The relation between building assessment systems and building performance simulation

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THE RELATION BETWEEN BUILDING ASSESSMENT SYSTEMS AND BUILDING PERFORMANCE SIMULATION

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ABSTRACT: The aim of the paper is to reveal the relationship between building performance simulation and building assessment systems as a performance indicator.
The paper is part of an ongoing research project on developing a guideline for effective use of building performance simulation in design towards high performance buildings. The description of high performance buildings will be interpreted as sustainable (green) buildings and the assessment criteria of the level of performance will be evaluated by building assessment (rating) systems.
The rating systems' expectations are nearly the same based on global benefits, but vary depends on the stage where they are going to be questioned during design process. Thus, the paper will describe both the design process stages and the stakeholders as decision takers who affect the future performance of the building.
By analysing current rating systems as a performance indicator, the available information necessary for assessment during design process will reveal the possibilities *(potential?)* of using building performance simulation as a support tool for getting high performance buildings.

Keywords – assessment systems, building performance simulation, high performance building, performance indicators.

1. INTRODUCTION:

Any building forms a system with a number of sub-systems, characterised by a large quantity of parameters that need to be considered during the design process. Traditionally, the design process involves multiple design and engineering disciplines, which design, analyse and optimise individual subsystems and their components separately. Nevertheless, all building component parameters are inter-related and affect each other. In order to optimise the dynamic interaction between different building systems and components, it is necessary to use an integrated design approach (Hensen, 2003). The recent trend called "whole building design approach" asks the members of the design and construction team to look at materials, systems and assemblies from many different professional perspectives. The design is evaluated for cost, quality-of-life, future flexibility, efficiency, overall environmental impact, productivity and creativity and how the occupants will be enlivened. The basic aim of "whole building design" is to create a successful high-performance building. To achieve that goal, it is necessary for the people involved in the building design to interact closely throughout the design process.

To assess design decisions and subsequently the building performance during the design process, building performance modelling/simulation tools become gradually more important. However performance simulation tools are usually used as a "performance confirmation" at the almost final stage of design. It became clear that building simulation tools not always satisfy the end users need with regards to applicability to early design stages; considering the extend of the design process user group dedication and comparability of more than one design option.

In order to query the performance issues during various phases of design process, this paper aims to reveal the relationship between building performance simulation (BPS) and the building assessment systems as a performance indicator. The answers to the questions below have been investigated:

- What are the current design rating systems for sustainable buildings?
- Could rating systems be helpful to structure a basis of high performance building design?
- When and how is BPS effective for performance assessments and design decisions?

The rating systems' expectations are nearly the same based on global benefits, but vary depending on the stage where they are going to be questioned during design process. An extensive literature review has been carried out to describe both the design process stages and the rating systems approach to the future performance of the building. By analysing the current rating systems as a performance indicator, the available information necessary for assessment during design process has revealed the potential of using building performance simulation as a support tool for getting high performance buildings.

2. DEFINITIONS

In the literature, there are several terminologies used to define the performance characteristics of buildings. Different descriptions are made in their context to achieve high performance. The most frequently encountered terms are green building, sustainable building and high performance building.

National Renewable Energy Laboratory (NREL, 2005) made a description for high performance building as "…a high-performance building is a building that uses *whole-building design approach* to achieve energy, economic, and environmental performance that is substantially better than standard practice. Whole-building design creates energy-efficient buildings that save money for their owners, besides produces buildings that are healthy places to live and work. It helps to preserve our natural resources and can significantly reduce a building's impact on the environment." It is obvious that the explanation of NREL also includes the scores of green building.

Kibert, et al (2001) defined that a green building is the creation and maintenance of a healthy built environment based on resource efficient and ecological principles and they emphasised that the green building covers the definitions of high performance buildings, sustainable construction, ecological design and ecologically sustainable design.

Therefore whatever phrase is used, achieving high performance of buildings has a few basic benefits as to reduce the impacts of natural resource consumption, to improve the bottom line of costs, to enhance occupant comfort and health and to minimise strain on local infrastructures and improve quality of life.

In the paper, the context "high performance buildings" has been considered based on the conceptual frame explained above. Nevertheless, MacDonald (2000) emphasised that if one attempts to develop a definition of what a high performance building is, without also developing the metrics and approaches for assigning a performance rating, it will probably lead to quite extended development efforts. The process of developing the actual metrics and approach for obtaining a rating usually leads to insights into how performance should be defined. If the definition and metrics approach are not handled in tandem, serious problems with eventual use are likely to develop.

3. PERFORMANCE RATINGS AND BUILDING ASSESSMENT SYSTEMS

The *ASHRAE GreenGuide* (Grumman, 2003) defines green design as "…one that is aware of and respects nature and the natural order of things; it is a design that minimizes the negative human impacts on the natural surroundings, materials, resources, and processes that prevail in nature." Gowri (2004) interpreted this definition that it emphasised the need for a holistic approach to designing buildings as an integrated system. Green building rating systems transform this design goal into specific performance objectives and provide a framework to assess the overall design. Gowri (2004) highlighted that three major green building rating systems provide the basis for the various green building rating systems and certification programs used throughout the world.

3.1. Building Research Establishment Environmental Assessment Method (BREEAM)

BREEAM (Building Research Establishment Environmental Assessment Method) is by far the oldest building assessment system. Developed in 1988 by the Building Research Establishment (BRE), the national building research organization of the UK, it was initially created to help transform the construction of office buildings to high performance standards. BREEAM has been adopted in Canada, and several European and Asian countries (Kibert, 2003).

BREEAM assesses the performance of buildings in the following areas:

- *management*: overall management policy, commissioning site management and procedural issues
- *energy use*: operational energy and carbon dioxide (CO_2) issues
- *health and well-being*: indoor and external issues affecting health and well-being
- *pollution*: air and water pollution issues
- *transport:* transport-related CO_2 and location-related factors
- *land use*: greenfield and brownfield sites
- *ecology*: ecological value, conservation and enhancement of the site
- *materials*: environmental implication of building materials, including life-cycle impacts
- *water*: consumption and water efficiency

BREEAM has two categories; for "design & procurement assessment" at the beginning of the design process and "management & operation" assessment after it is in use.

3.2. Leadership in Energy and Environmental Design (LEED)

In North America, the U.S. Green Building Council (USGBC) developed the LEED rating system with a market driven strategy to accelerate the adoption of green building practices. The LEED rating system has gained a lot of momentum since Version 2.0 was released in March 2000. As of August 2004, about 1,450 projects have been registered for LEED certification (Gowri, 2004).

LEED is structured with seven prerequisites and a maximum of 69 points divided into six major categories which are listed below.

1. Sustainable Sites
2. Water Efficiency
3. Energy and Atmosphere
4. Materials and Resources

5. Indoor Environmental Quality
6. Innovation and Design Process.

LEED is still only used at the end of the construction process or design process for rehabilitation projects (LEED, 2005).

3.3. Green Building Challenge Assessment Framework (GB tool)

The Green Building Challenge is a collaborative of more than 20 countries committed to developing a global standard for environmental assessment. The first draft of the assessment framework was completed in 1998 and a spreadsheet tool (GBTool) was developed for participating countries to adapt the framework by incorporating the regional energy and environmental priorities (Gowri, 2004).

GB Tool provides a standard basis of comparison for the wide range of buildings being compared in Green Building Challenge. It requires a comprehensive set of information not only on the building being assessed, but also for a benchmark building for use in comparing how well the green building performs compared to the norm. GB Tool requires the group using it to establish benchmark values and weights for the various impacts (Kibert, 2003).

The basic difference of GBtool among others is to provide different assessments for every sub-phase of the design process.

3.4. Discussion

The wide variety in assessment criteria of the rating systems and different implementation phases during building process are the basic determinative of the selection of the effective system (Table.1).

Table.1. rating systems based on building process phases.

	BUILDING PROCESS →				
	Pre-design	Design	Construction	Operation	Renovation Demolishment
BREEAM	Design & Procurement Assessment			Management & Operation	
LEED				At the end of the construction process or design of rehabilitation	
GB-tool	Pre-design assessment	Design assessment	Construction assessment	Operation assessment	

Since buildings are so diverse, serving many different types of occupancies or functions, any attempt to develop a single system to define and rate performance of these buildings will not be perfect and will even be unsatisfactory for many potential users (MacDonald, 2000). Hence, it might be one strategy to at least define a flexible system that can have many possible configurations for dealing with the issues created by the diversity.

Mac Donald (2000) emphasised that; major issues related to who will be the users of such a rating system; how any rating results will impact actions of building owners, operators, and other building industry actors; how such abilities will be deployed and maintained; and how quality will be assured also exist. These and other wide-ranging issues must be considered during development of performance definition and rating methods, although abilities to adequately address them all will likely be limited.

On the other hand, inquirying the performance expectations during design process requires a decision support which could assist the designer while selecting the appropriate option among design alternatives. This is very essential particularly the early design phases when options are diverse and the decisions are fuzzy. Hence, researches are held on the redevelopment of the implementation fields of the design decision supports as to meet with above expectations. From this point of view, the efforts are made for the ways of enchancing the effective area of building performance simulations as a decision support tools through high performance buildings.

4. EFFECTIVE AREA OF BUILDING PERFORMANCE SIMULATION IN THE CONTEXT OF RATING SYSTEMS

Since the early 1970's, building performance simulation programs have been developed to undertake non-trivial building (design) analysis and appraisals (Kusuda 2001). Dramatic improvements in computing power, algorithms, and physical data make it now possible to simulate physical processes at levels of detail and time scales that were not feasible only a few years ago. This enables contemporary software to deliver an impressive array of performance assessments (see e.g. Augenbroe and Hensen 2004, Hensen and Nakahara 2001, Hong et al. 2000). However at the same time, the ever increasing complexity of the real world built environment and the issues to be addressed (environmental for example) create barriers to routine application of building performance simulation in practice, mainly, in the areas of quality assurance, task sharing in program development and program interoperability (see e.g. Augenbroe and Eastman 1998, Bazjanac and Crawley 1999, Blis 2002, Bloor and Owen 1995, Crawley and Lawrie 1997, Eastman 1999), and because the use is mainly restricted to the final stages of the overall building design process. (Hensen, 2004).

Although there are many efforts held to overcome these barriers, it is an increasing awareness in design practice as well as in the building simulation research community that there is no need for more of the same. However there is definitely a need for more effective and efficient design decision support applications (Hensen, 2004).

On the way to apply building performance simulations as decision support tools, it is obvious to consider exactly the answers of the questions: what is going to be decided?, when is the correct time for effective decisions?, what are the limitations?. If one would like to make people aware of the knowledge and skills to perform simulation, it is essential to put the limits and needs of every level of simulation abstraction and the appropriate assessment tools for every level. The performance indicators assist for evaluation of the expected results with available knowledge capability.

Hitchcock (2003) defined that performance indicators (metrics) are intended to explicitly represent the performance objectives of a building project, using quantitative criteria in a dynamic, structured format. Performance Indicators (PI) can be used to more clearly and quantitatively define the performance objectives for a building. Documenting and communicating performance data can provide value across the complete life cycle of a building project, from planning, through design and construction, into occupancy and operation. Performance criteria are limited based on several assessment indicators for sustainability directly related with building performance simulation.

In Table.2, the indicators that can directly be obtained from simulation results are listed. There is no need to put a weight on the indicators to highlight their significance, as the weight for each building design might vary for the same performance indicators.

Table.2. Performance Indicators that are obtained from simulation results.

Performance Criteria	**Performance Indicators (PI)**		**Simulation Approach**
1. Energy	a. Heating energy demand		BES
	b. Cooling energy demand		BES
	c. Electricity consumption		BES
	d. Gas consumption		BES
	e. Primary energy		BES
2. Comfort	*A. Thermal*	f. Predicted Percentage Dissatisfied (PPD)	BES
		g. Max temperature in the zone	BES
		h. Min temperature in the zone	BES
		i. Over heating period	BES
		j. Local discomfort	AFN-CFD
	B. Indoor Air Quality (IAQ)	k. Contaminant distribution	AFN-CFD
		l. Ventilation efficiency	AFN
	C. Visual	m. Lighting level	DLA
	D. Acoustic	n. Reverberation time	AA
3. Cost	o. Investment costs		CA
	p. Energy costs		CA
	r. Life cycle costs		CA
4. Environmental Impact	s. Embodied energy		LCA
	t. CO2 emissions		LCA

Table.3. The match of rating systems criteria and BPS criteria.

Performance Criteria of BPS	LEED	BREEAM	GB Tool
1. Energy	**Energy and atmosphere**	**Energy use**	**Energy and resource consumption**
	* Energy performance	* Operational energy	* Electrical demand
2.Comfort	**Indoor environmental quality**	**Health and well being**	**Indoor environmental quality**
	* Daylight and views * Ventilation effectiveness * Thermal comfort	* Indoor and external issues	* Indoor air quality * Ventilation * Air temperature and relative humidity * Daylighting and illumination * Noise and acoustics
3. Cost	**---**	**---**	**Social and economic aspects**
			* Cost and economics
4. Environmental Impact	**Energy and atmosphere**	**Energy use**	**Environmental Loadings**
	* CO_2 emissions	* CO issues	* Greenhouse gas emissions
		Pollution	
		* Air and water pollution	

Performance criteria listed at Table.2 can be assessed by different kinds of simulation tools based on their abilities. "*1. Energy*" performance assessment can be held by "building energy simulations (BES)", "*2A. Thermal comfort*" by "building energy simulations (BES) and air flow network (AFN)", "*2B. Indoor air quality*" performance by "air flow network (AFN)", "*2C. Visual comfort*" by "daylighting analysis (DLA)", "*2D. Acoustic comfort*" by "acoustic analysis (AA)", "*3. Cost*" performance by "cost analysis (CA)" and "*4. Environmental impact*" performance by "life cycle assessment analysis (LCA)".

The comparison between the expectations of rating systems and the performance criteria which can be obtained from the results of building performance simulation shows that among many other criteria like urban design and site development, waste management, materials and transport; the issues directly related with *health*, *comfort* and *energy* can be questioned by building performance simulations (Table.2, Table.3).

Matching the rating systems criteria with the performance assessments by BPS listed above will show the integration possibilities of BPS to the rating system assessments. Table.3 shows the match of rating systems criteria and BPS. The further step will be the exploration of the simulation integration based upon the simulation tool capabilities. An enhanced information of the rating systems intent and the possible simulation integration opportunities are listed in Appendix.A at Table.4.A-B-C. The table includes issues only related with energy and comfort as an examplar.

5. CONCLUSION

The ability to define and measure building performance is a stepping stone to many other important goals, including performance improvement and recognition of good performance. The process of developing building performance definition and metrics approaches should be guided by the need to put reasonable limits on what metrics are expected to accomplish, in order to keep this important ability distinct and able to serve its purpose and also to not retard its development (MacDonald, 2000).

The research has been continued on the development of a guideline for effective use of building performance simulation in design towards high performance buildings. The rating systems analysis will make a basis for definition and expectation of high performance building. Revealing the limits of building performance simulation together with the effective implementation area will assist the designer who would like to use building performance simulations in decision support applications. Since, integrating BPS into the design needs to focus on the complexity level of BPS depends on design process requirements in each phase, the exploration of necessary information for design process phases and expected challenges and expected results of BPS should be the next step of the research.

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Appendix .A

Table.4.A. LEED categories intents and BPS integration possibilities.

BPS abilities / Rating system/category	1. Energy simulation	
LEED* Energy and Atmosphere	Minimum energy performance (Prerequisite 2)	
	Intent	*Simulation integration*
	Establish the minimum level of energy efficiency for baseline building	- model the energy performance relative to baseline building - identify the most cost effective energy measures
	Optimize energy performance (Credit 1)	
	Intent	*Simulation integration*
	Increase energy performance to reduce environmental impacts	- model energy performance to demonstrate that design energy cost is < energy cost budget
	Measurement and verification (Credit 5)	
	Intent	*Simulation integration*
	Provide for the ongoing accountability and optimization of energy and water performance	- model the energy and water systems to predict saving that will be compared with actual consumption

BPS abilities / Rating system/category	2. Daylighting Analysis		3. Multizone Air Flow	
LEED* Indoor Environmental Quality	Daylight and views (Credit 8.1)		Ventilation effectiveness (Credit 2)	
	Intent	*Simulation integration*	*Intent*	*Simulation integration*
	Provide a connection between indoor spaces and the outdoors via the use of daylight and views	- model the daylighting strategies to assess footcandle levels and daylight factors achieved	Provide for the effective delivery and mixing of fresh air to support the safety, comfort and well-being of building occupants	- include a table summarizing the air flow simulation results for each zone
			Thermal Comfort (Credit 7.1)	
			Intent	*Simulation integration*
			Provide a thermally comfortable environment that supports the productivity and well-being of building occupants	- establish temperature and humidity comfort ranges and design the building envelope and HVAC system to maintain these comfort ranges

* information from IBPSA educational presentation for engineers

Table.4.B. BREEAM categories intents and BPS integration possibilities.

BPS abilities / **Rating system/category**	**1. Energy simulation**	
BREEAM Energy Use	Operational energy (E01-E03)	
	Intent	*Simulation integration*
	To reduce the dependency of the building on mechanical systems to provide thermal comfort conditions and so reduce energy and CO_2 emissions and also the pollution aspects of systems use.	-model the energy performance strategies to predict the looses and gains in kWh/m2 according to the form and fabric of the building

BPS abilities / **Rating system/category**	**4. Acoustic Analysis**	
BREEAM Health and Well-Being	Acoustic performance (HW10)	
	Intent	*Simulation Integration*
	To encourage adoption of good acoustic performance standards	-model the acoustic strategies testing to confirm that standards have been met on site

BPS abilities / **Rating system/category**	**2. Daylighting analysis**		**3. Multizone Air Flow**	
BREEAM Health and Well-Being	Daylighting, lighting design and control (HW01-HW06)		Thermal zoning and thermal comfort (HW07-HW08)	
	Intent	*Simulation integration*	*Intent*	*Simulation integration*
	-To improve the level of daylighting for building users -To ensure lighting has been designed in line with best practice for suitability and visual comfort	- model the daylighting strategies to assess that the building is adequately daylit. -model the lighting strategies to maintain the illuminance levels in each space	To ensure that thermal comfort is achieved and to encourage it to be optimized without resorting to mechanical systems.	Encouraging to use design tools to confirm that a thermal comfort assessment has been undertaken
			Ventilation and indoor air pollution (HW13-HW15)	
			Intent	*Simulation integration*
			-To provide sufficient, controlled and controllable ventilation for indoor air quality and health and hygiene	-Model the zone to confirm fresh air rates and naturally ventiated building criteria listed are met.

Table.4.C. GB Tool categories intents and BPS integration possibilities.

Rating system/category	BPS abilities	Category	*Intent*	*Simulation integration*
GB TOOL Energy and Resource Consumption	**1. Energy simulation**	Electrical peak demand (B2)	To minimize the peak monthly electrical demand for building operations, especially where the grid is near peak capacity.	Model the electrical systems that average of peak monthly electrical demand for one year,, as predicted by means of an acceptable method or tool.
GB TOOL Energy and Resource Consumption	**1. Energy simulation**	Primary energy used (B1.2)	To minimize the amount of non-renewable energy used annually for building operations.	Model the building that MJ of delivered non-renewable energy per m2 of net area as predicted by means of an acceptable method or tool.
GB TOOL Indoor Env. Quality	**2. Daylighting Analysis**	Daylighting and illumination (D4)	-To ensure an adequate level of daylighting in all primary occupied spaces. -To ensure that lighting systems provide adequate illumination and quality levels in public and work areas.	-The predicted Daylight Factor in a typical occupancy area located on the ground floor of the building, as indicated by simulations. -Model lighting strategies that appropriateness of illumination levels and lighting quality to planned tasks
GB TOOL Indoor Env. Quality	**3. Multizone Air Flow**	Ventilation (D2)	-To ensure that the number, placement and type of the openings in a naturally-ventilated building are capable of providing a high level of air quality and ventilation. -To ensure that mechanical ventilation and cooling systems are designed in a manner that will ensure a satisfactory level of air quality and ventilation.	-Model to conformance of the design to the requirements of a recognized relevant standard, such as ASHRAE or CIBSE. -Ensure, through the use of appropriate simulation programs, that the ventilation system in mechanically-ventilated non-residential occupancies will bring ventilation air to where it is needed,
GB TOOL Indoor Env. Quality	**3. Multizone Air Flow**	Indoor air quality (D1)	-Ensure that zones generating chemical pollutants, are separately ventilated and isolated from other occupied spaces. -To ensure that CO2 concentrations stay below acceptable levels in typical primary occupancy areas.	-Model that confirm measures taken to isolate areas or rooms where pollutants may be generated. -Model for HVAC systems that conform to ASHRAE, CIBSE or other acceptable protocol.
GB TOOL Indoor Env. Quality	**3. Multizone Air Flow**	Air temperature and relative humidity (D3)	To ensure acceptable temperature and humidity control within established ranges per climate zone, to provide on-going monitoring of thermal comfort performance and the effectiveness of humidification and/or dehumidification system.	-Model to confirm compliance of mechanical ventilation systems with recognized design standards such as ASHRAE or CIBSE. -Predicted ability of natural ventilation systems to maintain temperatures within an acceptable range.
GB TOOL Indoor Env. Quality	**4. Acoustic Analysis**	Noise and acoustics (D5)	-To ensure that primary occupancies are designed to ensure a satisfactory level of acoustic performance.	-Model acoustic strategies that predicted reverberation time in seconds, as indicated by design characteristics.