteria. Criteria are scored according to the following scale:

-1=Deficient
0=Minimum acceptable performance
+3=Good Practice
+5=Best practice

Criteria scores are then weighted. Category scores are the total of weighted Criteria scores. Issue scores are the total of weighted Category scores.

Source:

Related information can be found at: <http://www.iisbe.org/sbtool>.

A.24. SBAT (Africa)

(SBAT©)

Overview:

The Sustainable Building Assessment Tool (SBAT) was developed as a way of supporting the implementation of more sustainable practices in the building and construction industry in developing countries and in South Africa in particular. In order to reflect the priorities in developing countries the tool places a strong emphasis on social and economic aspects of sustainability as well as environmental issues (Strand & Fossdal, 2003).

Assessment criteria:

SBTool's assessment criteria system consists of three main categories as in Table A.16.

Table A.16: SBAT's assessment criteria summary

Environmental	Economic	Social
Water	Local Economy	Occupant Comfort
Energy	Efficiency of Use	Inclusive Environments
Waste	Adaptability and Flexibility	Access to Facilities
Site	On-going Costs	Participation and Control
Materials and Components	Capital Costs	Education, Health and Safety
		Local contractors

Data source: (Gilbert, 2001)

Assessment method:

The main advantage of SBAT is that it is very concise and user friendly. The number of questions is kept to the minimum. Users will fill in the building's data and measurement and the tool will automatically come up with points archived for each question as well as the overall assessment. Final report is very simple (in form of a single graph) (see Figure A.4). The tool is in Excel format.

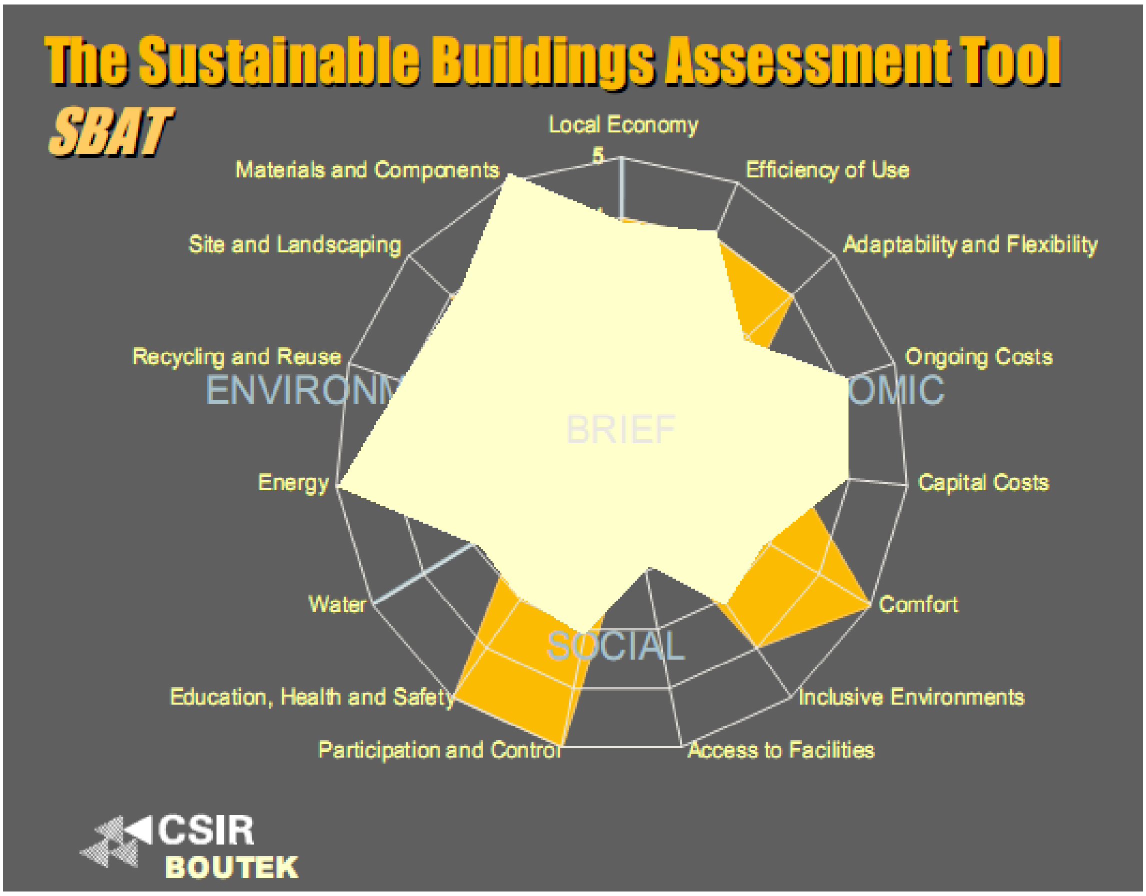


Figure A.4: SBAT's result sheet example

Source: CSIR Boutek <http://www/csir.co.za>.

Source:

The Excel tool is available at:
<http://www.csir.co.za/Built_environment/Architectural_sciences/sbat.html> or
<http://researchspace.csir.co.za/dspace/handle/10204/1233>.

A.25. SE Checklist (UK)

Checklist South East

Overview:

The South East Sustainability Checklist (SE Checklist) is a new, easy-to-use online tool that has been developed by SEEDA and BRE. Devised specifically to guide the design of new developments by making sense of current policy, the Checklist highlights best practice, complementing Eco-homes and the new Code for Sustainable Homes (BRE, 2010a).

Assessment criteria:

SE Checklist's assessment criteria system consists of eight categories as in Table A.17.

Table A.17: SE Checklist's assessment criteria summary

Climate Change and Energy Flooding Heat island Water efficiency Sustainable energy Site infrastructure	**Transport and Movement** General policy Public transport Parking Pedestrians and cyclists Proximity of local amenities Traffic management
Community Promoting community networks and interaction Involvement in decision making Supporting public services, social economy and community structure Community management of the development	**Ecology** Conservation Enhancement of ecology Planting
Place Making Efficient use of land Design process Form of development Open space Adaptability Inclusive communities Street lighting / light pollution Crime and Security	**Resources** Appropriate use of land resources Environmental impact Locally reclaimed materials Water resource planning Refuse composting Noise pollution Construction waste
Buildings Eco-Homes / BREEAM or Code for Sustainable Homes	**Business** Competitive business Business opportunities and Business types Employment

Data source: (BRE, 2010a)

Assessment method:

Once filled in all the information, users can produce final reports about their buildings/projects. There are three levels of report:

- The summary report that is a simple graphical representation of the project;
- The section report that looks at a whole section;
- A full detailed report that shows a complete breakdown of your project.

Source:

The checklist and related documents are available at:
<http://southeast.sustainability-checklist.co.uk>.

A.26. SPeAR (UK)

ARUP
SPeAR®

Overview:

SPeAR (the Sustainable Project Appraisal Routine) is a sustainability performance evaluation tool developed by ARUP for use in their projects. The software was developed by ARUP as a way of breaking down sustainability into constituent parts so that issues could be dealt with on a discrete per instance basis rather than as a conceptual ideal. ARUP has used SPeAR on several projects including the Chongming Dongtan City development and the National Aquatics Centre in Beijing. Increasingly the tool is being used to supply project planning and management guidance as well as to influence the design process.

Assessment criteria:

Figure A.5 shows the basic setup of a SPeAR evaluation. The four-quadrant model uses Environment, Societal, Natural Resources, and Economic macro categories to gauge sustainability. Within each quadrant are a number of subcategories that are chosen to specifically represent the project. Each subcategory is rated and the aggregate of all the subcategories gives an overall score to the quadrant (Braithwaite, 2009).

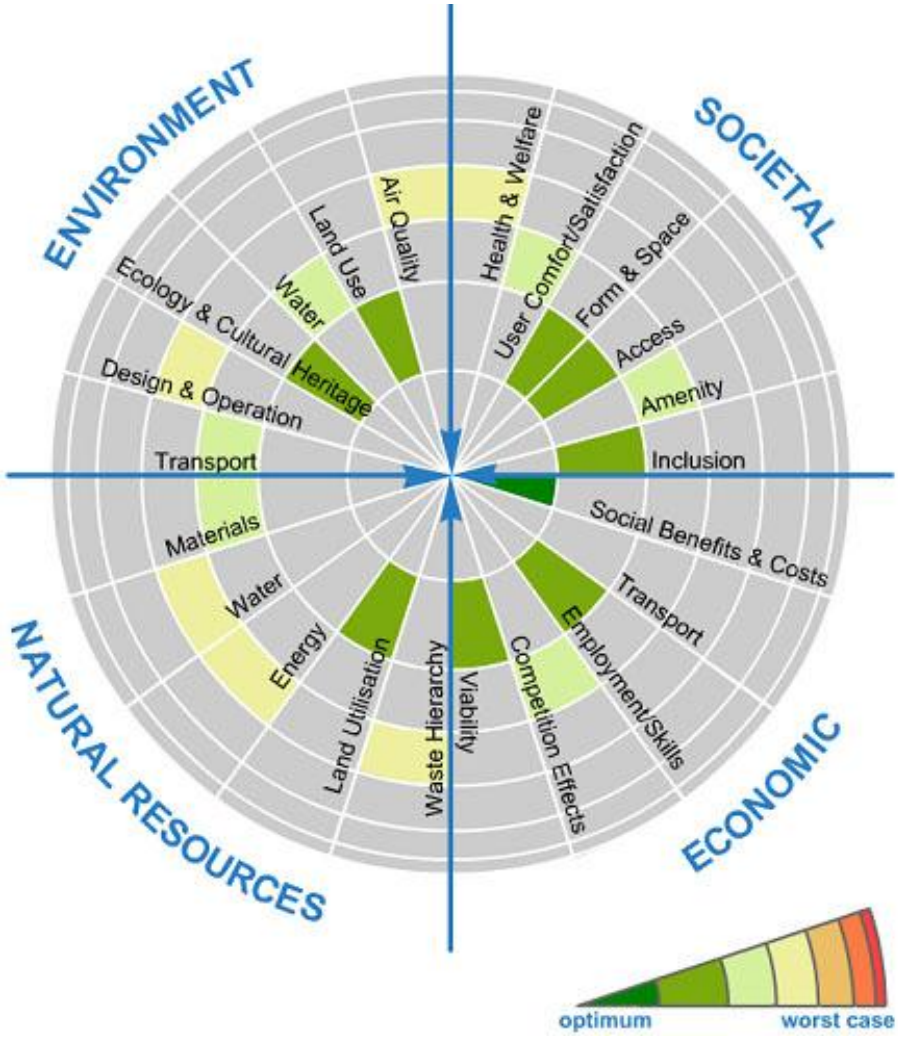


Figure A.5: SPEAR's assessment diagram example

Source: (Braithwaite, 2009)

Assessment method:

The diagram is generated automatically from scores entered by the user. In order to display both positive and negative results, an equator is shown in the centre of the diagram, which corresponds to good practice. Performance beyond good practice is displayed towards the centre of the diagram. Aspects of the project that have negative effects are shown towards the edge.

Source:

Further information can be found at:

<http://www.arup.com/Services/Sustainability_Consulting.aspx>.

A.27. SPIRIT (Sustainable Project Rating Tool) (U.S.)

Overview:

SPiRiT is a required rating tool that offers a checklist, strategies, and scores to help the U.S. Army installations rate themselves on their demonstrated abilities to create and maintain sustainable facilities, and to plan improvements to the process of planning, programming, designing, building, and maintaining sustainable facilities. SPiRiT, which is based on LEED 2.0, is a good example of an assessment tool developed from a major tool and tailored to serve specific type of projects/building (i.e. military projects/buildings). Thus it would be a good reference for TPSI's development although it is not a very powerful and accurate measurement for tall-buildings.

Assessment criteria:

100 points are given to various aspects, divided into eight categories (see Table A.18).

Table A.18: SPIRIT's assessment criteria summary

Category	Points	Criteria
Sustainable Sites	20	Erosion, Sedimentation, and Water Quality Control, Site Selection, Installation/Base Redevelopment, Brownfield Redevelopment, Alternative Transportation, Reduced Site Disturbance, Storm Water Management, Landscape and Exterior Design to Reduce Heat Islands, Light Pollution Reduction, Optimise Site Features, Facility Impact, Site Ecology
Water Efficiency	5	Water Efficient Landscaping, Innovative Wastewater Technologies, Water Use Reduction
Energy and Atmosphere	28	Building Systems Commissioning, Minimum Energy Performance, CFC Reduction in HVAC&R Equipment, Reduce ozone depletion, Energy Performance, Renewable Energy, Additional Commissioning, Measurement and Verification, Green Power, Distributed Generation
Materials and Resources	13	Storage and Collection of Recyclables, Building Reuse, Construction Waste Management, Resource Reuse, Recycled Content, Local/Regional Materials, Rapidly Renewable Materials
Indoor Environmental Quality	17	Minimum IAQ Performance, Environmental Tobacco Smoke (ETS) Control, IAQ Monitoring, Increase Ventilation Effectiveness, Construction IAQ Management Plan, Low-Emitting Materials, Indoor Chemical and Pollutant Source Control, Controllability of Systems, Thermal Comfort, Daylight and Views, Acoustic Environment /Noise Control, Facility In-Use IAQ Management Plan
Facility Delivery Process	7	Holistic Delivery of Facility: Encourage a facility delivery process that actively engages all stakeholders in the design process to deliver a facility that meets all functional requirements while effectively optimizing trade-offs among sustainability, first costs, life cycle costs and mission requirements
Current Mission	6	Design for operation and maintenance for specific needs of missions
Future Mission	4	Design for adaptation, renewal and future uses

Data source: (Flanders *et al.*, 2002)

Assessment method:

Buildings can achieve one of four ratings from Bronze to Platinum.

Source:

The tool is available in PDFs at: <https://eko.usace.army.mil/fa/sdd/>.

A.28. Scottsdale's Green Building Program (Commercial Buildings) (U.S.)

Overview:

Scottsdale's Green Building Program is more like a checklist than an actual assessment tool. The checklist (along with other specific checklists for Homes, and Multi-family residents) is a part of the result of Arizona's Green Building Program. The checklist for Commercial Building is quite suitable for tall-buildings assessment. A green building point rating system is used to qualify projects into the program. Design flexibility is achieved by offering over 150 green building options, while maintaining a whole building systems approach.

Assessment criteria:

Although driven by local Arizona's local issues, the assessment criteria of the tool are mostly based on LEED and are as in Table A.19:

Table A.19: Scottsdale's Green Building Program – Assessment criteria summary

Sustainable sites Site Selection and Disturbance Transportation Heat Island Effect – Orientation, Exterior Design and Landscaping Light Pollution Reduction	**Water Efficiency** Water Efficient Landscaping Indoor Water Use Reduction Innovative Wastewater Use
Energy and Atmosphere Energy Performance Building Commissioning Renewable Energy	**Materials and Resources** Building Reuse Waste Management Resource Efficiency, Recycle Content and Reuse Local Regional Materials Rapidly Renewable Materials Wood Products
Indoor Environmental Quality Air Quality Low-Emitting Materials Systems Control Daylight and Views Noise Reduction	**Special Options**

Data source: (Scottsdale Green building Program, 2010a; 2010b)

Assessment method:

There are four rating levels for each building/project:

- Level 1 - Meet all prerequisites of checklist items;
- Level 2 - Acquire 25 - 49 % of checklist items;
- Level 3 - Acquire 50 - 74% of checklist items;
- Level 4 - Acquire 75% or more of checklist items.

Source:

Checklists are free to download at: <http://www.scottsdaleaz.gov/greenbuilding>.

A.29. TERI GRIHA (India)

Overview:

TERI Green Rating for Integrated Habitat Assessment (TERI GRIHA**)** is the national rating system of India. It has been adopted by the India Ministry of New and Renewable Energy**.** This tool, by its qualitative and quantitative assessment criteria, is able to 'rate' a building on the degree of its 'greenness.' It can be applied to new building stock of varied functions – commercial, institutional, and residential. The system has been developed to help 'design and evaluate' new buildings (buildings that are still at the inception stages). A building is assessed based on its predicted performance over its entire life cycle – inception through operation.

The stages of the life cycle that have been identified for evaluation are:

- Pre-construction stage;
- Building planning and construction stages;
- Building operation and maintenance stage.

Assessment criteria:

GRIHA rating system consists of 34 criteria, which are categorised under various sections such as Site Selection and Site Planning, Conservation and Efficient Utilisation of Resources, Building Operation and Maintenance, and Innovation Points. Eight of these 34 criteria are mandatory; four are partly mandatory, while the rest are optional. Each criterion has a number of points assigned to it. It means that a project intending to meet the criterion would qualify for the points. There are also bonus points given to innovative features of buildings (see Table A.20).

Table A.20: TERI GRIHA's assessment criteria

1. Site planning	- Conservation and efficient utilisation of resources; - Health and well-being.
2. Building planning and construction stage	- Conservation and efficient utilisation of resources; - Recycle, recharge, and reuse of water; - Waste management; - Health and well-being.
3. Building operation and maintenance	
4. Innovation	

Data source: (TERI, 2006)

Assessment method:

Different levels of certification (one star to five stars) are awarded based on the number of points earned (see Table A.21).

Table A.21: TERI GRIHA's ratings

Points scored	Rating
50–60	One star
61–70	Two stars
71–80	Three stars
81–90	Four stars
91–100	Five stars

Data source: (TERI, 2006)

Source:

The tool and related materials can be found at: <http://www.grihaindia.org/>.

APPENDIX B: TPSI'S WEIGHTING FACTORS – DATA FIELD

This Appendix presents the data field for the selection of weighting factors according to the following variables:

- *Climate zones (Cold-polar, Hot-humid, Hot-dry or Temperate);*
- *Project's social context (City-centres or Rural Areas);*
- *Building types (Mixed-use, Office, Commercial, Residential, Hotel, Health-care or Education).*

This explains the mechanism behind the Dynamic Weighting System, which is implemented into TPSI Calculator (see Section 7.8.4 and Chapter 7 for more details on TPSI Calculator and the Dynamic Weighting System).

Please note that this data field's development mainly serves the purpose of illustrating the function of the Dynamic Weighting System. The value of these weighting factors, therefore, should not be considered a reference source outside the scope of this research.

Table B.1. Weighting factors: Mixed-use buildings in City-centres

	City-centres								
	B1	**B2**	**B3**	**B4**	**E1**	**E2**	**E3**	**E4**	**IN**
Cold-polar	12%	15%	7%	6%	21%	7%	15%	9%	8%
Hot-humid	12%	14%	8%	8%	18%	8%	15%	9%	8%
Hot-dry	12%	14%	8%	8%	19%	8%	15%	9%	7%
Temperate	13%	16%	8%	5%	20%	9%	14%	7%	8%

Table B.2. Weighting factors: Mixed-use buildings in Rural Areas

	Rural Areas								
	B1	**B2**	**B3**	**B4**	**E1**	**E2**	**E3**	**E4**	**IN**
Cold-polar	11%	14%	8%	7%	21%	7%	15%	10%	7%
Hot-humid	12%	14%	8%	8%	17%	8%	16%	9%	8%
Hot-dry	11%	14%	9%	8%	18%	8%	15%	9%	8%
Temperate	13%	15%	9%	6%	19%	9%	14%	7%	8%

Table B.3. Weighting factors: Office buildings in City-centres

	City-centres								
	B1	**B2**	**B3**	**B4**	**E1**	**E2**	**E3**	**E4**	**IN**
Cold-polar	13%	14%	6%	7%	21%	7%	16%	10%	8%
Hot-humid	12%	14%	8%	8%	17%	8%	15%	10%	8%
Hot-dry	13%	14%	7%	8%	19%	8%	15%	9%	7%
Temperate	13%	16%	8%	5%	20%	9%	14%	7%	8%

Table B.4. Weighting factors: Office buildings in Rural Areas

	Rural Areas								
	B1	**B2**	**B3**	**B4**	**E1**	**E2**	**E3**	**E4**	**IN**
Cold-polar	11%	13%	8%	8%	21%	7%	15%	10%	7%
Hot-humid	12%	14%	8%	8%	16%	9%	16%	9%	8%
Hot-dry	12%	13%	9%	9%	19%	8%	15%	9%	8%
Temperate	13%	15%	9%	6%	18%	9%	14%	8%	8%

Table B.5. Weighting factors: Commercial buildings in City-centres

	City-centres								
	B1	**B2**	**B3**	**B4**	**E1**	**E2**	**E3**	**E4**	**IN**
Cold-polar	14%	13%	6%	7%	20%	8%	16%	10%	8%
Hot-humid	12%	14%	8%	8%	18%	8%	14%	10%	8%
Hot-dry	13%	13%	8%	8%	20%	8%	14%	9%	7%
Temperate	13%	16%	8%	5%	20%	9%	14%	7%	8%

Table B.6. Weighting factors: Commercial buildings in Rural Areas

	Rural Areas								
	B1	**B2**	**B3**	**B4**	**E1**	**E2**	**E3**	**E4**	**IN**
Cold-polar	11%	13%	8%	8%	21%	7%	15%	10%	7%
Hot-humid	13%	14%	8%	8%	16%	9%	15%	9%	8%
Hot-dry	12%	13%	8%	9%	20%	8%	15%	9%	8%
Temperate	13%	15%	8%	7%	18%	9%	14%	8%	8%

Table B.7. Weighting factors: Residential buildings in City-centres

	City-centres								
	B1	**B2**	**B3**	**B4**	**E1**	**E2**	**E3**	**E4**	**IN**
Cold-polar	14%	14%	6%	7%	20%	7%	16%	10%	8%
Hot-humid	12%	13%	8%	8%	17%	8%	16%	10%	8%
Hot-dry	12%	14%	7%	9%	19%	8%	15%	9%	7%
Temperate	13%	16%	8%	5%	20%	9%	14%	7%	8%

Table B.8. Weighting factors: Residential buildings in Rural Areas

	Rural Areas								
	B1	**B2**	**B3**	**B4**	**E1**	**E2**	**E3**	**E4**	**IN**
Cold-polar	12%	12%	8%	8%	21%	7%	15%	10%	7%
Hot-humid	12%	14%	8%	8%	16%	9%	16%	9%	8%
Hot-dry	13%	12%	9%	9%	19%	8%	15%	9%	8%
Temperate	13%	15%	9%	6%	18%	9%	14%	8%	8%

Table B.9. Weighting factors: Hotel buildings in City-centres

	City-centres								
	B1	**B2**	**B3**	**B4**	**E1**	**E2**	**E3**	**E4**	**IN**
Cold-polar	14%	13%	6%	8%	29%	8%	16%	10%	8%
Hot-humid	12%	14%	8%	8%	18%	8%	14%	10%	8%
Hot-dry	13%	13%	8%	8%	20%	8%	14%	9%	7%
Temperate	13%	16%	8%	5%	20%	9%	14%	7%	8%

Table B.10. Weighting factors: Hotel buildings in Rural Areas

	Rural Areas								
	B1	**B2**	**B3**	**B4**	**E1**	**E2**	**E3**	**E4**	**IN**
Cold-polar	11%	13%	8%	8%	21%	7%	15%	10%	7%
Hot-humid	13%	14%	8%	8%	16%	9%	15%	9%	8%
Hot-dry	12%	13%	8%	9%	29%	9%	15%	9%	8%
Temperate	13%	15%	8%	7%	18%	9%	14%	8%	8%

Table B.11. Weighting factors: Health-care buildings in City-centres

	City-centres								
	B1	**B2**	**B3**	**B4**	**E1**	**E2**	**E3**	**E4**	**IN**
Cold-polar	14%	14%	6%	7%	20%	7%	16%	10%	8%
Hot-humid	12%	13%	8%	8%	17%	8%	16%	10%	8%
Hot-dry	12%	14%	7%	9%	19%	8%	15%	9%	7%
Temperate	13%	16%	8%	5%	20%	9%	14%	7%	8%

Table B.12. Weighting factors: Health-care buildings in Rural Areas

	Rural Areas								
	B1	**B2**	**B3**	**B4**	**E1**	**E2**	**E3**	**E4**	**IN**
Cold-polar	12%	12%	8%	8%	21%	7%	15%	10%	7%
Hot-humid	12%	14%	8%	8%	16%	9%	16%	9%	8%
Hot-dry	13%	12%	9%	9%	19%	8%	15%	9%	8%
Temperate	13%	15%	9%	6%	18%	9%	14%	8%	8%

Table B.13. Weighting factors: Education buildings in City-centres

	City-centres								
	B1	**B2**	**B3**	**B4**	**E1**	**E2**	**E3**	**E4**	**IN**
Cold-polar	14%	11%	6%	9%	20%	9%	13%	10%	8%
Hot-humid	12%	14%	8%	8%	18%	8%	14%	10%	8%
Hot-dry	12%	14%	8%	8%	20%	8%	14%	9%	7%
Temperate	13%	16%	8%	5%	20%	9%	14%	7%	8%

Table B.14. Weighting factors: Education buildings in Rural Areas

	Rural Areas								
	B1	**B2**	**B3**	**B4**	**E1**	**E2**	**E3**	**E4**	**IN**
Cold-polar	15%	12%	7%	7%	20%	7%	15%	10%	7%
Hot-humid	13%	14%	8%	8%	16%	9%	15%	9%	8%
Hot-dry	12%	13%	8%	9%	29%	9%	15%	9%	8%
Temperate	14%	14%	8%	7%	18%	9%	14%	8%	8%

APPENDIX C: SAMPLE ASSESSMENT RESULTS

TALL-BUILDING PROJECTS SUSTAINABILITY INDICATOR

Manual: TPSI Technical Manual 2010 Version. Software: TPSI Calculator Vol1.

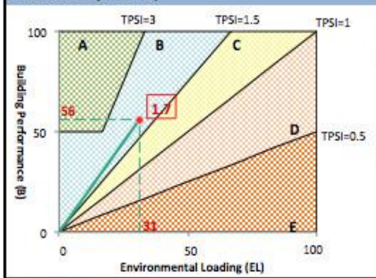
ASSESSMENT RESULT-1

1. PROJECT INFO.

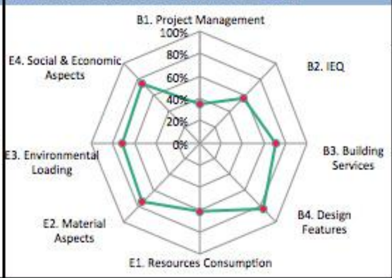
Project Name	Ocean Park Building		Height	77	m (Roof)
Location	Hanoi, Vietnam			85	m (Antena/Spire)
Area Type	City-centers		Number of floors	19	Floors
Climate Zone	Hot-humid			2	Basements
Building Type	Office		Structure type	Rigid Frame	
Completion Date	20/11/2007	Completed	Occupancy	450	
Site Area	3050	m^2	Architect	University of Sheffield	
Construction Area	n/a	m^2	Client/Owner	Binh Nguyen	
Gross Floor Area	34600	m^2	Assessment Date	20/11/2010	

2. OVERALL RESULT

TPSI FACTOR (Unit = %)



ASSESSMENT RESULTS OF MAIN CATEGORIES

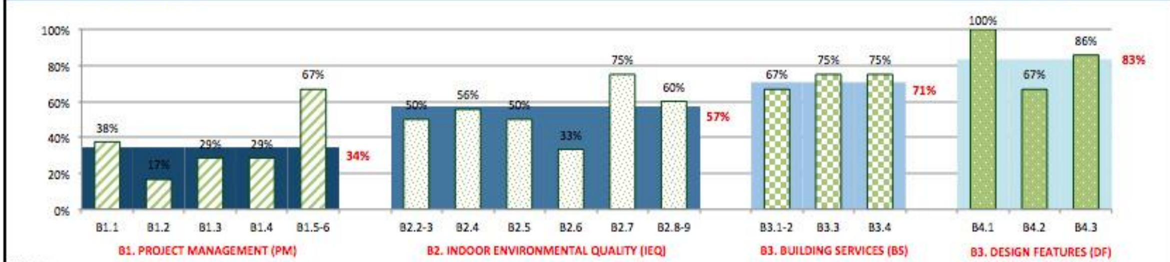


RANKING

TOTAL SCORE	61%
Building Performance: B=	56%
Environmental Loading: EL = 100%-E =	31%
TPSI FACTOR =	1.7
RANKING	C GOOD

3. SECTION SCORE

B-BUILDING PERFORMANCE SCORE OF B= 56%



Notes:

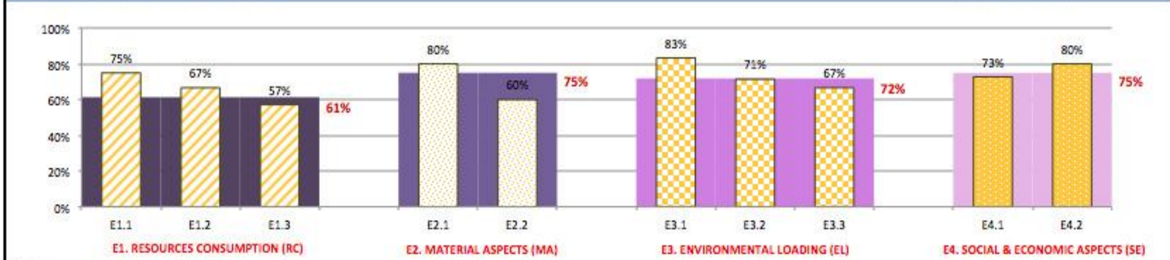
B1.1. Overall Management
B1.2. Design Process
B1.3. Construction Issues
B1.4. Contractual & Commission
B1.5-6. Operation & Demolition

B2.2-3. Water Quality & Hygiene
B2.4. IAQ
B2.5. Ventilation
B2.6. Thermal Comfort
B2.7. Lighting & View
B2.8-9. Acoustic, Vibration & Other

B3.1-2. Building Amenities & Basic Equipment
B3.3. Security & Safety
B3.4. Vertical Transportation & Earthquake Devices

B4.1. Design for Energy Efficient
B4.1. Design for Functionality & Usability
B4.3. Design for Flexibility & Adaptability

E-ENVIRONMENTAL LOADING REDUCTION SCORE OF E= 69%



Notes:

E1.1. Land Use
E1.2. Water Use
E1.3. Energy Use

E2.1. Selection of Materials
E2.2. Efficient Use of Materials

E3.1. Waste
E3.2. Pollution
E3.3. Ecology & Microclimate

E4.1. Social Aspects
E4.2. Economic Aspects

TALL-BUILDING PROJECTS SUSTAINABILITY INDICATOR

Manual: TPSI Technical Manual 2010 Version. Software: TPSI Calculator Vol1.

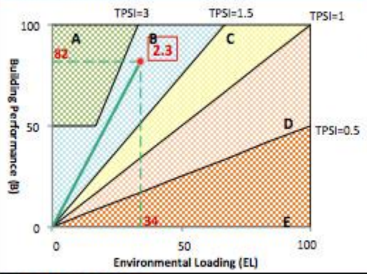
ASSESSMENT RESULT-1

1. PROJECT INFO.

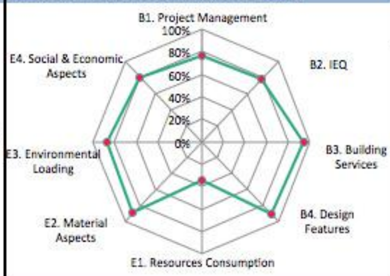
Project Name	Keangnam Hanoi Landmark Tower		Height	336	*m (Roof)*
Location	Hanoi, Vietnam			345	*m (Antena/Spire)*
Area Type	City-centers		Number of floors	70	*Floors*
Climate Zone	Hot-humid			4	*Basements*
Building Type	Mixed-use		Structure type	Tubular Structure	
Completion Date	10/03/2011	*Completed*	Occupancy	n/a	
Site Area	46000	m^2	Architect	Heerim, Samoo, Aum & Lee	
Construction Area	46000	m^2	Client/Owner	Keangnam	
Gross Floor Area	579000	m^2	Assessment Date	15/08/2011	

2. OVERALL RESULT

TPSI FACTOR (Unit = %)



ASSESSMENT RESULTS OF MAIN CATEGORIES

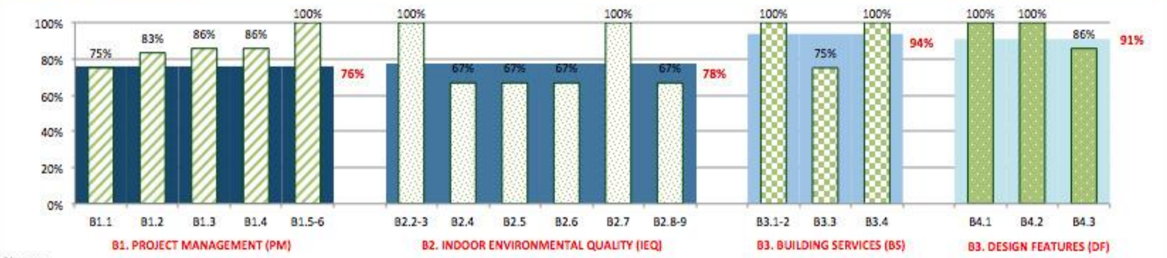


RANKING

TOTAL SCORE	**75%**
Building Performance: B=	**82%**
Environmental Loading: EL = 100%-E =	**34%**
TPSI FACTOR =	**2.3**
RANKING	**B** EXCELLENT

3. SECTION SCORE

B-BUILDING PERFORMANCE SCORE OF B= 82%



Notes:

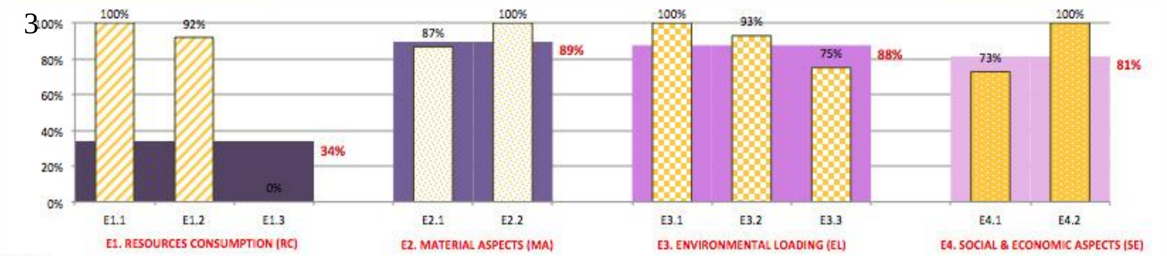
B1.1. Overall Management
B1.2. Design Process
B1.3. Construction Issues
B1.4. Contractual & Commission
B1.5-6. Operation & Demolition

B2.2-3. Water Quality & Hygiene
B2.4. IAQ
B2.5. Ventilation
B2.6. Thermal Comfort
B2.7. Lighting & View
B2.8-9. Acoustic, Vibration & Other

B3.1-2. Building Amenities & Basic Equipment
B3.3. Security & Safety
B3.4. Vertical Transportation & Earthquake Devices

B4.1. Design for Energy Efficicent
B4.1. Design for Functionality & Usability
B4.3. Design for Flexibility & Adaptability

E-ENVIRONMENTAL LOADING REDUCTION SCORE OF E= 66%



Notes:

E1.1. Land Use
E1.2. Water Use
E1.3. Energy Use

E2.1. Selection of Materials
E2.2. Efficient Use of Materials

E3.1. Waste
E3.2. Pollution
E3.3. Ecology & Microclimate

E4.1. Social Aspects
E4.2. Economic Aspects

TALL-BUILDING PROJECTS SUSTAINABILITY INDICATOR

Manual: TPSI Technical Manual 2012 Version. Software: TPSI Calculator 2012 Version.

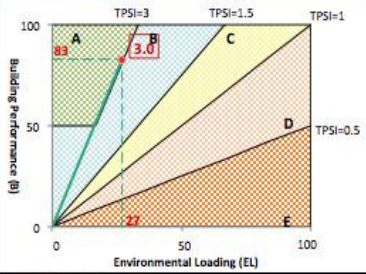
ASSESSMENT RESULT-1

1. PROJECT INFO.

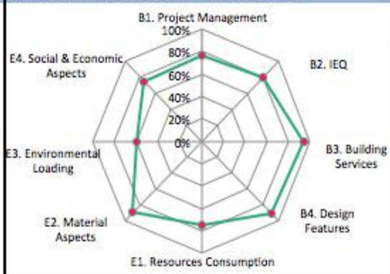
Project Name	Kobe Sannomiya Tower Mansion Proj		Height	190	m (Roof)
Location	Kobe, Japan			190	m (Antena/Spire)
Area Type	City-centers		Number of floors	54	Floors
Climate Zone	Temperate			0	Basements
Building Type	Mixed-use		Structure type	Rigid Frame	
Completion Date	29/03/2013	Scheduled	Occupancy	n/a	
Site Area	10000	m^2	Architect	n/a	
Construction Area	10000	m^2	Client/Owner	Sumitomo Realty & Development Co., Lt	
Gross Floor Area	90000	m^2	Assessment Date	09/04/2011	

2. OVERALL RESULT

TPSI FACTOR (Unit = %)



ASSESSMENT RESULTS OF MAIN CATEGORIES

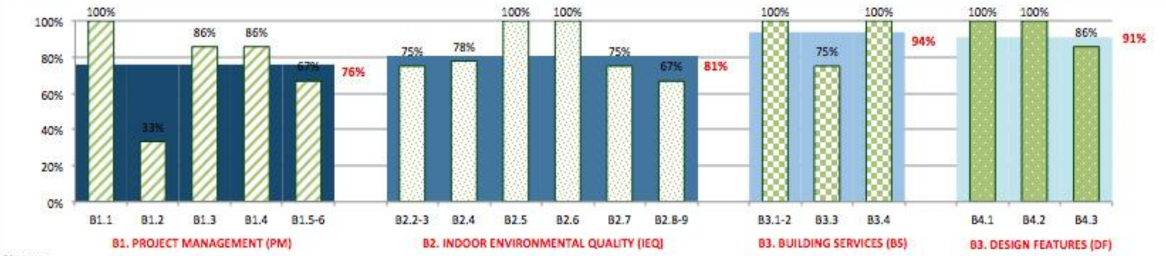


RANKING

TOTAL SCORE	78%
Building Performance: B=	83%
Environmental Loading: EL = 100%-E =	27%
TPSI FACTOR =	3.0
RANKING	B EXCELLENT

3. SECTION SCORE

B-BUILDING PERFORMANCE SCORE OF B= 83%



Notes:

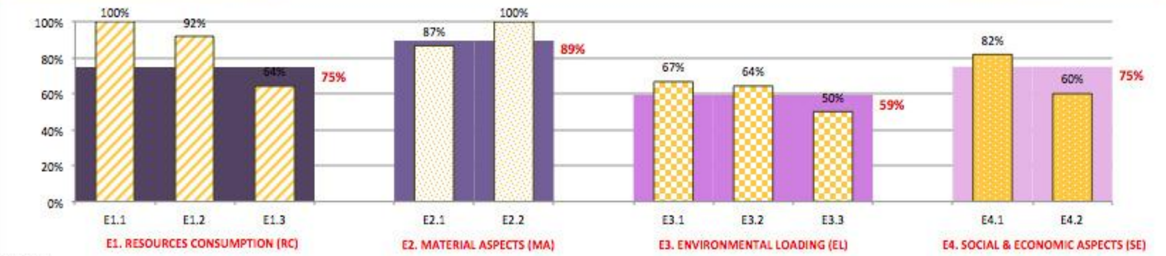
B1.1. Overall Management
B1.2. Design Process
B1.3. Construction Issues
B1.4. Contractual & Commission
B1.5-6. Operation & Demolition

B2.2-3. Water Quality & Hygiene
B2.4. IAQ
B2.5. Ventilation
B2.6. Thermal Comfort
B2.7. Lighting & View
B2.8-9. Acoustic, Vibration & Other

B3.1-2. Building Amenities & Basic Equipment
B3.3. Security & Safety
B3.4. Vertical Transportation & Earthquake Devices

B4.1. Design for Energy Efficicent
B4.1. Design for Functionality & Usability
B4.3. Design for Flexibility & Adaptability

E-ENVIRONMENTAL LOADING REDUCTION SCORE OF E= 73%



Notes:

E1.1. Land Use
E1.2. Water Use
E1.3. Energy Use

E2.1. Selection of Materials
E2.2. Efficient Use of Materials

E3.1. Waste
E3.2. Pollution
E3.3. Ecology & Microclimate

E4.1. Social Aspects
E4.2. Economic Aspects

APPENDIX D: SURVEY DOCUMENTS

D.1. APPROVAL FROM THE DEPARTMENT'S ETHICS REVIEW PANEL

The University Of Sheffield.

Office Of The Vice-Chancellor.

Stephen Walker

School of Architecture
The Arts Tower
Western Bank
Sheffield
S10 2TN
Telephone: +44 (0) 114 222 0234
Fax: +44 (0) 114 279826
Email: s.j.walker@sheffield.ac.uk

21st November 2011

Mr Binh Khanh Nguyen
School of Architecture

Dear *Binh Khanh Nguyen*

PROJECT TITLE: '*TPSI – Tall-building Projects Sustainability Indicator*'

On behalf of the University ethics reviewers who reviewed your project, I am pleased to inform you that on 21st November 2011 the above-named project was unconditionally approved on ethics grounds, on the basis that you will adhere to the following document that you submitted for ethics review:

- University research ethics application form (19.11.2011)
- Participant cover letter, information sheets and consent form
- Participant questionnaire format

If during the course of the project you need to deviate significantly from the above-approved document please inform me since written approval will be required. Please also inform me should you decide to terminate the project prematurely.

Yours sincerely

Stephen Walker
Ethics Administrator

THE QUEEN'S ANNIVERSARY PRIZES

D.2. PARTICIPANT INFORMATION SHEET

THE UNIVERSITY OF SHEFFIELD
School of Architecture

The Arts Tower
Western bank Sheffield
S10 2TN
Tel: 0114 222 20399

INFORMATION SHEET

Research Title: TPSI – Tall-building Projects Sustainability Indicator

This Information Sheet's purpose is to give potential participants a better understanding of TPSI research's nature and procedure, so they can have an informed decision on taking part in the survey process.

The market place of the design and construction of high performance buildings is dynamic and evolving. Professionals throughout the building industry use Sustainability Assessment/Rating Systems' to evaluate and differentiate their products or designs. After 20 years of development, sustainability rating systems have become inevitable, as sustainable development is now the global trend. Among the extensive development of hundreds of rating tools, tall-buildings' sustainability evaluation is a neglected area. As there is no specialised rating system for tall-buildings so far, most of the existing systems are used for all type of projects, which causes major inappropriateness and inaccuracy.

This research aims to improve the quality of tall-buildings' sustainability assessment activities by developing a rating system that specialised for tall-building projects. The name of the system is: 'TPSI – Tall-building Projects Sustainability Indicator.' TPSI can be used as a 'design tool' or a 'checklist' to compare and improve the sustainability features of tall-building design schemes; or can be used to evaluate the sustainability of existing tall-building projects.

TPSI System comprises of two components: the 'Technical Manual' (in form of a booklet) and the 'Calculator' (in form of an Excel tool). The users will claim 'credits' for their tall-building project by demonstrating compliance with the assessment criteria that are detailed in the 'Technical Manual.' The achieved credits will be input into the 'Calculator' accordingly. The 'Calculator' will then produce assessment results in form of ratings (percentage), charts, graphs, comments and recommendations on how to improve the design, etc.

The research is expected to be an original and practical contribution to the development of sustainable architecture in general and tall-building sustainable design in particular; as well as other academic, social and commercial benefits.

A survey process is now carried out to test the performance of the first version of TPSI - TPSI 2012 Version, as well as to compare its feature to those of other existing rating systems. The survey process will help verify the advantages of TPSI as well as identify its disadvantages. Details of this survey process can be found in the Cover Letter/Consent Form.

D.3. COVER LETTER/CONSENT FORM

THE UNIVERSITY OF SHEFFIELD
School of Architecture

The Arts Tower
Western bank Sheffield
S10 2TN
Tel: 0114 222 20399

COVER LETTER / CONSENT FORM

Research Title: TPSI – Tall-building Projects Sustainability Indicator

Dear Sir/Madam,

You received his letter because recently you have shown interests in an independent research project named 'TPSI - Tall-building Projects Sustainability Indicator'. This research aims to develop a sustainability rating system that specialised for tall-building projects. More information on this research can be found in the Information Sheet attached to this letter. You are now formally invited to take part in the study.

As agreed upon, a trial version of TPSI will be provided to you by the mean of your choice. You are entitled to use it free of charge (for three months) in at least one of the tall-building projects that you are involved in. After the trial use, please express your experiences with TPSI System by filling in the enclosed questionnaire as much as you can. This will only takes 10-15 minutes. Your involvement will help improving the TPSI System in particular and tall-building environmental design in general.

Please be aware that the University of Sheffield holds the copyright on TPSI System. You must use the trial version of TPSI with your selected case-study(s) only. Distributions and commercial uses of this version without written permission from the University of Sheffield are illegal. Utilisation of this version after three months of trial period must also be approved in writing by the University of Sheffield.

All survey data are completely anonymous and will be held in accordance with the **Data Protection Act**. All information that you provide will be completely confidential and used only for this research. Your participation is entirely voluntarily and you can withdraw from the study at any time regardless the reason.

Many thanks for your help.

Yours Sincerely,

Binh Nguyen (Principal researcher)

Please sign below to confirm your participation and acceptance of the above terms:

____

Name: Date:

Please scan the signed letter and send it to the principal researcher's email: binhshef1985@gmail.com and keep the original copy for your record. If you have any other question please contact the principal researcher using the same email.

D.4. ORIGINAL QUESTIONNAIRE

THE UNIVERSITY OF SHEFFIELD
School of Architecture **binhshef1985@gmail.com**

YOUR VIEWS ABOUT SUSTAINABILITY RATING SYSTEMS

Dear Sir/Madam,

This questionnaire is a part of a survey process that you have agreed to participate in, which supports a research named 'TPSI – Tall-building Project Sustainability Indicator.' The research aims to develop a sustainability rating system (also named TPSI) that specialised for tall-building projects. As agreed upon, a trial version of TPSI was provided to you to use in a case study of your choice. Please express your opinions about the aspects of TPSI System in comparison with other rating systems that you are familiar with (if applicable) and related issues by filling this questionnaire as much as you can. Please be aware that your participation is entirely voluntary. All information that you provide will be completely confident and will not be transferred to a third party. This research has been approved by the University of Sheffield' Ethics Review Procedure.

DETAILS	
Participant's Name:	Organisation:
Address:	Email:
	Phone:
Project Associated with the Review:	
Location:	Area/Zone:
	Climate Zone:
Completion Date:	Stage:
Site Area:	Construction Area:
Gross Floor Area (GFA):	Building Type:
Number of floors:	Basement:
Height:	Structure Type:

BACKGROUND	
1	Do you often (i.e. at least once a year) get involved in major sustainable/high-performance projects? ☐ YES ☐ NO Do you often (i.e. at least once a year) get involved in sustainable tall-building projects? ☐ YES ☐ NO *Note: Within this research, a 'sustainable tall-building' is defined as: "one in which the design team have struck a balance between environmental, economic and social issues at all stages – design, construction, operation and change of use/end of life".*
2	In what position do you often get involved in such projects? Manager ☐ Designer ☐ Constructor ☐ Inspector ☐ Engineer ☐ Technician ☐ Other ☐
3	Do you often use sustainable rating/assessment tools during your projects? ☐ YES ☐ NO If YES name the systems you often use:…………………………………………………… *If YES answer question 4.1, if NO answer question 4.2*

4	4.1. Do you have to use them because of some reasons (e.g. requirements of customer, etc.) or do you feel the need to use them? ☐ I have to use them althought I don't want to ☐ I feel the need to use them 4.2. Would you/your organisation be interested in having access to a sustainable rating/assessment tool to guide you through the projects and improve the sustainability of your projects? ☐ YES ☐ NO
5	During your projects, when dealing with sustainable issues, what do you often need? ☐ A *design tool* to help you making decisions, comparing design schemes, etc. ☐ An *assessment tool* to help you evaluate the performance of the projects ☐ Something to rely on, like a *checklist*, to help you manage sustainable issues ☐ All of the above ☐ None, I can tottaly deal with everything by myself
6	At what stage of the projects that you need such supports mentioned in (5)? Pre-Design ☐ Design ☐ Construction ☐ Contractual & Commission ☐ Operation ☐ Demolition ☐

1. AVAILABILITY

Give your opinion about TPSI and other sustainability rating systems that you used according to the following criteria:

- Easy to Access: Is it convenient to have full-possession of the system (i.e. easy to find and acquire/subscribe it)?
- System's Format: In what format and language is the system available? Is it convenient for use and transfer between parties?
- Cost of System: Do you think the cost of the system is acceptable?
- Availability of Information: Is it easy to find information/literature about the system?
- System's Openness: Is it easy to gather information on the rating system membership, represented organisations, and development process?

Give a '✓' if you think the criterion is met, give a '-' if otherwise.

	TPSI		
Easy to Access			
System's Format			
Cost of System			
Availability of Information			
System's Openness			

2. METHODOLOGY

Give your opinion about TPSI and other sustainability rating systems that you used according to the following criteria:

- Rating Levels: How many rating levels does the tool offer? Is it sufficient enough for your purposes?
- Quantitative criteria: Are the quantitative criteria (number, content, requirement, etc.) sufficient enough for the assessment?*
- Qualitative criteria: Are the qualitative criteria (design descriptions, illustrations, etc.) sufficient enough for the assessment?*
- Complexity: Assessment method's sophistication (Sophisticated – Average - Basic?)
- Efficiency: The level of efficiency of assessment method (Very High - High - Average - Low - Very Low?)

Give a '✓' if you think the criterion is met, give a '-' if otherwise

	TPSI		
Rating Levels			
Quantitative Criteria			
Qualitative Criteria			
Complexity			
Efficiency			

Note:

** Sustainable performance assessment, especially when dealing with energy and mass flows issues, requires criteria that are described in quantitative terms. On the other hand, the wider range of performance issues necessary within an assessment of 'green' performance currently cannot avoid using more qualitative metrics to evaluate a building comprehensively. A good rating tool therefore needs to be a harmonic combination of quantitative and qualitative criteria.*

3. APPLICABILITY

3.1 When using assessment tool(s) in tall-building projects (excluding TPSI), do you think there are certain sustainable aspects that are not covered by those tools?

☐ YES ☐ NO

And these aspects are:

☐ Sustainable aspects in general

☐ Particular aspects which are associated with tall-building projects only

Ignore this question if you have no experience of using sustainability assessment tools in tall-building projects.

3.2 Do you think there should be separate tools for low-rise buildings and high-rise buildings (in order to improve the accuracy of the assessments)?

☐ Yes, there should be separate tools such as TPSI

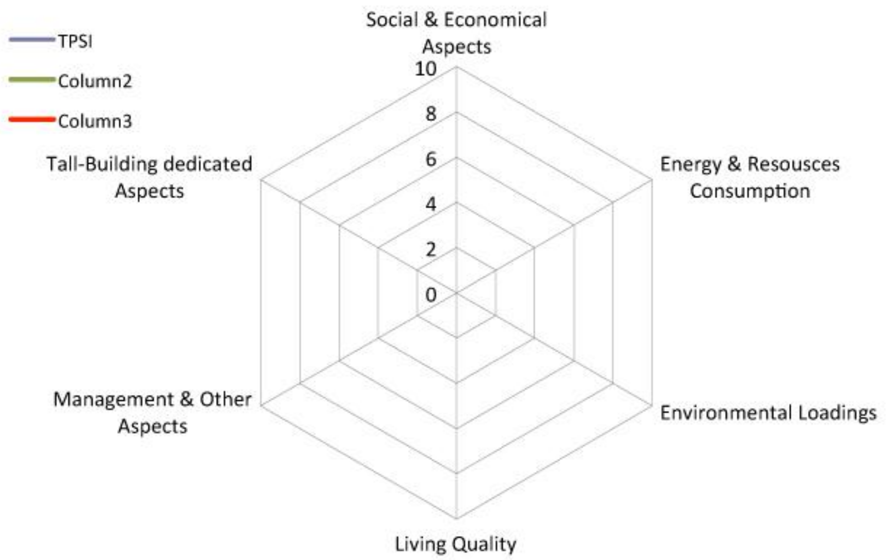
☐ I prefer a tool for both low-rise and high-rise buildings

3.3 Give a '✓' for each project stage that you think is well-covered by TPSI and other sustainability rating systems that you used:

Stages of building life cycle	TPSI		
Pre-Design/ Planning/ Site Selection			
Design/ Procurement			
Construction/Post Construction Review			
Management/Operations/Maintenance			
Tenant Fit-Out/ Refurbishment			
Demolition			

3.4 On a scale from 1-10 (10 being the highest performance), give your opinion on how well a certain sustainable aspect is covered by TPSI and other sustainability rating systems that you used:

Sustainable Aspects	TPSI		
Social and Economical Aspects			
Energy and Resources Consumption			
Environmental Loadings			
Living Quality			
Management and Other Aspects			
Tall-Building dedicated Aspects			



Note: This diagram is the illustration of the points you give for TPSI and other systems. It is for the principal researcher to calculate and finish. You do not have to finish it.

4. DATA COLLECTING

Give your opinion about TPSI and other sustainability rating systems that you used according to the following criteria:

- Data Collecting Method: Identify the method used to input data. Is that method sufficient?
- Evidence:* What type of evidence needed for the assessment? Is it easy to gather those documents?
- Measurability: Does the tool use measurable method to collect data?
- Convenience: Is it easy and quick to gather data? Is it possible to finish data inputting process without the need of excessive technical knowledge?

Give a '✓' if you think the criterion is met, give a '-' if otherwise

	TPSI		
Data Collecting Method			
Documentation			
Measurability			
Convenience			

Note:
** Evidence: sustainability rating systems often requires evidence or proofs to confirm that a certain criterion is fulfilled. Evidences are often in form of design descriptions, reports, contracts, and other types of documents.*

5. ACCURACY

On a 3-level-scale (High – Medium – Low), give your opinion on the accuracy of TPSI and other sustainability rating systems that you used, according to the following assessment stages:

Assessment Stages	TPSI		
Accuracy of Data Inputting Stage			
Accuracy of Data Processing Stage			
Accuracy of Data Outputting Stage			

6. USER-FRIENDLINESS

6.1 During your projects, when dealing with sustainable issues, what do you often need?

- ☐ A *simple, user-friendly* tool which can produce quick results (to compare your design schemes, etc.)
- ☐ An *sophisticate, technical-driven* tool which can produce highly accurate assessment
- ☐ Both
- ☐ Something in between
- ☐ Neither

6.2 On a scale from 1-5, give your opinion on the User-Friendliness/Handiness/Convenience of TPSI and other sustainability rating systems that you used:

	TPSI		
User-Friendliness/ Handiness/Convenience			

7. RESULTS PRESENTATION

Give your opinion about TPSI and other sustainability rating systems that you used according to the following criteria:

- Presentation Method: End products of assessment process, ratings, result product. Do you think the tool's method of presenting assessment result is sufficient enough?
- Clarity: Well-defined, easily communicated, and clearly understood among multiple parties?
- Comparability: The ability of comparing different design schemes and/or different projects using the results produced by the tool.
- Result Usability: Usability of result documentations for communicating the accomplishments of the building.

Give a '✓' if you think the criterion is met, give a '-' if otherwise

	TPSI		
Presentation Method			
Clarity			
Comparability			
Result Usability			

8. STANDARD COMPARISION

Complete the standard comparison below between TPSI and other sustainability rating systems that you used:

Roughly put the systems' ratings on the 'sustainable scale' like the examples given for BREEAM and LEED below (please feel free to modify them). The more rigorous standards are placed toward to the top of the scale.

9. BUILDING'S PERFORMANCE IMPROVEMENT

On a 3-level-scale (Significant – Medium – Low), give your opinion on the buildings' performance improvement after using TPSI and other sustainability rating systems that you are familiar with, according to the following aspects:

Sustainable Aspects	TPSI		
Social and Economical Aspects			
Energy and Resources Consumption			
Environmental Loadings			
Living Quality			
Management and Other Aspects			
Tall-Building dedicated Aspects			

NOTES

D.5. FILLED QUESTIONNAIRE SAMPLE FROM PARTICIPANTS

THE UNIVERSITY OF SHEFFIELD

School of Architecture **binhshef1985@gmail.com**

YOUR VIEWS ABOUT SUSTAINABILITY RATING SYSTEMS

Dear Sir/Madam,

This questionnaire is a part of a survey process that you have agreed to participate in, which supports a research named 'TPSI – Tall-building Project Sustainability Indicator.' The research aims to develop a sustainability rating system (also named TPSI) that specialised for tall-building projects. As agreed upon, a trial version of TPSI was provided to you to use in a case study of your choice. Please express your opinions about the aspects of TPSI System in comparison with other rating systems that you are familiar with (if applicable) and related issues by filling this questionnaire as much as you can. Please be aware that your participation is entirely voluntary. All information that you provide will be completely confident and will not be transferred to a third party. This research has been approved by the University of Sheffield' Ethics Review Procedure.

DETAILS	
Participant's Name: MA. CAO THI TU TRAM	Organisation: RSP Architect (Singapore)
Address: 7 Thong Tek Building - Singapore	Email: caothitutram@gmail.com Phone: n/a
Project Associated with the Review: Mulberry lane	
Location: Hanoi, Vietnam	Area/Zone: Sub-urban Climate Zone: Hot - climate
Completion Date: Sep 2013	Stage: Under - construction
Site Area: 19.900 m²	Construction Area: n/a
Gross Floor Area (GFA): 235.000 m²	Building Type: Residential
Number of floors: 35	Basement: No
Height: 122 m	Structure Type: Shear - wall

BACKGROUND

1. Do you often (i.e. at least once a year) get involved in major sustainable/high-performance projects?

   ☑ YES ☐ NO

   Do you often (i.e. at least once a year) get involved in sustainable tall-building projects?

   ☑ YES ☐ NO

   Note: Within this research, a 'sustainable tall-building' is defined as: "one in which the design team have struck a balance between environmental, economic and social issues at all stages – design, construction, operation and change of use/end of life".

2. In what position do you often get involved in such projects?

   Manager ☑ Designer ☑ Constructor ☐ Inspector ☐
   Engineer ☐ Technician ☐ Other ☐

3. Do you often use sustainable rating/assessment tools during your projects?

   ☑ YES ☐ NO

   If YES name the systems you often use: Green mark, BREEAM

   If YES answer question 4.1, if NO answer question 4.2

4	4.1. Do you have to use them because of some reasons (e.g. requirements of customer, etc.) or do you feel the need to use them? ☑ I have to use them althought I don't want to ☐ I feel the need to use them 4.2. Would you/your organisation be interested in having access to a sustainable rating/assessment tool to guide you through the projects and improve the sustainability of your projects? ☐ YES ☐ NO
5	During your projects, when dealing with sustainable issues, what do you often need? ☐ A *design tool* to help you making decisions, comparing design schemes, etc. ☐ An *assessment tool* to help you evaluate the performance of the projects ☑ Something to rely on, like a *checklist*, to help you manage sustainable issues ☐ All of the above ☐ None, I can tottaly deal with everything by myself
6	At what stage of the projects that you need such supports mentioned in (5)? Pre-Design ☑ Design ☑ Construction ☑ Contractual & Commission ☐ Operation ☐ Demolition ☐

1. AVAILABILITY

Give your opinion about TPSI and other sustainability rating systems that you used according to the following criteria:

- Easy to Access: Is it convenient to have full-possession of the system (i.e. easy to find and acquire/subscribe it)?
- System's Format: In what format and language is the system available? Is it convenient for use and transfer between parties?
- Cost of System: Do you think the cost of the system is acceptable?
- Availability of Information: Is it easy to find information/literature about the system?
- System's Openness: Is it easy to gather information on the rating system membership, represented organisations, and development process?

Give a '✓' if you think the criterion is met, give a '-' if otherwise.

	TPSI	GreenMark	BREEAM
Easy to Access	✓	✓	✓
System's Format	✓	✓	✓
Cost of System	✓	✓	-
Availability of Information	✓	✓	✓
System's Openness	✓	✓	✓

2. METHODOLOGY

Give your opinion about TPSI and other sustainability rating systems that you used according to the following criteria:

- Rating Levels: How many rating levels does the tool offer? Is it sufficient enough for your purposes?
- Quantitative criteria: Are the quantitative criteria (number, content, requirement, etc.) sufficient enough for the assessment?*
- Qualitative criteria: Are the qualitative criteria (design descriptions, illustrations, etc.) sufficient enough for the assessment?*
- Complexity: Assessment method's sophistication (Sophisticated – Average - Basic?)
- Efficiency: The level of efficiency of assessment method (Very High - High - Average - Low - Very Low?)

Give a '✓' if you think the criterion is met, give a '-' if otherwise

	TPSI	Green Mark	BREEAM
Rating Levels	✓	✓	✓
Quantitative Criteria	✓	-	✓
Qualitative Criteria	✓	-	-
Complexity	✓	✓	-
Efficiency	-	✓	✓

Note:

** Sustainable performance assessment, especially when dealing with energy and mass flows issues, requires criteria that are described in quantitative terms. On the other hand, the wider range of performance issues necessary within an assessment of 'green' performance currently cannot avoid using more qualitative metrics to evaluate a building comprehensively. A good rating tool therefore needs to be a harmonic combination of quantitative and qualitative criteria.*

3. APPLICABILITY

3.1 When using assessment tool(s) in tall-building projects (excluding TPSI), do you think there are certain sustainable aspects that are not covered by those tools?

☑ YES ☐ NO

And these aspects are:

☐ Sustainable aspects in general
☑ Particular aspects which are associated with tall-building projects only

Ignore this question if you have no experience of using sustainability assessment tools in tall-building projects.

3.2 Do you think there should be separate tools for low-rise buildings and high-rise buildings (in order to improve the accuracy of the assessments)?

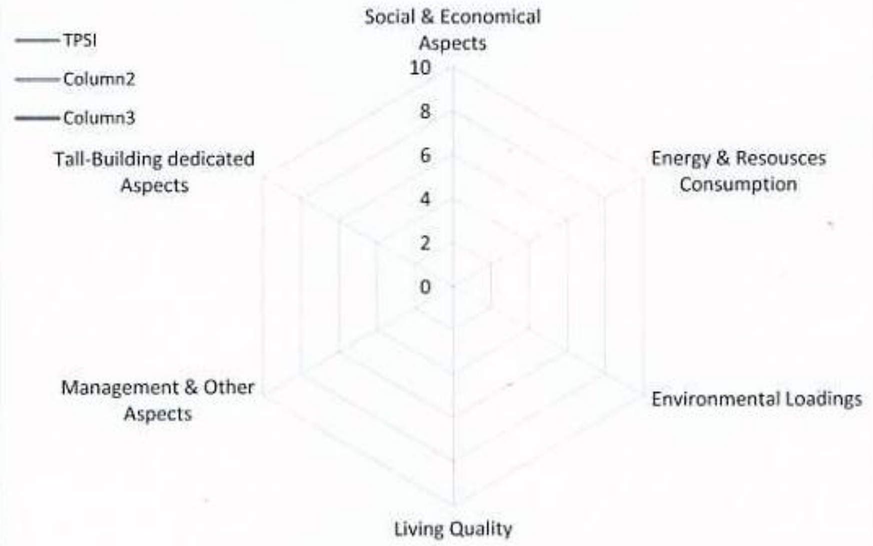
☑ Yes, there should be separate tools such as TPSI
☐ I prefer a tool for both low-rise and high-rise buildings

3.3 Give a '✓' for each project stage that you think is well-covered by TPSI and other sustainability rating systems that you used:

Stages of building life cycle	TPSI	Green Mark	BREEAM
Pre-Design/ Planning/ Site Selection	✓	✓	✓
Design/ Procurement	✓	✓	✓
Construction/Post Construction Review	✓	✓	-
Management/Operations/Maintenance	✓	-	✓
Tenant Fit-Out/ Refurbishment	✓	-	✓
Demolition	✓	-	-

3.4 On a scale from 1-10 (10 being the highest performance), give your opinion on how well a certain sustainable aspect is covered by TPSI and other sustainability rating systems that you used:

Sustainable Aspects	TPSI	Green Mark	BREEAM
Social and Economical Aspects	✓	-	-
Energy and Resources Consumption	✓	✓	✓
Environmental Loadings	✓	✓	✓
Living Quality	-	✓	-
Management and Other Aspects	✓	-	✓
Tall-Building dedicated Aspects	✓	-	✓



Note: This diagram is the illustration of the points you give for TPSI and other systems. It is for the principal researcher to calculate and finish. You do not have to finish it.

4. DATA COLLECTING

Give your opinion about TPSI and other sustainability rating systems that you used according to the following criteria:

- Data Collecting Method: Identify the method used to input data. Is that method sufficient?
- Evidence:* What type of evidence needed for the assessment? Is it easy to gather those documents?
- Measurability: Does the tool use measurable method to collect data?
- Convenience: Is it easy and quick to gather data? Is it possible to finish data inputting process without the need of excessive technical knowledge?

Give a '✓' if you think the criterion is met, give a '-' if otherwise

	TPSI	Green Mark	BREEAM
Data Collecting Method	✓	✓	✓
Documentation	✓	✓	✓
Measurability	✓	✓	-
Convenience	✓	✓	✓

Note:
** Evidence: sustainability rating systems often requires evidence or proofs to confirm that a certain criterion is fulfilled. Evidences are often in form of design descriptions, reports, contracts, and other types of documents.*

5. ACCURACY

On a 3-level-scale (High – Medium – Low), give your opinion on the accuracy of TPSI and other sustainability rating systems that you used, according to the following assessment stages:

Assessment Stages	TPSI	Green Mark	BREEAM
Accuracy of Data Inputting Stage	Med	High	Med
Accuracy of Data Processing Stage	High	High	Med
Accuracy of Data Outputting Stage	High	High	Med

6. USER-FRIENDLINESS

6.1 During your projects, when dealing with sustainable issues, what do you often need?

- [x] A *simple, user-friendly* tool which can produce quick results (to compare your design schemes, etc.)
- [ ] An *sophisticate, technical-driven* tool which can produce highly accurate assessment
- [ ] Both
- [ ] Something in between
- [ ] Neither

6.2 On a scale from 1-5, give your opinion on the User-Friendliness/Handiness/Convenience of TPSI and other sustainability rating systems that you used:

	TPSI	GreenMark	BREEAM
User-Friendliness/ Handiness/Convenience	5	5	4

7. RESULTS PRESENTATION

Give your opinion about TPSI and other sustainability rating systems that you used according to the following criteria:

- Presentation Method: End products of assessment process, ratings, result product. Do you think the tool's method of presenting assessment result is sufficient enough?
- Clarity: Well-defined, easily communicated, and clearly understood among multiple parties?
- Comparability: The ability of comparing different design schemes and/or different projects using the results produced by the tool.
- Result Usability: Usability of result documentations for communicating the accomplishments of the building.

Give a '✓' if you think the criterion is met, give a '-' if otherwise

	TPSI	GreenMark	BREEAM
Presentation Method	✓	✓	-
Clarity	✓	✓	✓
Comparability	✓	-	✓
Result Usability	✓	✓	✓

8. STANDARD COMPARISION

Complete the standard comparison below between TPSI and other sustainability rating systems that you used:

Roughly put the systems' ratings on the 'sustainable scale' like the examples given for BREEAM and LEED below (please feel free to modify them). The more rigorous standards are placed toward to the top of the scale.

BREEAM (Example)	LEED (Example)	TPSI	Green Mark	Breeam
Excellent		A	Platinum	Excellent
	Platinum			
Very good		B	Gold +	Very Good
Good	Gold			
	Silver	C	Gold	Good
Pass		D	Certified	Pass
	Certified			
		E		

9. BUILDING'S PERFORMANCE IMPROVEMENT

On a 3-level-scale (Significant – Medium – Low), give your opinion on the buildings' performance improvement after using TPSI and other sustainability rating systems that you are familiar with, according to the following aspects:

Sustainable Aspects	TPSI	Greenmark	BREEAM
Social and Economical Aspects	Sig	Med	Med
Energy and Resources Consumption	Med	Med	Sig
Environmental Loadings	Sig	Sig	Med
Living Quality	Med	Med	Med
Management and Other Aspects	Sig	Sig	Sig
Tall-Building dedicated Aspects	Sig	Med	Med

NOTES

Investigator's note: MA Cao Thi To Tram has worked for a Singapore Architecture firm for a long time before she came to UK to study sustainable Architecture. She therefore has lots of experiences with BREEAM and Green Mark

APPENDIX E: PUBLISHED PAPERS AS PART OF THE RESEARCH

Key published papers as part of the research:

Nguyen, B.K. & Altan, H. 2011. TPSI – Tall-building Projects Sustainability Indicator. *Proceedings of 2011 International Conference of Green Buildings and Sustainable Cities*. Procedia Engineering. Vol. 21 pp. 387-394.

Nguyen, B.K. & Altan, H. 2011. Comparative Review of Five Sustainability rating systems. *Proceedings of 2011 International Conference of Green Buildings and Sustainable Cities*. Procedia Engineering. Vol. 21 pp. 376-386.

Nguyen, B.K. & Altan, H. 2011. Strategies to Reduce Lateral Forces on High-rise Buildings that Use Diagrid Structural System. *Proceedings of 2011 World Congress on Engineering and Technology*. IEEE Press. Vol. 5 pp. 795-798. ISBN: 978-1-61284-362-9.

Nguyen, B.K. & Altan, H. 2012. Tall-Building Projects Sustainability Indicator (TPSI): A New Design and Environmental Assessment Tool for Tall Buildings. *Buildings*. MDPI. Vol. 2 (1). ISSN: 2075-5309. [In Press].

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Procedia Engineering 00 (2011) 000–000

Procedia Engineering

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2011 International Conference on Green Buildings and Sustainable Cities

TPSI – Tall-building Projects Sustainability Indicator

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Abstract

The paper presents the features of TPSI (Tall-building Projects Sustainability Indicator) – a 'Sustainable Rating System' that specializes for tall building projects. The system was developed by Binh K. Nguyen and Hasim Altan at the University of Sheffield, UK in 2010. It can be used as a 'design tool' of a 'checklist' to compare and to improve the sustainable performance of tall-building design schemes and at the same time can be used to evaluate the sustainability of existing tall building projects.

Keywords: Tall Building, High-rise, Building Sustainability, Rating System, Assessment Methodology

Available online at www.sciencedirect.com

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Procedia Engineering 21 (2011) 376 – 386

Procedia Engineering

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2011 International Conference on Green Buildings and Sustainable Cities

Comparative review of five sustainable rating systems

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Abstract

The paper presents the comparative review of five prominent sustainable rating systems namely BREEAM, LEED, CASBEE, GREEN STAR and HK-BEAM. The review process adopts a system of criteria which encompasses all features of sustainable rating tools. The main goal of the study is to consider all aspects of the systems in order to find out the best one(s). The study provides a deep insight into sustainable rating tools and can be a recommendation and reference for users when choosing between rating systems.

Keywords: Building Sustainability, Rating Systems, Sustainability Methods, Assessment Tools.

Strategies to Reduce Lateral Forces on High-rise Buildings that Use Diagrid Structural System

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***Abstract*— The study focuses on strategies to enhance the performance of a building against lateral forces and earthquake. The strategies range from aerodynamic modifications to structure reinforcement to adopting auxiliary damping devices/systems. The study's direction was toward Diagrid structural systems – the latest trend in high-rise projects.**

Keywords-component; lateral forces; tall-buildings; high-rise; diagrid, damping strategies.

I. Introduction

The evolution of tall-building structural systems, based on new structural concepts with newly adopted high-strength materials and construction methods, has been towards 'stiffness' and 'lightness'. Structural systems are becoming *stiffer* and *lighter*. *Diagrid*[1], acknowledged worldwide as a very light structure and one of the best when it comes to withstanding lateral forces, has been leading the trend.

The lighter a structure is, the higher it can rise. On the other hand, it is also easier to blow away a light subject than a heavy one. Diagrid can save from 20% to 30% the amount of structural steel in a high-rise building. Moreover, high-strength material technology has come a long way since the invention of modern high-rise building in 1930s. Materials themselves are stronger and lighter.

It is common knowledge that, rather than directly standing the forces, it is better to reduce them and dissipate the magnitude of vibrations. A high-rise structure needs both stiffness and damping characteristics. The strategies to enhance tall-buildings' lateral performance can be divided into 3 categories: (1) *Aerodynamic Modifications*; (2) *Structural Reinforcements*; and (3) *Using Auxiliary Damping Devices/Systems*. The strategies presented below are the ones that can be used for that use Diagrid structure. However, most of the strategies can be applied to other types of tall-building structures.

[1] *Diagrid* (or *diagonal grid*) is a design for constructing large buildings with steel that creates triangular structures with diagonal support beams. It requires less structural steel than a conventional steel frame. It also obviates the need for large corner columns and provides a better distribution of load in the case of a compromised building.

978-1-61284-365-0/11/$26.00 ©2011 IEEE

II. Aerodynamic Modifications

A. Aerodynamic Shapes

The form of a tall-building is usually limited to rectangular prisms. From geometrical point of view, this form is rather susceptible to lateral drift. Other building shape such as cylindrical, elliptical, crescent, triangular and like, offer better lateral performance due to inherent strength in their geometrical form. They provide higher structural efficiency and allow greater building height at lower cost. Building codes permit a reduction of the wind pressure design loads for circular or elliptical buildings by 20%-40% of the usual values for comparably sized rectangular building [1].

B. Corner Modification

Investigations have established that corner modifications such as chamfered corners, horizontal slots, and slotted corners can significantly reduce the along wind and across wind responses when compared to a basic perpendicular building shape [2]. Fig. 1 shows some types of modification to building corner.

Chamfers of the order of 10% of the building width makes 40% reduction in the along wind response and 30% reduction in the across wind response [3]. Excessive rounding of corners of the cross section, approaching a circular shape in the cross section, significantly improves the response against wind. With a building of roughly 70 stories, peak deflection of the model in circular cross section was about half of the one with square cross section [3].

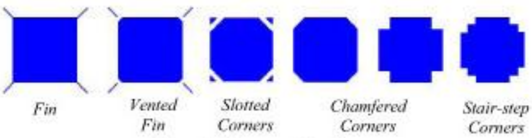

Figure 1. Corner modification types

C. Tapering and Setbacks

Reducing floor areas gradually toward the top is a good strategy to enhance lateral performance of a building. This way, the mass of the building is concentrated in the lower floors. More importantly, when hitting a building using

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Article

Tall-Building Projects Sustainability Indicator (TPSI): A New Design and Environmental Assessment Tool for Tall Buildings

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Abstract: The paper presents the features of Tall-building Projects Sustainability Indicator (TPSI) - a 'Sustainability Rating System' that specialises for tall-building projects. The system comprises of two components; the 'Technical Manual' in form of a booklet and the 'Calculator' in form of an Excel tool. It can be used as a 'design tool' and/or as a 'checklist' to compare and to improve the sustainable performance of tall-building design schemes. At the same time, the system can be used to evaluate the sustainability of existing tall-building projects. The first version of TPSI rating system (TPSI 2012 Version) has been released as an online tool (GreenLight) and thoroughly examined and validated by multiple parties.

Keywords: Tall Building, High-rise Project, Building Sustainability, Rating System, Assessment Method, Environmental Rating.