The Development of a Tool for Sustainable Building Design:
Facilitates investigation of the creative space

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ABSTRACT: The understanding of sustainable building has changed over time along with the architectural interpretation of sustainability. The paper presents the results of a comparative analysis of the indicators found in different internationally acclaimed and Danish certification schemes and standards for sustainable buildings, as well as, an analysis of the relationship between the different approaches (e.g. low-energy, environmental, green building, solar architecture, bio-climatic architecture etc.) to sustainable building design and these indicators. The paper furthermore discusses how sustainable architecture will gain more focus in the coming years, thus, establishing the need for the development of a new tool and methodology, The paper furthermore describes the background and considerations involved in the development of a design support tool for sustainable building design. A tool which considers the context that the building is located in, as well as, a tool which facilitates the discussion of which type of sustainability is achieved in specific projects.
Keywords: Design support tool, Inter-disciplinary design approach, sustainable architecture

INTRODUCTION

The understanding of sustainable building has changed over time along with the architectural interpretation of sustainability. This paper discusses how different approaches to 'sustainable building' emphasise on different issues of sustainability.

The purpose of this paper is, furthermore, to provide insights into work associated with turning the definitions available in international standards, publications and the aim set for sustainable development in the Brundtland Report [1] into a design support tool applicable to designers of sustainable buildings through an inter-disciplinary design approach and design support tool development.

WHAT IS A SUSTAINABLE BUILDING?

The understanding of what sustainable building entails has changed constantly over the past decades [2-16]. This development is also interlinked with the industrial development where focus has developed from a social concern since the early industrial era to include an environmental concern since the 1960s and 70s, and to include an economic and climatic concern since the late 1970s.

Attempts were made to develop international consensus about sustainable building design in ISO 15392 entitled 'Sustainability in building construction – General principles' [17]. The ISO standard defines three interlocking types of sustainability; economic, social and environmental sustainability. These are the same three types of sustainability defined in the Brundtland report from 1987. In other words – the ISO standard confirms the understanding of sustainability suggested in the Brundtland report, but aside from this it does not provide building designers with any valuable design principles.

An issue that the ISO standard does not face is the fact that the term 'climatically sustainable building' is gaining popularity. Climatic sustainability is regarded as a way of creating a link between energy-efficient buildings and sustainable building design.

The question is, thus, whether the definition of sustainable building should be revised to include a fourth type of sustainability – climatic sustainability – so buildings that purely focus on energy-consumption are segregated from 'environmentally' sustainable buildings?

It seems that the understanding of sustainable buildings in Denmark, and the rest of Europe, is, finally, reaching a point where sustainability is – once again – about more than just energy-efficiency. This development does, however, complicate the decision-making process, because it entails a lot more variable parameters, which influence the assessment of the total sustainability of a building. This recent development,

therefore, calls for the urgent development of a tool, which can facilitate the decision-making process for sustainable building.

When it comes to the assessment of sustainable projects practitioners currently rely on certification schemes such as BREEAM (Building Research Establishment Environmental Assessment Method [18]) and LEED (Leadership in Energy Efficient Design [29]). These certification methods primarily focus on environmental sustainability. They do however also include issues relating to social and economic sustainability.

A new EU-funded certification method, LEnSE [20], is currently under development, which supplements BREEAM and LEED on the three types of sustainability in the ISO 15392 standard. The work on LEnSE seems to have slowed down since 2007, which might mean that the indicators developed in LEnSE will never be completed.

A comparative analysis of BREEAM, LEED and LEnSE has revealed how these certification schemes supplement each other, as well as the identification of the variety of indicators relating to the different types of sustainability as illustrated in table 1-4.

Table 1: Overview of indicators identified for climatic sustainability

Climatic sustainability
Considerate constructors
Construction site impacts
Risk assessment
Building user guide
Publication of building information
Provision of public transport
Proximity to amenities
Cyclist facilities
Travel plan
Maximum car parking capacity
Travel point information
Fuel efficiency and alternative vehicles for transport
Refrigerant Global Warming Potential and Ozone Depletion Potential
Prevention of leaks
Reduction of CO_2 emissions - occupation
Submetering of substantial energy uses high energy loads and tenancy areas
External lighting
Zero and low carbon technologies
Building fabric performance and airinfiltration
Cold storage
Lifts, escalators and travelling walkways
Free cooling
Energy-efficient fume cupboards
Swimming pool ventilation and heating
Labelled lighting controls
Building Management System
Provision of energy-efficient equipment
Heat Island Effect

Table 2: Overview of indicators identified for economic sustainability

Economic sustainability
Commissioning
Ease of maintenance
Good corporate citizen
Shared facilities
Security
Life Cycle Costing
Risk assessment
Branding and external expression
Exchange value
Added value
Building adaptability
Building user guide
Publication of building information
Floodrisk
Reduction of CO_2 emissions - occupation
Submetering of substantial energy uses high energy loads and tenancy areas
External lighting
Zero and low carbon technologies
Building fabric performance and airinfiltration
Cold storage
Lifts, escalators and travelling walkways
Free cooling
Energy-efficient fume cupboards
Swimming pool ventilation and heating
Labelled lighting controls
Building Management System
Provision of energy-efficient equipment
Heat Island Effect

Table 3: Overview of indicators identified for environmental sustainability

Environmental sustainability
Considerate constructors
Construction site impacts
Risk assessment
Building user guide
Publication of building information
Provision of public transport
Proximity to amenities
Cyclist facilities
Travel plan
Maximum car parking capacity
Travel point information
Fuel efficiency and alternative vehicles for transport
Refrigerant Global Warming Potential and Ozone Depletion Potential
Prevention of leaks
NOx and SOx (etc.) emissions from heatsource
Minimising water course pollution
Reduction of night time light pollution
Noise attenuation

Construction site waste
Recycled aggregates
Recyclable waste storage
Composting
Completion
Material specification for major building elements
Hard landscaping and boundary protection
Reuse of building facade, construction, non-structural elements
Responsible sourcing of materials
Insulation material - embodied energy vs. reduction in consumption
Designing for robustness
Regionally sourced and produced materials
Rapidly renewable materials
Salvaged materials
Water consumption
Water meters
Water recycling
Irrigation systems
Vehicle wash
Water-efficient appliances/machines
Reuse of land
Contaminated land
Ecological value of site
Impact and enhancement of site ecology
Development footprint
Site investigation

Table 4: Overview of indicators identified for social sustainability

Social sustainability
Considerate constructors
Shared facilities
Security
Risk assessment
Branding and external expression
Added value
Building user guide
Consultation with neighbours
Publication of building information
Development as a learning ressource
Provision of public transport
Proximity to amenities
Pedestrian and cyclist safety
Deliveries and manoeuvring
Noise attenuation
Daylighting
View out
Glare control
High-frequency lighting
Internal and external lighting levels
Lighting zones and control
Potential for natural ventilation
Indoor air quality
Volatile Organic Compounds
Thermal comfort
Thermal zoning
Microbial contamination
Acoustic performance
Office spaces <500m^2
Provision of outdoor spaces
Provision of drinking water
Specification of laboratory fume cupboards
Containment level 2 and 3
Arts in health
Provision of private space
Social cost-benefit analysis
Socially responsible and ethical procurement of goods and services
Design quality
Preservation of buildings
Mix of residents
Local employment opportunities

The analysis has revealed that BREEAM has a greater focus on social sustainability than LEED does, while LEnSE supplements both schemes in the field of economic and social sustainability. The analysis has also revealed that BREEAM and LEnSE seem to relate better than LEED to the European views on people, as well as, European legislation.

The current certification schemes are applicable to benchmarking sustainable buildings. However the credit schemes are not context sensitive. In other words; the schemes are not sensitive to whether the projects are located in an area supplied with Combined Heat and Power (CHP) or an area with a surplus of water.

Furthermore, the focus on the different parts of the building design is a bit fussy, which is a barrier for implementation of the schemes during the design phase. Lastly the schemes do not provide the design team with an understanding of which approach to sustainability they are applying to their project through the selection of which BREEAM and/or LEED criteria for the project.

ARCHITECTURAL REPRESENTATIONS OF SUSTAINABLE BUILDING DESIGN

Changes in the understanding of sustainable building have influenced the architectural interpretation of sustainability. This has resulted in emphasis on different design principles, as well as, different approaches to the design of sustainable buildings (e.g. passive, low-energy, solar, bioclimatic and eco architecture).

The relationships between the different approaches to sustainable building and the current understanding of sustainability (based on Tables 1 to 4) are presented in figure 1.

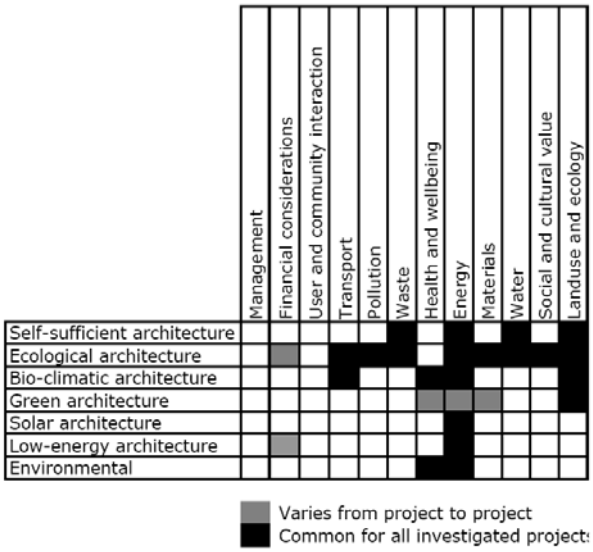

Figure 1: Themes covered by the different approaches to sustainability [2-16]

DANISH ENGINEER CONSULTANCIES, ARCHITECT STUDIOS AND THE GLOBAL MARKET

Sustainable architecture is a field that will gain focus in the Danish engineer consultancies and architect studios in the coming years. The field has not yet obtained a foothold in the industry because it requires a methodical, as well as, possibly an organizational change. Sustainable architecture furthermore requires inter-disciplinary collaboration on projects at other stages in the process than in the current methodology applied by the majority of the building industry. A new method is, thus, an important next step towards more sustainable building design.

This method should accommodate inter-disciplinary cooperation between engineering consultants and architects rather than be embedded in either the architect studio or the engineering consultancy.

If this is not achieved one of two things might happen; 1. The building becomes too calculated at the cost of the architectural quality of the building design or 2. The architect relies on static design principles to solve the problem instead of relying on the professional expertise of the engineer.

To ensure both the architectural and building technical quality in future environmental and sustainable construction, it is, therefore, essential that architects and consulting engineers work together, in a different way than they do today.

In addition to a new methodical approach this requires an organizational review of the existing cooperation between the architect and engineering consultants when it comes to the provision of projects and the establishment of a fundamentally different approach to the flow in these projects. The development of more dynamic tools could also facilitate inter-disciplinary interaction between engineers and architects. These tools are necessary to support ongoing design reviews of both qualitative and quantitative criteria related to different stages of the design process.

Intention of increasing cooperation in the initial stages of building projects already exists in the industry. These intentions are, however, difficult to achieve because the methodical differences and the traditional professional demarcations take a long time – possibly generations – to change. Another reason is that the tools are available to engineers and architects in their current form do not support application in the initial stages of design projects.

METHODICAL APPROACH TO SUSTAINABLE BUILDING DESIGN

A study of the methodical approaches described in publications and an interview with two experienced designers with Arup Associates has resulted in the conclusion that:

- the design of sustainable buildings should occur in a multi-professional environment from the very beginning of the project
- the design process involved in sustainable building design should preferably be inter-disciplinary in order to achieve synergy between building technology and architectural aesthetics
- the key to success lies in the development and realisation of an inter-disciplinary concept and vision for the specific building project

The development of project specific inter-disciplinary concepts and visions requires a proactive investigation of combinations of different variable parameters in the creative solution space defined in a specific project [21].

Sensitivity analysis was recently tested in a PhD project as a methodical approach that facilitates proactive investigations in the sketching stages of sustainable projects. It was the conclusion of the PhD thesis, entitled 'SENSITIVITY ANALYSIS as a Methodical Approach to the Development of Design Strategies for environmentally sustainable buildings' [21], that sensitivity analyses can facilitate the development of project specific design strategies through proactive investigation of project specific solution spaces. The application of sensitivity analyses was performed in a theoretical study. It has since the completion of the thesis been applied in practice by the engineering company Ramboll.

So far experiences with the practical application of sensitivity analyses are that:

- sensitivity analyses are quite time consuming if not embedded in a tool or a series of tools
- if set in the right mix of workshops and input from architects and clients (professional builders) the methodology has a lot of potential to enable proactive investigations in the initial stages of a design project performed via calculations
- some architects find it difficult to step outside their sketches and identify the parameters varied in their sketches, while others find it to be an easy transition
- that some of the time usually spent in the detailing phase needs to be transferred to the initial stages of the design process, which takes up a larger percentage of the total time than in a conventional approach. This means that the conventional economic division in relation to the respective phases sometimes work as a barrier of inter-disciplinarity, because it forces architects and engineers back into the conventional design process.
- some types of design related investigations are more relevant for sensitivity analysis (e.g. design of building envelope and geometry) while comparative analyses seem more applicable for other design issues (e.g. selection of materials)

DEVELOPMENT OF A DESIGN SUPPORT TOOL

The certification methods (LEED, BREEAM and LEnSE) facilitate the setting of goals for sustainable projects, as well as the evaluation and comparison of sustainability of project sketches and final projects, i.e. reactive investigations.

They do, however, not facilitate proactive investigation of the creative solution space of a project (the creative solution space can be deducted from the variations presented in the initial sketches for a building design) or the architectural aesthetics involved in building design, which the authors of this paper believe is required to achieve innovation and synergy in integrated design projects (please refer to the previous section).

It is, therefore, necessary to develop tools which facilitate proactive investigation of project specific solution spaces, whilst enabling certification of the project once it is finished.

The engineering company Ramboll is currently working on the development of a tool to support sustainable building design. The project is in its initial stages and a test version of the tool is expected to be complete in the summer of 2009.

The tool relies on the understanding of sustainability represented by the indicators found in the comparative analysis of the BREEAM, LEED and LEnSE certification schemes, supplemented with a few more indicators.

The methodical approach behind the tool development relies on the conventional approach to building design as well as the IDP method developed at the department of Architecture and Design at Aalborg University (Denmark) [22].

The tool does not attempt to replace the internationally acclaimed certification schemes (BREEAM and LEED), but aims to enable LEED and/or BREEAM certification of the final project. The tool, furthermore, aims at framing the sustainability of a building in relation to the different phases of the design process and the context the project is situated in.

Lastly the tool aims at producing a visual impression of how the different types of sustainability are weighted by the project team, thus, visualising the approach taken to sustainability in the specific project. This visualisation is expected to serve as a tool in the dialogue with the client and the rest of the project team as a demonstration of areas which could be improved further in the project, thus, serving as a design support tool.

So far the tool does not have the possibility of performing sensitivity analyses, as the tool needs to be tested on projects before more time and money will be spent on further development. However, in the future the tool might be developed to include sensitivity analyses to assess the sensitivity of the sustainability of specific projects in relation to the context the projects are situated in, but for now this is left out of the tool.

CONCLUSION

It is the conclusion of this paper that the intention of increasing cooperation in the initial stages of sustainable building projects already exists in the Danish building industry. These intentions are, however, difficult to achieve because the engineering consultants and architecture studios apply different methodological approaches and tools in their work. And because the tools that are available to engineers and architects in their current form do not support the application in the initial stages of the design of a building and construction project.

It is very time consuming to develop new tools and only time will tell whether the developed tool will

prove to perform as a design support tool in practice and whether sensitivity analyses will eventually become part of the tool. A lot of time was spent deciphering the requirements presented in the BREEAM, LEED and LEnSE certification schemes, and a lot of thought was put into turning the knowledge deducted from the different schemes into something that would be applicable to designers of sustainable buildings.

One of the big issues one faces when dealing with sustainable building design and multi-disciplinary design teams is how to visualise the approach taken to sustainability in the project, as well as, how to secure that the vision and concept developed in the beginning of the project is realised. The tool developed by Ramboll Denmark attempts to overcome this by including the main phases of the design process in the assessment of the tool and visualise discrepancies throughout the project, as well as, by visualising how the decisions made influence the approach to sustainability taken in the project.

Another important issue one faces when designing sustainable buildings is, that sustainable building is very much influenced by the context the building is located in. What would be a sustainable solution in one context might not be in another. For instance; designing a passive house in an area with Combined Heat and Power (CHP) might not be as sustainable as designing a low-energy house (i.e. an energy-efficient house which uses slightly more energy than the passive house) in that area due to emphasis on the extra embodied energy and costs associated with reducing the heat loss in the building the last few kWh/m^2.

The tool tries to take this into account by establishing the weighting of the different issues presented in BREEAM, LEED and LEnSE based on a series of context related questions.

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