# AN APPRAISAL OF KNOWLEDGE BASED SYSTEMS FOR BUILDING PERFORMANCE SIMULATION

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## ABSTRACT

The useful integration of building performance simulation (BPS) to support building design requires the successful implementation of existing knowledge and experience.

One comment regularly made by practitioners during interviews conducted, was that limited design information is available during the early design stages which does not provide the required detail for a virtual building and system representation.

The exchange of non software specific knowledge and information between BPS users is limited to email lists and design guides published by professional/ public bodies.

This paper is dedicated to knowledge systems to facilitate the exchange of non software specific design experience by providing a parametric data pool to support concept generation and optimization. A literature review was carried out identifying a number of systems which were compared and assessed based on their applicability to the problem domain.

Initial results will be presented addressing issues such as organizational behavior, user needs and information structure.

## KEY WORDS

Knowledge system, building performance, optimization, organizational behavior, interviews

## INTRODUCTION

Building design requires different engineering and design disciplines to work collaboratively on one design project. The traditional highly hierarchal project team has evolved into an integrated design team due to the need for a more efficient process. In order to streamline the point to point design process, recognized by the majority of parties involved in building design, building performance simulation is used more extensively to reduce design iteration.

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However, a software review and interviews with design professionals confirmed the hypothesis that state of the art Building Performance Simulation (BPS) tools do not serve the needs of practitioners during the early design stages.

It was found that the abstract problem resolution level characterizing design concepts requires an extensive amount of assumptions representing the building and its systems.

In order to make past design experience available for the generation, evaluation and selection of new concepts the authors argue that managing design knowledge plays a significant role.

The paper does not address techniques to simplistically represent buildings and their systems for the use in virtual building and system design/analysis tools at abstract resolution levels. However, the paper is dedicated to systems which can be used to store, retrieve and manipulate relevant design data, information and knowledge.

## METHODOLOGY

The work presented makes use of two research methods. Firstly, interviews were conducted to identify problems encountered during the early design stages. Secondly, literature and software was reviewed to obtain information about knowledge systems and how software vendors consider the representation of design concepts, respectively. Finally, preliminary conclusions were formulated, resulting in a proposal how to facilitate knowledge management for the building performance simulation community of practice (BPS COP).

## INTERVIEWS WITH DESIGN PROFFESIONALS

Interviews with 15 international design professionals were conducted. The interviewees, being either academics or industrial professionals were at first selected by availability for trial interviews and later targeted specifically based on their design involvement and experience. All of the interviewees had in common that they are typically involved very early in the design process. However, they represented different design disciplines as building physicists, mechanical engineers, structural engineers and architects.

Being questioned on issues as problems repeatedly encountered during the design process, use of computational support for building design, and his/her wish list for future developments a multitude of interesting points were raised from which a selection, important for the line of arguments on knowledge systems, is presented below.

- Unsynchronized multidisciplinary design process.
- Different attitude towards building simulation.
- Consideration of different design experience levels.
- Conversion of analysis results to design input.
- Recycling of proven design concepts.
- Steep learning curve to appropriately use BPS tools

## BUILDING PERFORMANCE SIMULATION SOFTWARE REVIEW

A software review was conducted addressing the tools operational applicability to the early stages of the design process. The output accuracy was not considered for the tool assessment. The six tools considered eQUEST, h.e.n.k., MIT Design Advisor, Building Design Advisor, ORCA, Energy10, were selected based on the vendor's applicability reference. The selection included public license tools as well as commercially available tools. Two of the six tools specifically address the Dutch market, whilst the remaining four are being used internationally. The key questions being considered during the assessment were: How is the software used? Who is the intended user group? Has the software being tested on accuracy and user group?

It was found that although the tools reference themselves to the early design stages only two were assessed to be of use for the conceptual design (Hopfe et al., 2005). The criteria being considered important during the assessment process were:

- Input defaulting due to highly diffuse design information.
- Geometric design space resolution level meeting the level of design problem abstraction.
- Number of value drivers being addressed by the tools referencing multiple design disciplines.
- Numerical output requires time intensive interpretation for compilation of performance indication.
- Steep learning curve to appropriately use BPS tools.

## KNOWLEDGE EXCHANGE WITHIN THE COMMUNITY OF PRACTICE BPS

It is widely recognized that the appropriate use of BPS tools requires extensive experience in building design and its associated building physics. To facilitate the exchange of software specific operational analysis experience and to allow for discussions on design aspects related to BPS, the industry established open communities of practice (COP) in form of mailing lists.

State of the art BPS tools contain databases in order to ease the process of assembling building systems such as composition of structural elements, HVAC systems etc. However, the provided data does not suffice the generation of an innovative design.

Software specific mailing lists exist for a great variety of tools such as ESP-R and TRNSYS among others. Whilst those lists allow for the exchange of experience among users of the same tool, another example, BLDG–SIM, is a more general mailing list dedicated to building performance simulation. (http://www.gard.com/ml/bldg-sim.htm, 2006)

The BPS dedicated mailing lists provide technical support to analysis tool users. However issues related to design concept generation, evaluation and selection are not specifically addressed.

The use of BPS during the earlier design stages, where limited information is available, requires the access to design experience. The authors argue that knowledge management system could play an important role to provide that information to the COP.

The idea of knowledge management systems (KMS), adopted by a number of institutions over the last decades, aims to provide a platform to facilitate the storage, retrieval and manipulation of design data, information and knowledge.

The reason for the KMS integration is the institutional recognition that in order to sustain the competitive advantage the deployment and maintenance of expertise is of great importance. (Subramani et al., 2002)

Although being institutional organized the COP BPS is commonly highly specialized and therefore in the least cases sufficiently served by existing institutional KMS's. The cross – institutional knowledge transfer is therefore desired.

## STATE OF THE ART IN KNOWLEDGE MANAGEMENT

The concept of knowledge management (KM) is as old as mankind. Knowledge transfer as one of its basic ideas, works exemplary, informally from parents to their offspring i.e. and formally, from academic staff to pupil and/or students i.e.

The definition of knowledge is still subject of an ongoing debate between philosophers.

Davenport and Prusak define knowledge as a: "…fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the midst of knower. In organizations it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms."

Citing the "Dizionario di Filosofia" (2001): "Knowledge is structured information about an object or any technique that is deemed suitable to give (structured) information about an object, as well as these techniques themselves, or the results of applying these techniques."

Subramani et al., (2002) used an author Co-citation analysis attempting to categories recent scientific contributions into research streams to allow for greater focus and direction for future research. As an outcome of their work they identify eight subfields that form the conceptual foundation for KM in current research.

Table 1, Conceptual foundations of KM

| Pos. | Description |
|---|---|
| 1 | Knowledge as Firm Capability |
| 2 | Organizational Information Processing & IT support for KM |
| 3 | Knowledge Communication, Transfer and Replication |
| 4 | Situated Learning and Communities of Practice |
| 5 | Practice of Knowledge Management |
| 6 | Economic and Analytic Views of Innovation and Change |
| 7 | Philosophy of Knowledge |
| 8 | Organizational Learning, Learning organizations |

Based on Chun Wei Choo's, (2004) work, identifying and comparing two influential models of knowledge management, one can distinguish two important approaches; firstly, the Davenport and secondly, the Nonaka approach. Whilst Nonaka and Takeuchi (1995) analyze the dynamics of knowledge creation, stressing the importance of converting implicit into explicit knowledge, Davenport and Prusak (1998) concentrate on the design of processes facilitating knowledge generation, transfer and codification.

Davenport and Prusak (1998) worked with the Data, Information, Knowledge, Wisdom (DIKW) model where each layer adds attributes to the previous one. Data being the most basic level, context is added at the information level, how to use it at the knowledge level and when to use it at the wisdom level. However this higher order model does not account for the order of applications the knowledge might be applied too.

The most fundamental aspect Nonaka and Takeuchi (1995) contribute is the distinction between implicit and explicit knowledge, where explicit knowledge refers to knowledge that can be expressed in words and numbers being easily to communicate and transferred in form of codified procedures or principles. Especially interesting is their suggestion that the generation of new knowledge involves a process of "organizationally" amplification of knowledge created by individuals. To aspects were identified to potentially drive the process:

- converting implicit to explicit knowledge, and
- moving knowledge from the individual level to the organizational and the inter-organizational level

Four possibilities are formulated by which organizational knowledge can be created through the conversation and interaction of implicit and explicit knowledge: socialization, externalization, combination and internalization.

## DESIGN KNOWLEDGE

Whilst the above section is dedicated to general models of knowledge management a different subject, design knowledge, is discussed here. The relevance to building performance simulation lies in the fact that without being able to describe the type of knowledge required integrating into a KMS, a KMS dedicated to BPS is deemed to fail in building design practice.

Van Aken (2005) categorized general design knowledge in three different groups: realization object and process knowledge.

Realization knowledge is summarized as "knowledge on the various physical processes to be used to realize designed artifacts". Object or substantive knowledge is defined as "knowledge about the characteristics and properties of artifacts and their materials". Process or operative knowledge is described as "knowledge about the characteristics and properties of design processes, which can be used to produce process-designs". As van Aken putt's it: "Most designers obtain their process knowledge in craftsman-like manner". Process knowledge is implicit knowledge because it is gained via experience made in passed projects. Furthermore, van Aken describes the coherency of the knowledge applications by starting from process over object to realization design.

## REVIEW OF KNOWLEDGE MANAGEMENT SYSTEMS

The literature review conducted indicates the existence of a great variety of knowledge management systems. Sheila Corrall (1998) summarizes her review of existing systems by formulating three categories typical applications fall into: firstly, knowledge networks and discussions dedicated to the exchange of implicit knowledge; secondly, knowledge route maps and directories providing both implicit and explicit knowledge and thirdly, knowledge (data)bases and repositories making explicit knowledge available. (See Table 2)

Table 2, Overview Knowledge Management Systems

| Corrall's Categories | Provider | Type of Knowledge |
|---|---|---|
| Databases and repositories | Databases | Explicit |
| Route maps and directories | Knowledge base | Explicit and Implicit |
| Networks discussions | Distributed systems | Implicit |

Many companies implemented expenditure intensive information and communication technology (ICT) and software to support of knowledge management within their institutions. However an institutional embedded ICT and software structure is no guaranty for the success of a knowledge management system.

Following Alavi and Leidner (2001) successful knowledge management requires in addition to appropriate technology, information and an adequate cultural setting. KM failure factors by Fontain and Lesser (2002) include among others:

- Failure to align knowledge management efforts with organizations strategic objectives.
- Creation of repositories without addressing the need for content management.
- Focusing knowledge management efforts only within organizational boundaries.

To implement KMS successfully, Leavitt's model of organizational change (1965) stresses the importance of balancing and coordinating four organizational subsystems: technology, structure, tasks and people. As knowledge can only be volunteered the cultural setting needs to encourage people to contribute to the KMS. Therefore, it is necessary to change the traditional (westerly) institutional culture of rewarding people based on their individual performance, which subsequently leads to knowledge hoarding.

(Hurley and Green, 2005) Sharratt and Usoro (2003) argue that extrinsic rewards for knowledge contributions are perceived less attractive than the perceived potential of career advancement. However, the set up of communities of practice might better serve the process of creating knowledge as people use a common language and understanding which encourages a collective – knowledge base. (Brown and Duguid, 1998)

## KNOWLEDGE MANAGEMENT SYSTEMS FOR THE BPS COMMUNITY OF PRATICE

As indicated in the above section, the application of KMS in Communities of Practice has apparent benefits. The already existing BPS COP´s which facilitate the knowledge exchange by mailing lists can be arguable characterized as a non–profit communities. Knowledge contributors, however, are commonly tied to either academic or commercial institutions, giving the COP a unique character by considering the reviewed literature.

The Communities, refereeing to each individual mailing list as separate entity, were brought to live in order to allow for the exchange of building simulation experience and software support. Reconsidering Corrall´s categorization with respect to the state of the art of knowledge exchange with the COP BPS, it soon becomes clear that BPS user regularly fall back onto the one or more of the knowledge providers. Databases typically form one integral part of a BPS package the user is able to manipulate. One might also recognize that distributed systems, in form of web-connected computing equipment, enables BPS user to contribute to dedicated mailing lists.

One can refer to this type of resourcing as a two level approach. Level 1, describes the distributed system for the provision of implicit and explicit knowledge; and level 2, being the integral database for the provision and manipulation of explicit knowledge. It becomes clear that the conversion from implicit to explicit knowledge is not supported but left to the user's interpretation.

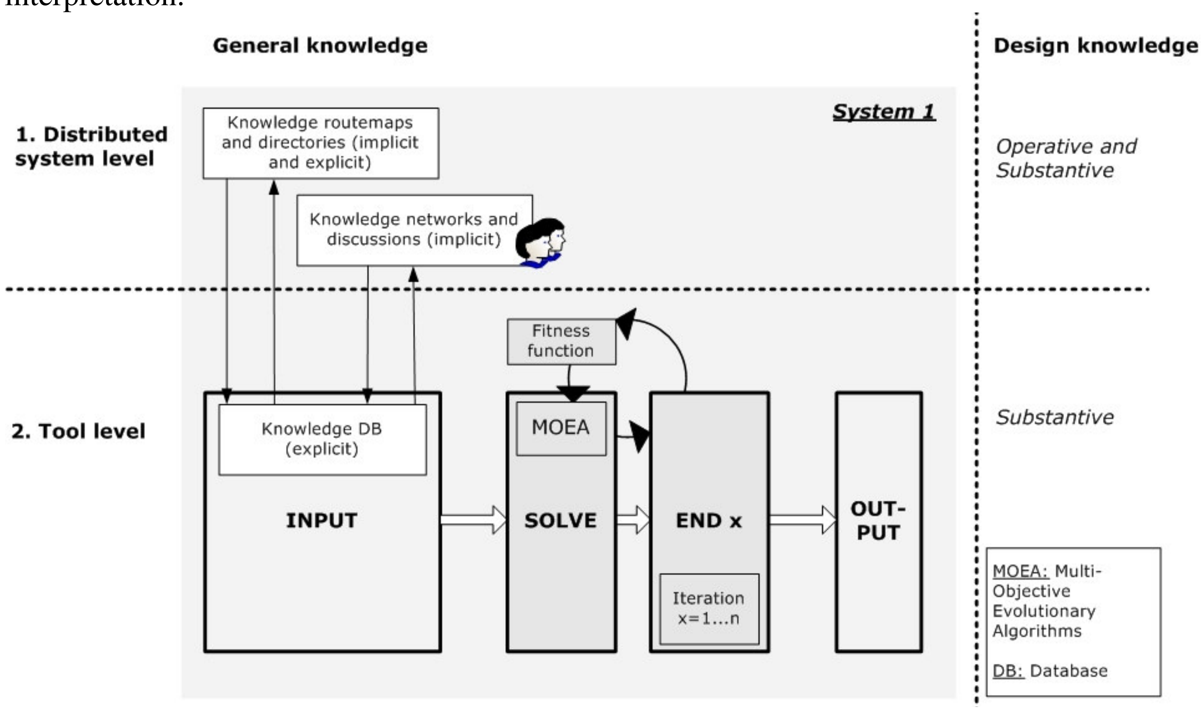


Figure 1: Two level resourcing appraoch

In order to allow the use of BPS tools during the early design stages where design decisions have the greatest impact on the success of the design as well as during later stages of the design where design optimization becomes important the integration of available implicit design knowledge is of significance.

Ellie de Groot (1999) describes a design decision support system that uses a knowledge management system as integral part of its structure, also comprising off databases and associated management, user interface and analysis models. Her aim was to facilitate the conversion of implicit expert to explicit design knowledge for concept design. In order to capture the expert knowledge workshops and interviews with design professionals were conducted. The obtained knowledge was ordered and held in databases for retrieval. However the static one way knowledge conversion is not reversible and loses transparency.

In order to serve the demand for design knowledge starting from process over object to realization knowledge the codification of design knowledge needs to be reversible, thereby establishing the need for a knowledge converter.

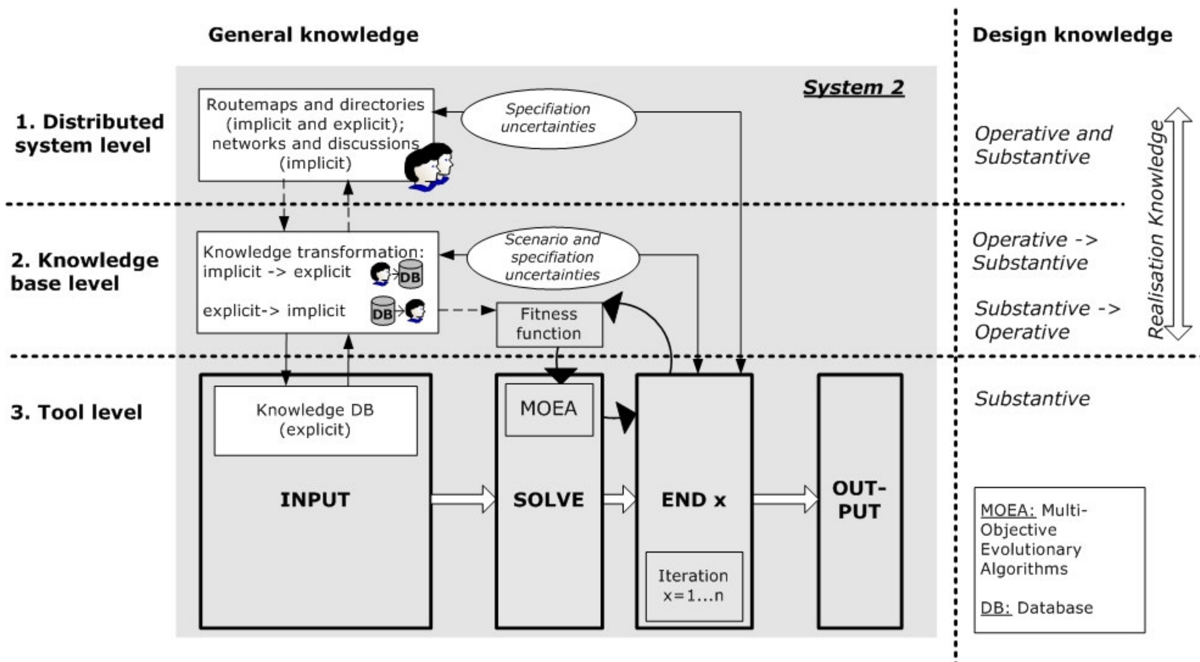


Figure 2: Three level resourcing appraoch (3LRA)

Figure 2 indicates the three level resourcing approach in order to allow an reversible knowledge conversion. The foundation for the approach is to feed knowledge to the knowledge base from both ends, tool level and distributed system level. Contributions being provided from the distributed system level could be document collections datasets, competency profiles and research interests among others. Contributions from the tool level could be problem characterising uncertainties and/or fitness functions which could be reused by community members as starting point for the generation of design input.

Building performance simulation touches on design aspect of many different design professions. The proposed dynamic knowledge management system needs to be operated and used and contributions peered.

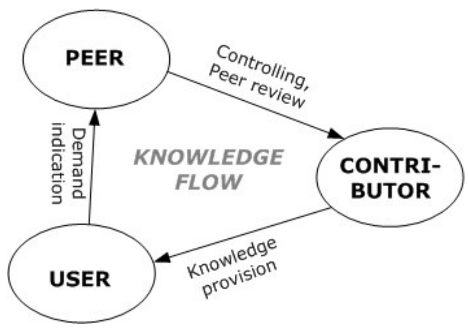


Figure 3: 3LRA-Knowledge Flow

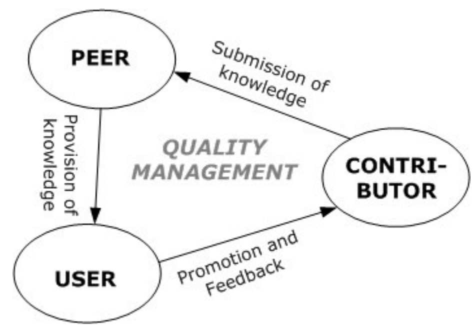


Figure 4: 3LRA-Qualitiy Management

Figure 3 and 4 indicate potential solutions to channel the knowledge contributions and manage the contribution quality, respectively.

## PRELIMINARY CONCLUSIONS

Interviews and a software review revealed that the currently available building performance simulation tools do not support the early design sufficiently. The conclusions of those two initiatives indicated a potential lack of design data as input to detailed building simulation tools. As the problem resolution level is "abstract" the tool user needs additional support to describe the problem appropriately.

To do so it was found that the BPS COP are lacking support in converting implicit to explicit and explicit to implicit design knowledge. A three level resourcing approach was derived by extensively reviewing literature on knowledge management systems which by considering known failure factors has a good potential to serve the BPS COP.

The aim is to activate and moderate the dormant potential of building design knowledge for performance simulation for a great variety of involved parties during the entire design process. Apart from providing a methodology for better informed design decisions, the proposal has the potential to increase the quality of building design in terms of quality of use, life cycle costs, investment and maintenance costs.

However it is also anticipated that the success or failure of an KMS for the COP BPS hard to measure as direct institutional recognition is not immediately available due to the character of the COP.

## FUTURE WORK

More effort will be invested to identify which parametric analysis derivatives are most suitable to inform future design decisions.

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