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Roles of quantified expressions of building performance assessment in facility procurement and management

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ABSTRACT

This paper treats rational expressions of building performance in order to better support dialogues between stakeholders. These expressions are based on the notion of objectively quantifiable performance measures, which are introduced through a set of "performance indicators". The indicators can be used to quantify expectations and fulfillments in structured dialogues between different stakeholders. The focus of the paper is on the introduction of two types of indicators: (1) based on normative models in biophysics and physiology and (2) based on empiricist models of Environment–Behavior studies. The treatment is positioned to support rational decision making during different stages of building delivery and use. The focus of this paper is specifically on informing decisions during design evolution, and facility and portfolio management phases of a building's lifecycle.

1. Stakeholder dialogue around the fulfillment of quantified expectations in multiple domains

Communication constitutes a vital component of a building procurement process, especially since the communication takes place among a varied set of stakeholders. Some pay for the building, some occupy them, some maintain the facilities, and yet others get associated only for a limited period of time bringing in different expertise. Paying clients expect to achieve organizational objectives in the areas of finance, business processes, and customer satisfaction. Occupants are typically concerned with work/environmental support, stress, well being, and comfort, among others. Architectural, engineering and other consultants bring in their expertise to cater to the goals and expectations of the people paying for, occupying, and/or maintaining the facility.

The key construct to note here is 'expectations'. The complexity in the term 'expectations' arises from the fact that the various stakeholders come from vastly different backgrounds. Their interests are different, and their vocabularies are as varied as their backgrounds. They focus on different issues that directly influence their operation/interests, without the required appreciation of the interactions between the different sets of issues being discussed. As a result, dialogues between stakeholders in a building procurement process frequently take the form of extremely complex processes of social negotiations. In addition, power, authority and perceived importance within or without one's organization frequently threaten to veer the negotiation process away from the primary intentions behind the negotiation process itself. One could assert that the shortcoming lies in the absence of a common vocabulary bearing the potential to engage the stakeholders in a constructive dialogue where the things being negotiated are commonly understood and agreed upon. The purpose of this paper is to articulate the role of 'performance indicators' (PIs) as quantified expressions of performance in structured dialogues among stakeholders. The following sections will focus on two distinct subsets of indicators that quantify two relevant domains of building performance.

2. Expressions of building performance as potential enhancer of negotiation

Partly owing to the complexity of the negotiation process, the disconnect between expectations and fulfillment has traditionally been a problem in the building delivery process. Better matching of the two is considered an important target for the building industry to become more client driven, and to provide better value overall [1]. Building performance has the potential to play a major role in articulating the expectations expressed by owners and occupants, and the fulfillment of them by designers and building operators. As a result, predicted performance can be used as negotiating

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instruments among stakeholders at various phases of the building procurement process. Several phases during building procurement stand out as important from the viewpoint of stakeholders negotiations: (1) programming, (2) early design, (3) design development, (4) specifications, and finally (5) facility and portfolio management. Traditionally the dialogues mentioned above have been cast in prescriptive terms, i.e. by addressing the aspects of the solution rather than making statements about the solution. Building codes and regulations have long contributed to this by basing their approach on prescriptive specification methods. This is no longer the case as many countries are moving parts of their regulations and standards to the performance domain [2]. Statements of building performance, thus, promise to enhance the dialogue process, while simultaneously casting a portion of the dialogue within the framework of building code requirements. In this context, the paper introduces a fine-grained set of objective performance quantifiers that rely on metrics derived from first order physical principles and facility evaluation data.

In this paper two domains of knowledge are used to develop performance indicators of designed settings. One set of indicators is founded on existing knowledge in biophysics and physiology (referred to henceforth as 'hard' indicators – indicators backed by hard objective science), and offers predictive tools to assess building performance in the areas of energy, lighting, thermal comfort and maintenance. Human behavior in built settings, however, is also influenced by cultural, social and personal factors. The second approach is based on theories and models in the field of Environment and Behavior (EB, a multi-disciplinary branch of scientific inquiry that originated from environmental psychology in the early 1960s [3]) that study interactions between the built environment and its users (referred to as 'soft' indicators – indicators quantified based on less objective cultural and personal factors, and subjective interpretations).

The first set of indicators, founded on normative theories of biophysics and physiology was developed as part of an on-going research project funded by the U.S. General Services Administration (GSA). These measures quantify the performance of a building system in producing a desired condition, related to an activity or need of the tenant or any other stakeholder. The second set of indicators was developed as part of a doctoral dissertation work in the Georgia Institute of Technology. The indicators integrate variables from the physical, environmental and cultural/personal domains, that take into account variations in setting types, personal attributes and cultural factors. Founded on data from buildings-in-use, the indicators enjoy a higher degree of ecological validity [4]. The two types of indicators are elaborated in the subsequent sections.

It should be pointed out how our approach differs from the Serviceability Tools and Methods (ST&M) approach [5]. The two approaches are related, but used for different purposes and based on a different framework. One of the strengths of the ST&M method is its roots in how consultants think about buildings, be it the clients perspective in terms of what to expect, or from the design supply perspective in terms of how to fulfill these expectations. ST&M set out to do something ambitious when it aimed to categorize and standardize the expectations–fulfillment pairings (criteria) and develop scales for their quantification [6]. This is where the approach advocated in this paper takes an orthogonal approach, as it starts from the notion that every rational decision moment is different, governed, not by a pre-classified set of criteria, but by a set of criteria that are specific to the situation. This requires a methodology that associates criteria with objectively measurable indicators that can serve to rationalize the decision between competing options. This paper focuses on two important aspects of the methodology: identification of indicators and their quantification methods.

3. Normative models based performance assessment – hard indicators

This section introduces the concept of a virtual experiment as a formal quantification method of 'hard' performance indicators (PIs). Fig. 1 shows the basic notion of a performance "analysis function" (AF) as a mapping of experimental input variables, environmental and control variables and system properties ($\underline{p}$) to a PI ($\underline{p}$) through a specified aggregation procedure. Fig. 1 can be explained by looking at the calculation of a PI for thermal comfort. One can state that thermal comfort performance is delivered by the "comfort control system", composed of the heating, cooling, control and enclosure systems. The calculation of the PIs is based on the following experiment: a human is placed in a certain location in a given space of the building, which is subjected to the local climate. The experiment itself is normally conducted virtually by performing a dynamic computer simulation. The experiment control variables are thermostat control, ventilation actions (opening of windows), and observer properties such as activity level and clothing. It should be observed that there is no unique way to perform the aggregation over the output data (observable states) of the experiment. In fact, many types of performance indicators for thermal comfort can be introduced, e.g. based on (i) number of hours per year that the room air temperature exceeds a certain comfort threshold, or (ii) the yearly predicted mean vote (PMV) occurrence distribution [7]. Both PIs are based on the same virtual experiment but use different metrics (a different aggregation method). We argue that the multiplicity of PIs is necessary to support rational dialogues because the context and purpose of the dialogue vary constantly.

A couple of observations can be made about the types of experiments. Firstly, the mapping from ($\underline{p}$) to the behavior of the system is the key part of the quantification of a PI. It should be noted that the theoretical foundation of this mapping determines the reliability of the PIs. In case of a real experiment, the experimental set-up must be such that all disturbances are kept to a minimum and the monitoring noise does not significantly influence the "measured" behavior (the output state information). In a virtual experiment, one must be able to guarantee that the calculation tool's representation is adequate enough to predict the behavior of the system.

The above explanation articulates the PIs ($\underline{p}$) mapping procedure, based on a set of rules that describe the experiment in precise terms to perform the following two steps without any ambiguity:

Step 1: Perform experiment which results in *Object_state (experiment_variables, object (*$\underline{p}$*); t)*.
Step 2: Perform time and space aggregation over *Object_State* resulting in *PI (experiment_variables,* $\underline{p}$*)*.

Although the resulting value cannot be taken as an absolute measure for an observable physical variable, the approach is ideal

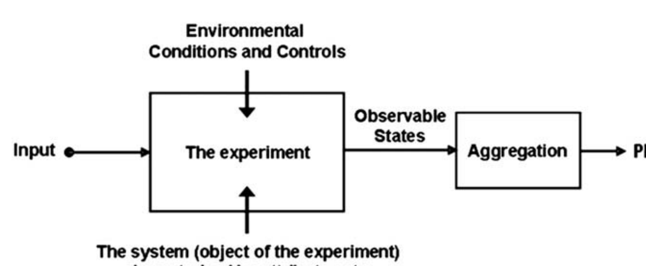

Fig. 1. The virtual experiment and aggregation that defines the PI.