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RELATION BETWEEN DESIGN REQUIREMENTS AND BUILDING PERFORMANCE SIMULATION

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ABSTRACT:
The aim of this paper is to reveal the relation between basic design requirements and the use of building performance simulation in current design practice.
As a starting point to focus future research on building performance simulation a number of interviews with building design practitioners were conducted to find the answer to the question: "What general information can be obtained on the building design requirements, providing a background for the context in which future building performance simulation tools or support environments will be used?"
The results of the interviews with world leading building services professionals are elaborated focusing on the relationship of value drivers and design requirements, which prescribe the building performance.
The literature review on architectural programming together with the outcomes of the interviews will reveal whether the value drivers such as flexibility, functionality and sustainability are identified in the program of requirements, accommodating the client's expectation on the building performance or not.
The results are summarized and interpreted suggesting alternatives for the use of building performance simulation.
Keywords: design requirements, architectural programming, building performance simulation

INTRODUCTION:
This paper reports on the relation between design requirements and building performance simulation in current building design practice. The work presented in the paper forms a common basis for three PhD-projects dealing with better support for decision-making and optimisation in building design.

Typical design assessment criteria are cost, future flexibility, energy efficiency; environmental impact as well as productivity and creativity of occupants. The basic aim of the building design is to create a fully functional building that meets a set of pre-defined performance criteria. To achieve that goal, it is necessary for design contributors to interact closely throughout the design process. A great number of decisions need to be taken during the design process. It is self-explanatory, that decisions at earlier phases of the design have a bigger impact on the building performance than decisions/ measures taken at later design stages or during building operation (Hopfe et al., 2005). Moreover, the appreciation of performance requirements during the development of the design brief will potentially enhance the awareness towards performance targets at the programming stage.

Recently a number of studies were conducted to enhance the ways of supporting the decisions of early stages of design even the programming stage by the help of

performance simulations. This paper investigates potential influences of the design requirements on the use of building performance simulations. By exploring the benefits of building performance simulations at the programming stage, the paper aimed to identify if the latest developments in architectural programming are supportive towards the use of building performance simulation during earlier design stages.

Research concerning design requirements (through an extensive review of literature on design briefs and architectural programming) and the experiences of practitioners on effectiveness of design requirements and value drivers during building design (through a set of interviews with practitioners) have been combined, and are reported in this paper.

METHODOLOGY:

The research was done in two parts. The first part is dedicated to interviews conducted with 15 international professionals. The second part is dedicated to a literature review to reveal whether the general understanding of design requirements and value drivers of the practitioners are similar or not in the literature definitions of requirements in architectural programming. The translation possibilities of the design requirements to performance indicators and comparison with the abilities of building performance simulations were also discussed.

DESIGN BRIEF:

A design team consists of different professions like e.g. architects, civil engineers, building services engineers, etc.. The design brief (DB) provides a framework for the design team to generate design concepts. The aim is to communicate all the expectations in a written document to the different design team members to familiarize all participants with the building project.

The DB states the vision for the project, sets limits like budget and timescale. It also defines design criteria and principles for the design, e.g. the quality for the design and the construction, accessibility and the involvement of the artists. The design brief also provides relevant information about the funding context and information about significant partner.

The DB should include the mission, objectives, priorities, timeframe, performance requirements and measure etc. of the project (BBEMRC, 2002).

In summary, the design brief contains the requirements, but does not provide any answer. Finding solution under the given constraints remains to the design team members by developing a design which fulfils the project needs (SDWC, 2004).

The design brief is refined according to the design progress. Furthermore, each participating design discipline "translates" the document into discipline specific requirements, which are than taken forward to develop programs/ concepts.

This paper specifically considers the process of architectural programming. Although it seems that architectural programs are one form of a disciplinary specific interpretation of the design brief, an architectural program can be read as a multi-disciplinary document in which the relevant values of the client, user, designer and society are identified; important project goals are articulated; facts

about projects are uncovered and facility needs are made explicit (Hershberger, 1999).

ARCHITECTURAL PROGRAMMING:

The literature review on design requirements shows that there is change in concept definitions from Pena (1977) to Hershberger (1999). It can be observed that the design requirements are transformed to "architectural programming" by the time and this transformation can be appraised briefly in three basic steps. For the first step, the programming was separated from design process and only considered as a pre-design pursuit. The application of the first step to the practice can be called a transition to the integration with design, in the second step. Finally, the programming aims to adapt completely to the structure of design (Dinç, 2002). This means that the analysis of the design process structure could not be considered separately from design requirements any more and this is very essential for the design process researches.

Architectural programming finally results in a program document which includes the objectives of the project, the instruments used to catch these objectives, the scope of the project, the qualities of the design itself and the end product, the requirements, wishes and values of the client (Hershberger, 1999). Actually, a more general definition of architectural programming made by Erhan (2004) based on his literature review is "…*an information refinement process where higher-level (non-spatial) requirements are gradually transformed into measurable and operational (spatial) requirements at lower-levels*".

Based on the interviews, the general understanding of design requirements can be explained as follows: The program of requirement prescribes building performance criteria, which were derived from a number of value drivers. It dictates details on user requirements, user conditions (like moisture production, heat release etc.), limit and target values (consumption of energy, water, comfort) and the geometric boundary conditions (floor area, ceiling height, etc.). The program of requirements is very important to the building design as it expresses the clients "wish list". But above all the program of requirements can also prove to be a hindrance during the design process if it prescribes engineering solutions (Hopfe, C., et al., 2005).

Besides the content of the program, the variety of the team members being involved in drafting the architectural program has a significant impact on the program. It should not only be a "client's wish list", even can not be questioned only from perspective of one participant discipline. Therefore, the way of providing better building design solutions will be achieved by considering the whole performance of the building and framing the expectations of each participant respect to their discipline.

VALUE DRIVERS:

During interviews, the authors were introduced to the expression "value drivers" relevant to design and building performance. The value drivers were mentioned as a key issue by each interviewee but differing depending on their engineering discipline. Based on the interviews, a value driver can be understood as a responsive variable, which when changed, has a significant impact on the value of

the final design. Value drivers mentioned by the interviewees include costs, spatial flexibility, thermal and acoustic comfort, energy consumption, indoor environmental quality, sustainability, productivity etc. (Hopfe, et al., 2005).

In literature, the expression "value drivers" is usually used in economical performance definitions and described as (Higgins, 2001) *"...the tools to show executives where the value creation opportunities exist. Value drivers improve financial performance, the product or service, time to market and customer satisfaction..."* Nevertheless, if the value being refereed to the design value or an architectural value, the definition might change to "improving the final performance of the building and the occupant satisfaction which simultaneously increases the quality of design".

In order to explain the role of the design values in architectural programming; Hershberger (1999) emphasizes that "…*the first responsibility in architectural programming is to articulate the values to which the architect should respond in design. Values in this context mean those beliefs, philosophies, ideologies, understandings, purposes, or other deeply held ideas or feelings that are the reason for building and should influence how the building is designed."*

The interviewees mentioned that at the very beginning of design practices, the number of concepts developed, often depends on the complexity and or resolution level of the design problem. Usually more than one concept is being developed and discussed during design team meetings. In order to assess concepts, performance indicators related to value drivers are being used. Value drivers can be characterized as either being discipline and/or project specific. The interviewees agreed that economic value drivers such as costs, planning issues (time schedules) etc. are of greatest important for scaling the success of any building project. However a condensed collection of disciplinary value drivers such as flexibility, functionality and sustainability are identified in the program of requirements accommodating the client's expectation on the building performance (Hopfe, et al., 2005).

EXPLORING THE TRANSFORMATION OF DESIGN VALUES TO PERFORMANCE INDICATORS

Building performance simulation is a technique for performance predictions of the buildings prior to construction. Improving the decision support abilities of the tools are still subject of research studies. The exploration of relationships between the performance confirmation and the design requirements will be a first step on the way to enhance of the implementation area of building performance simulations.

There is an ongoing discussion about the evaluation of design values. Whilst it is mentioned that it is common practice to compute measurable phenomena like costs associated with design and construction, the objective assessment of architectural values as esthetics i.e. is very difficult. Many of the values of good design are hard to measure – in a word, they are *intangible*. And, if something cannot be measured it is likely to be under-valued or even ignored completely. It is necessary to find ways to represent intangible benefits which enable them to be compared directly with computable indicators, so that an informed view can be taken about an

appropriate level of performance that will deliver real value for buildings (ERC, 2005).

Research effort should be invested into exploring the performance of buildings depending on values while searching for ways to increase the number of tangible values to be considered/ integrated for architectural programming.

One of the questions during the interviews queried the interviewees understanding of values during design practice. It was revealed that each interviewee has a different value definition and can mention a range of values based on their personal and professional experiences. If one reviews literature dedicated to values which may be the base of design requirements, it is possible to collect a chronological list of change in phrasing the values that affect programming. Formerly, Pena (1969-1977) used the phrase "*information categories*", White (1972) used "*fact categories*", Marcus (1972) "*systems*", Palmer (1981) "*factor categories*", Verger and Kaderland (1993), "*design issues*", Kumlin (1995) "*priority statements*" and Cherry (1998) described design values as "*context definition*". Recently, "*values*" is referred to design values by Hershberger (1999). (Erhan, H., and Flemming, U., 2004). The change of terminology used for "values" can give insight information about the change of the understanding of the phrase "value".

A frequently referred to publication, Hershberger's "Architectural Programming"(1999), identifies values which will be explained here briefly and used for the exploration of their relation to building performance.

Hershberger divided potential values into eight categories accredited with an easy to remember acronym, which reads "TEST EACH".

Temporal: growth, change, permanence,
Economic: finance, construction, operations, maintenance, energy,
Safety: structural, fire, chemical, personal, criminal,
Technological: materials, systems, processes,
Environmental: site, climate, context, resources, waste,
Aesthetic: form, space, color, meaning,
Cultural: historical, institutional, political, legal,
Human: functional, social, physical, physiological, psychological.

The values listed and their associated issues can not be the value driver of one stakeholder. The relatively importance of each value reveals the tendency of the client and a significant clue for the programmer. The tangible interpretations of each issue can help to convince the stakeholders with respect to the relative importance of each value. These issues are examined in the matrix with the relevance of building performance in Table.1. Nevertheless, each value listed in the table that affects the development of the architectural programming is not directly equivalent to performance indicators or metrics.

Performance is the manner in which a mechanism performs and one way of making this manner tangible can be by numeric results. Building performance indicators relevant to the values of the architectural programming are indicated with grey rows in Table.1. The use of building performance simulation is thereby limited to the measurable issues highlighted in the table.

Table.1. Relationship between design values and performance indicators.

	DESIGN VALUE	EXPLANATION	EXAMPLE INDICATORS or METHODS
HUMAN	FUNCTIONAL	Providing information on the hierarcy or relative importance of various activities, essential relationships, adjances or proximities of activities, specific space sizes and equipment needs, furnishings, etc.	---
	SOCIAL	Be aware of the social relationships	---
	PHYSICAL	Requirements depending on the needs and physical characteristics of the occupants (age, sex, disability, etc.)	---
	PHYSIOLOGICAL	Sensitivity to the information of the physiological necessities of the occupants like age, sex, clothing, activity level, etc.	Thermal comfort, visual comfort, acoustic comfort
	PSYCHOLOGICAL	Be aware of the psychological issues of design.	---
ENVIRONMENTAL	SITE	A few major site considerations like topography, site views, geology, hydrology.	---
	CLIMATE	Climate is a major programmatic and design issue.	Range of sun position, Prevailing wind direction, rainy days, humidity, day-night temperature differences, monthly- hourly climate data
	CONTEXT	Natural landforms and building features beyond the site should be considered.	Over shadowing
	RESOURCES	Water, air, fuel, building materials are the basics of the resources which affect design considerations.	Energy consumption analysis, natural ventilation, renewable sources, recycled materials
	WASTE	Considering the waste products from buildings	Waste management strategy
CULTURAL	HISTORICAL	Evaluation of the location based on its historical context.	---
	INSTITUTIONAL	Identification of the nature of the organization and institutional purposes.	---
	POLITICAL	Identification of the various community ordinances and procedures.	---
	LEGAL	Making legal requirements become a design issue by aware of the rules and regulations	Code compliance analysis
TECHNOLOGICAL	**MATERIALS**	Not dictating but include the preferences or requirements of the stakeholders in order to give these materials special consideration.	Thermo physical and optic specifications of the materials in the database
	SYSTEMS	Selection of construction materials for structural systems and identification of the mechanical and electrical systems.	Mechanical and electrical systems analysis for heating, cooling, ventilating, air-conditioning (HVAC) and lighting.
	PROCESSES	The methods, techniques and tools employed in the design process have a profound influence on the resulting architecture.	BPS as tool or a method in design process
TEMPORAL	GROWTH	The potential of the facility growth for expansions.	---
	CHANGE	Ability to accommodate changes in occupants or occupant needs.	---
	PERMANENCE	Intention of having a long buildings live time.	Mix of indicators and methods

Table.1. Relationship between design values and performance indicators (*continuation*).

ECONOMIC	FINANCE	Financial feasibility analysis	---
	CONSTRUCTION	Based on client's budgetary limitations, careful delineation of the building budget and accurate assessment of probable construction costs.	Construction cost analysis
	OPERATIONS	Effective programming relating to the client's plan for operating a facility	Operation of the building (by occupant schedule), operation of the HVAC and lighting systems (by operation schedules)
	MAINTENANCE	Opposite to the client's desire to obtain a building at the least initial cost; with many materials and nearly all systems, initial costs are inversely related to maintenance costs.	Initial cost analysis
	ENERGY	Considering the seriousness of energy costs is essential because of their continuity for the life of the building and can increase to become major costs.	Energy cost calculations
AESTHETIC	FORM	Based on communities' ordinances, there are quite specific in terms of the acceptable form of buildings to be considered.	---
	SPACE	The importance of space preferences and the reflection of inside to outside form.	---
	MEANING	A specific image that the clients have a desire to communicate to the community	---
SAFETY	**STRUCTURAL**	Consideration to the strength of the structure for usual (dead and live) and unusual loads.	Structural performance simulations
	FIRE	Be aware of any especially hazardous situations	Means of egress analysis, human behavior simulation
	CHEMICAL	The building could itself be a producer or user of products that might damage the health of the occupants or even of persons off-site (like pollutants, contaminants, asbestos,etc.)	Contaminant flow analysis
	PERSONAL	Safety of occupants for dangerous equipment and situations within the building and on the site.	---
	CRIMINAL	The architect must know if there are likely to be problems that threaten the physical safety of users so that strategies can be employed to mitigate these problems.	---

It is obvious that buildings will be different due to the importance given to each of its value drivers. A multitude of values can be captured in a one dimensional matrix however it is not possible to describe their interaction. This may require the use of mapping methods or weighting systems to ensure that the relative importance of any cluster of values can be adjusted according to the building type and given environment. Not every building will be designed to achieve high value against every cluster (ERC, 2005).

The relative importance of values and their acceptable limits for a given building type should be carefully considered by all stakeholders during preparatory discussions about the design brief.

CONCLUSION:

The role of the performance simulations in theory is very clear. Many research studies to the integration of building performance simulation into the different

stages of design show that it is possible to use these tools from earlier until the almost final stages. Nevertheless, the interviews showed that almost none of the tools that reference themselves to the earlier phases of design can effectively be used in daily pactice (Hopfe et al., 2005).

With respect to the use of building performance simulations effectively in the earlier stages of design, one way of questioning the performance requirements at the beginning of design may define the performance targets at the programming stage. The intentions of the stakeholders defined during programming will help to develop a target for the final performance. The expectations revealed at programming stage will guide the designer through all the stages of design to find out the efficient usability of performance simulations.

Therefore, the assessment of the building performance based on calculations and developing tangible (measurable) values for more issues becomes essential from the beginning of design even at the programming stage.

The design brief itself can have an impact on the use of building performance simulation during the design if it prescribes an extraordinary structural and/or environmental performance as can be found for landmark buildings.

If the building is required to meet very stringent performance criteria the building performance simulation is potentially earlier and more extensively used as for standard developments.

However by considering the architectural programming as exemplary discipline specific response to the design brief it becomes clear that the traditionally value assessment approach has changed. Many new value assessment criteria have been implemented which overlap with other participating disciplines. This potentially allows the design disciplines to interact more closely making the concept appraisal more complex. The increasing complexity might lead to a more extensive use of building performance simulation tools during the design process especially during the early design stages.

Exploring of the effective use of building performance simulation in early stages of design will be the main objective of future collaborative work. The authors will continue with working on the use of building performance simulation tools for the early stages of design to improve the tools in three different areas: optimization, quality assurance and concept development.

REFERENCES:
BBEMRC, (2002), Britannia Beach Environmental Mining Research Center, Community Design Charrette, "Design Brief", The University of British Columbia, December 2002.

DINÇ P., (2002), "Building Programming: From "Problem Seeking" to Architectural Values", Journal of The Faculty of Engineering and Architecture of Gazi University, Vol. 17, No:3, pp. 101-119.

ERC, (2005), Eclipse Research Consultants, "Better Designed Buildings: Improving the Valuation of Intangibles", RIBA online article, http://www.riba.org/fileLibrary/, last accessed, 30.11.05

ERHAN H., FLEMMING U., (2004), "Interactive Support for Modeling and Generating Building Design Requirements", Generative CAD Symposium Proceedings, Carnegie Mellon University, Pittsburgh, PA.

HERSHBERGER R., (1999), "Architectural Programming and Pre-design Manager", McGraw-Hill, NewYork, USA.

HIGGINS, J., (2001), "Value Drivers: The Road to Improve Performance", Everest Partners, http://www.outsourcingbestpractices.com, last accessed, 29.11.05

HOPFE C. J., STRUCK C., HARPUTLUGIL G. U., HENSEN J. L. M., DE WILDE P., (2005), "Exploration of the Use of Building Performance Simulation for Conceptual Design", IBPSA-NVL Conference, 20 October, Technische Universiteit Delft, Netherlands.

PENA W., PARSHALL S., KELLY K., (1977), "Problem Seeking, An Architectural Programming Primer", AIA Press, USA.

SDWC, (2004), Squamish Downtown Waterfront Charrette, "Design Brief", February 2004.