A co-creation platform for post-occupancy design decision support

Poorang Piroozfar[1],

School of Environment and Technology, University of Brighton, Cockcroft Building, Brighton, BN2 4GJ, East Sussex, UK, a.e.piroozfar@brighton.ac.uk

Kemi Adeyeye,

School of Environment and Technology, University of Brighton, Cockcroft Building, Brighton, BN2 4GJ, East Sussex, UK, o.adeyeye@brighton.ac.uk

Micah Rosenkind,

School of Computing, Engineering and Mathematics, University of Brighton, Watts Building, Brighton, BN2 4GJ, East Sussex, UK, m.m.rosenkind@brighton.ac.uk

Graham Winstanley

School of Computing, Engineering and Mathematics, University of Brighton, Watts Building, Brighton, BN2 4GJ, East Sussex, UK, g.winstanley@brighton.ac.uk

[1] Corresponding author

Abstract

Buildings during their service life are subject to dilapidation, obsolescence, deterioration and change and hence require constant upkeep on a daily basis and/or specific adaptation to change the functionality or improve the performance of the building. For this reason the constant and up-to-date flow of information about a building is crucial. However, data collection is just part of a successful post-occupancy practice. What is more important is how the data, information and knowledge are retrieved and packaged to provide the most effective support for making decisions.

In the UK, education up to tertiary level is the direct responsibility of the central government and takes remarkable efforts, consuming a significant amount of their annual budget. Capital investment fund for schools was £683 million in 1996-97, £3.8 billion in 2003-04, and £8.2 billion in 2010-2011.

This paper reports on partial findings of a research project on post-occupancy design in school projects in South East England. It provides a brief review of key factors, and major players in post-occupancy processes. The decision processes will then be established. It also investigates the relationship between the stakeholders and how this impacts the decision processes. A quick review of Decision Support Systems (DSS) will be provided to correlate the existing context with the means the toolkit will be utilising to offer the most efficient platform to serve the set target of the research. The main contribution of this paper however, remains to be how the collaborative processes were streamlined for all the stakeholders to work together and co-create knowledge and value to devise a platform.

Keywords

Building performance, Design decision making, Decision support systems, Knowledge management, Post-occupancy processes, Mass customisation, Co-creation of knowledge and value

Introduction

The end product in construction industry is subject to rapid change in functionality, fitness for purpose, performance requirements and efficiency. There has been a uniform call for more agility, mutual collaboration, and learning from the other industries' best practice over the past two decades (see for instance Eagan report, 'Rethinking Construction', and Latham report, 'Constructing the Team'). This is partially due to the dynamic nature of our times on one hand, which stimulates individuality in users' profiles, and is a result of rapid pace of introducing new materials, novel methods and better products, on the other. The response to this change however, appears to be totally different in construction and manufacturing industries. Despite other industries in which the product life tends to become shorter and shorter, in building industry the requirements alteration calls for physical and spatial improvement to extend the effective service life of the buildings. This has widely been acknowledged (see amongst the others Constantino and Sivo 1999) and often translates to post-occupancy building practices; what can be defined as continuous interventions to minimise obsolescence, dilapidation, deterioration, deficiencies in performance and sustainability of buildings (Douglas 2006).

A substantial amount of post-construction activities and resources are spent on the performance upkeep of buildings. Lack of engagement of designers, builders and sometimes even procuring clients with building performance may create one-off or chronic problems, which tend to persist, or result in innovation targets being missed, and true successes being overlooked - even in some of the best buildings (Bordass and Leaman 2005). The justification of this research project therefore, lies in identifying and minimising design-sourced problems in the post-occupancy stages of school projects.

In this context the aim of the study is to facilitate knowledge exchange and information flow for collaborative decision processes of stakeholders during post-occupancy works and to improve the existing practices. This aim was envisaged to be achieved through the following objectives:

1. To review PO processes and to establish correlations between those processes and minor and major works in schools
2. To review the existing practices, codes, legislations, funding mechanisms, and of PO works for school projects
3. To identify and map operational, maintenance and design criteria with reference to post-occupancy requirements, information flows and performance management
4. To develop an integrated framework for knowledge exchange and information flow, to achieve collaborative decision processes at post-occupancy stages.

The study focuses on post-occupancy design issues in primary and secondary schools in South East England. In close collaboration with major stakeholders in school projects, the research provides an overarching review of the key factors in post-occupancy performance, outlines the maintenance and management of these premises and maps out the flow of information and the exchange of knowledge in this process.

This paper aims to partially present some findings of this research project. It provides a brief review of key factors, and major players in post-occupancy processes. The decision processes during the major capital projects or minor maintenance and operational processes will then be established. It also investigates the relationship between the stakeholders and how this impacts the decision processes. A quick review of Decision Support Systems (DSS) will then be provided to correlate the existing context with the means the toolkit will be utilising to offer the most efficient platform for the purpose of this project. The main contribution of this paper however, remains to be how the collaborative processes were streamlined for all the stakeholders to work together and co-create knowledge and value to devise a platform. This platform, in return, will act as a hub to facilitate information flow and knowledge exchange as a decision support system for post-occupancy works in school buildings. The paper will finally conclude with what measures need to be taken into account, should co-creation of values be targeted, enhanced and used as a common working platform by the stakeholders across this particular sector.

Background

Central government in the UK are responsible for pre-university education and have put remarkable effort and spent significant budgets on this sector. Capital investment fund for schools was £683 million in 1996-97, £3.8 billion in 2003-04, and £8.2 billion in 2010-2011.

Known as Building Schools for the Future (BSF), a new investment programme was launched by the former Department for Education and Skills DfES in 2005-2006 to help boost education in deprived and low-performing areas in England. BSF was primarily targeted at secondary education, and followed by its counterpart for primary schools in March 2006: the Primary Capital Programme (PCP). The main aim of BSF (and PCP) was to provide school buildings for the 21st century at the scale that has not been seen since Victorian times. It was designed to rebuild or refurbish all secondary schools in England over a 15 year period at a cost of £45 billion, with local authorities participating in a series of 15 'waves'. Even at its peak, it was believed to be an immensely ambitious programme (House of Commons 2007).

The new coalition government believed that BSF had not been able to fulfil its targets; hence an overhaul to England's school building programme was announced in July 2010(DfE 2011a). This affected all school building programmes especially the BSF. Nevertheless, the Department for Education (DfE), are still committed to creating a world-class state education system by giving greater autonomy to schools, improving parental choice, offering more support for the poorest, whole system improvement, and great quality provision for children (DfE 2011b).

Setting the scene

The initial scope of this study is post-occupancy activities in school premises. These activities can range from day-to-day operational tasks, one-off or regular maintenance work to major construction works to increase the capacity or add new spaces to existing buildings. Post-occupancy building work, referred to as any work proposed or carried out on an existing building, includes building adaptation work as well as operational and management activities. It involves four independent but interacting areas and agents including: stakeholders, processes, information (and knowledge) and decisions (and actions). Figure 1 indicates these areas:

Figure 1

Figure 2 further clarifies the context of this study:

Figure 2

Post-occupancy design processes

The decision mechanisms for post-occupancy work are supported by post-occupancy evaluation (POE). A POE provides feedback on how a spatial environment performs in provision of support for the occupying organisations and individuals (Oseland 2007). Preiser define POE as a process of systematically evaluating the performance of buildings after they have been built and occupied for some time (Preiser 2002). There are two levels of performance management: performance upkeep and performance adjustment (see Figure 3).

Figure 3

The performance of every building deteriorates over time, resulting in loss of value. In certain instances, loss of value is inevitable due to: design and development briefs that give no flexibility to the design team, inappropriately high quality standards, and delays in decision making, the use of one-off design solutions, poor information supply and unmanaged change (Addy 2004). Addy also identifies people issues as: poor communication, conflicting agendas, fixed mindsets, recycling old ineffective solutions and the lack of collaborative working. The response to diminishing building performance depends on building users, asset and value expectations and statutory requirements.

Preiser and Vischer (2004) identify three priority levels for building performance:

- Health, safety and security performance
- Functional, efficiency and work flow performance
- Psychological, social, cultural and aesthetic performance.

They also assert that performance evaluation is based on feedback and evaluation at every phase of the building ranging from strategic planning to occupancy, throughout the building's life cycle.

Whyte and Gann (2001) suggest a number of plausible benefits for conducting a POE:

- applying design skills more effectively;
- improving commissioning process;
- improving user requirements;
- improving management procedures;
- providing knowledge for design guides and regulatory processes; and
- targeting of refurbishment

Despite an increasing interest in building performance assessment and POE, such exercises are simply not undertaken, results not routinely available or used widely by most design and building teams (Bordass and Leaman 2005). POEs are carried out to fulfil a number of purposes (see for instance Whyte and Gann 2001, and also Hadjri and Crozier 2009). The focus of this research is obtaining performance feedback on quantitative (building) and qualitative (stakeholder) level. Vischer (2001) recommends procedural steps that reiterate the need for standardised data gathering, but also includes the requirement to balance qualitative and quantitative datasets, as well as establishing the nature of the focus group to which the information is to be disseminated.

Post-occupancy design factors

The literature depicts design intent and brief, decision methods, information and knowledge processes, collaborative working among stakeholders and performance monitoring as the factors with an impact on continuous and efficient performance of buildings.

Design intent/criteria

Design criteria are the explicit goals that a project must achieve in order to be successful (Perelman *et al.* 2001). The design intent is embodied in the briefing document. The briefing process is often implemented in two stages. The first is concerned with understanding the client's business processes and expectations while the second comprises the conceptualisation of built solutions and issues of performance specification. Although the first stage is considered evidently more problematic (Green and Simister 1999), Kelly *et al.* (2005) contend that the second stage is more tactical in nature and is primarily concerned with issues of performance specification. They further observe that many corporate clients perform the first stage before engaging the design team. The briefing document should not only comprise the client's requirements but should contain information on resources available and possibly methods of meeting the requirements. Therefore a process of requirements definition, analysis, tracking and verification is essential.

This is why all stakeholders' involvement in second stage is important; more so in a school adaptation project, where the understanding of existing situations and constraints is important for making design and construction decisions.

Design decision making

Kelly et al (2005) also argue that the different stages of briefing require different information, expertise and knowledge. This can definitely affect the quality of the decision at each stage, hence portraying the approach to decision making as fundamental. To that end, design quality indicators (DQIs) are often used to define and measure design intent. DQIs often have performance metrics attached to each criterion. Performance metrics help provide a complete and coherent representation of both design intent and the basis of design (Hitchcock *et al.* 1998). They also contribute to creating value, for and on behalf of the client.

Combined with other technical, structural and environmental requirements, the performance metrics will contribute to information required for making decisions and the design team will be able to retrieve information as required and request further information to fill in the gaps.

Information and knowledge processes

McDermott (1999) argues that leveraging knowledge involves a unique combination of human and information systems (Figure 4). Gigerenzer (1996) suggests that people are interested in good judgement; what requires an analysis of content, in addition to laws, principles, and axioms.

Figure 4

Design and management decisions require a combination of both knowledge and information to varying degrees. From a classical logic viewpoint the greater the uncertainty of the task, the greater the amount of information would be (Galbraith 1977). According to Winch (2002), the fundamental problem in the management of information is uncertainty. Björk (1999) believes information-related processes in building projects consist of person-to-person communication, creation of new knowledge, information retrieval and storage, then making this information available.

Koutamanis *et al.* (2008) identify additional requirements for design information as integration (of many aspects at a given moment in a process) and continuity (throughout a process). One way to militate against the design failures in projects is to employ sharing of knowledge and information for making design decisions during the early stages of the process (Quanjel and Zeiler 2007).

Bouchlaghem *et al.* (2004) suggest that the type of information would generally include time, cost, quality, health and safety, environmental impact, and the exchange of information.

Collaborative working practices

The interests of three distinct client groups - the owners, the users and the society - are broadly represented during the project execution (Bertelsen and Emmitt 2005). To effectively achieve project objectives, Emmitt and Gorse (2003) describe a collaborative approach to design, where different people with varying knowledge and expertise work together. What they deem important to make an informed decision, is that the most relevant information is accessed. The collaborative working criteria are associated with other factors of post-occupancy design. This highlights the importance of the use of information for design decision making. Kalay (2006) emphasises this by saying that although participants in a project may be short-termed compared to the lifetime of the project, the effects of their collaboration, in terms of the decisions they make and the action they take when they are part of the project team, may well impact and constrain the freedom of action of other participants long after the original participants depart.

Performance monitoring

The performance concept is a systematic way of determining and achieving desired results by focusing on ends rather than means (CIB 1993). It is important to evaluate and understand the impact of the design on building performance i.e. functional activities when the building is operational. Hence the definition of building performance in BS 5240 is behaviour of a product in use. Building diagnostics is the systematic study and evaluation of building performance (Preiser *et al.* 1988). The reason for information acquisition in buildings is to capture and represent the passage of time (Giaini 1999), as well as to visually or digitally document the evolution of the building in respect to its form, structure, elements and components, in order to maintain, preserve or enhance its use, in the hope that the final outcome will be beneficial for acquiring and processing information usable for designing, evaluating, improving or repairing building infrastructure (Cory 2001).

The findings from the study proposed three additional factors, in addition to the five important post-occupancy factors identified in literature. Not surprisingly, these were time (lead-in time), quality and cost; the fundamental basis for value in project delivery.

Co-creation of value and knowledge

Literature indicates that collaboration between the stakeholders is the key to a successful post-occupancy performance of a building. In this project however, collaboration has been taken into next level and has been looked at as a platform to facilitate post-occupancy decision processes.

Mass customisation and its evolution to co-creation

Mass customisation superseded mass production as its main market drivers resulted in fragmentation of the mass market. A major shift to a more tailored and personalised approach to the market was therefore called for. This however, could not reverse the fact that some benefits of mass production were available and a paradigm shift did not need to neglect them and start from scratch. This resulted in an amalgamation of the best of the both worlds: the 'mass' factor of mass production paradigm and the 'customisation' factor of the craft production paradigm. Mass customisation was reportedly introduced during 1980s in major manufacture industries and ever since has evolved, adopted many concepts and adapted to new contexts and moved forward. Originally being a totally standalone concept, 'co-creation' is one of the latest notions to interweave with mass customisation, facilitate it and in return be promoted by it. In this sense co-creation builds on mass customisation's capacities to take a step forward to engage the customer in a more interactive way in the process of creation before the production process starts. However, it is a highly individualised process, with each person's uniqueness affecting the process (Etgar 2007). Co-creation is a market strategy which sets out to enhance customer participation in the value-chain by developing its extensionality beyond the traditional definitions. This however does not necessarily mean that the target is 'value' only. Quite the contrary this can also be done equally effectively through co-creation of knowledge. Lawer (2007) suggests two broad categories or styles of co-creation i.e. 'Firm-Centric' and 'Customer-Centric', under which he classifies eight styles of firm-customer knowledge and value co-creation:

- Value-added co-creation within a firm-centric perspective; including:
  - Product 'finishing'
  - New product design and development (lead user)
  - Existing product adaptation (customer feedback)
  - Mass customisation
  - Open community ideation and product design and development
  - New service design
- Customer-centric value-in-use co-creation; consisting of:
  - Real-time marketing & service adaptation
  - Personalised experience value and knowledge co-creation

Prahalad and Ramaswamy, who coined the term co-creation in 2000 probably for the first time, were primarily aiming at harnessing customer competence. As a strategy in market management, it seems to be capable of helping create mutual values through customer participation beyond immediate marketable values (Zwass 2010). Collective creativity is what Sanders and Stappers (2008) take co-creation to refer to. More opportunities for improvement of relationship experience and enhancement of co-creation with customers arise as suppliers learn more about their customers (Payne *et al.* 2007; Payne *et al.* 2009). Prahalad and Ramaswamy (2004) suggest the DART of co-creation, i.e. Dialogue, Access, Risk-Return and Transparency, if co-creation is going to be implemented successfully.

Project stakeholders

The Part A of the Building Bulletins BB98 and BB99, depending on the size and type of projects, defines the client team as:

- Those responsible for providing pupil places and the school estate, usually the Local Authority and/or diocese;
- The fund holder(s), e.g. governors, bursar, Local Authority building officers etc.;
- Building professionals, e.g. architects;
- Senior school staff and governors, who will need to ensure the design is suitable for the individual needs of the school;
- Other stakeholders, for example local community groups who may wish to use the facilities; and
- The main users of the project, i.e. the staff and pupils.

For this research, further distinctions are made with the Local authority – the fund holder, as the Client; the designers, contractors as building professionals; and the schools, as represented by the facilities/premises officers, bursars, governors, business managers, head teachers, as the user group, generally referred to as 'user' in the paper.

Decision Support Systems

Decision support systems (DSS) are computer technology solutions that can be used to support complex decision making and problem solving (Shim *et al.*, 2002), and were first coined by Gorry and Scott Morton (1971) as a combination of Anthony's categories of management activity (Anthony, 1965) with Simon's description of decision types (Simon, 1960).

Support system major components

A classic DSS is formed of three components:

- Database management capabilities to manage internal and external data, information and knowledge
- Modelling function accessible by a model management system, and
- Powerful yet simple user interface design to enable interactive queries, reporting and graphic functions (Shim *et al.*, 2002)

Major improvements in support of decision processes

Simon's description of decision process (1960) comprises of intelligence – search for problems, design – development of alternatives, and choice – analysis of alternatives and choosing one for implementation. Gorry and Scott Morton's DSS (1971) uses structured, semi-structured and unstructured processes, where a computer system can be devised to deal with structured section of DSS, accomplished by a judgment of a decision maker as semi- and unstructured parts of DSS; combining a human-machine system for problem solving.

During the past 20 years significant improvements have been achieved in design and building DSS. Those improvements include powerful tools (i.e. data warehouses, OLAP, data mining and web-based DSS) (Kimball, 1996, E.F. Codd & Associates, 1993, E. Thomsen, 1997), and evolution of DSS from individual standalone applications to highly interconnected networks of collaborative support systems [see among the others (Alavi and Keen, 1989, DeSanctis and Gallupe, 1987, Kinney and Panko, 1996, Warkentin *et al.*, 1997, McGrath and Hollingshead, 1994)].

Furthermore, optimisation-based decision support models are among the most recent techniques used in DSS. Optimisation takes place in three different stages: formulisation, solution and analysis. Formulation is the generation of a model in an acceptable form, where solution addresses the algorithmic resolution of the model and analysis uses a 'what-if' scenario to interpret, analyse and evaluate a solution (Shim *et al.*, 2002).

Kaklauskas *et al.* (2007) review web-based construction project performance monitoring system (Cheung *et al.*, 2004), internet-based computer-aided design tools and their possible utilisation in practice (Husin and Rafi, 2003) and predict an increase of importance of ICT in project planning, QA, as well as systems and document control in a decade ending in 2012 (Hassan and McCaffer, 2002). They also suggest that 'decision support systems are rarely applied at organisation level and hardly applied in a construction branch. The most samples of application are traced at project level' (Kaklauskas *et al.*, 2007).

MCDM

Multiple criteria problems can generally be divided into two categories: *multiple criteria discrete alternative problems* and *multiple criteria optimisation problems* (Wallenius *et al.*, 2008). The two differ in the size of alternatives, the level of uncertainty of values they can be modelled for, and the role of value function in the problem (Peng *et al.*, 2011, Wallenius *et al.*, 2008). There are different approaches devised to handle and solve the two types of problems (Dyer *et al.*, 1992). Multiple-Criteria Decision Making (MCDM) uses the most suitable approach for the type of problem it is trying to help make decisions for (Peng *et al.*, 2011) ranging from Multi Attribute Utility Theory (MAUT) (Keeney and Raiffa, 1976), Analytic Hierarchy Process (AHP) (Saaty, 1980), Preference Ranking Organisation Method for Enrichment of Evaluation (PROMETHEE) (Brans *et al.*, 1984) for multiple criteria discrete alternative problems, to goal programming (Lee, 1972), vector optimisation algorithms (Evans and Steuer, 1973) and evolutionary multi objective optimisation (Fonseca and Fleming, 1993) for multiple criteria optimisation problems.

Research methodology

Subsequent to literature search for the research, the primary data was obtained from a steering group (stakeholder forum) comprising of a sample of primary and secondary school representatives, local authority representatives and building professionals.

Invitations were sent to 60 randomly selected private and public, primary and secondary schools in the Sussex area. In addition, another 20 invitations were sent to the relevant local authority departments and building professionals. 2 design/academic experts were also invited to serve as advisers.

The result is a total of 13 members in the steering group. The composition is as follows:

Job roles	Count
Facilities manages /premises offices	3
Buildings experts (architect, engineering consultants)	3
Finance/ Business managers/Bursars	3
Academic experts	1
School Heads, governors	1
County councils (capital projects)	2

The composition of the steering group was accepted to be representative of the key decision stakeholders for major and minor works in a school project. Therefore the findings from the steering group meeting can be generalised even if there may be procedural or implementation variations at the local or individual school level in Sussex.

Following the data collection, visits were arranged to selected schools, and local councils and semi-structured interviews with school and council authorities were carried out. This was for ensuring that all the areas, which might not have been covered in steering group meetings, were explored in enough depth.

At the same time, research meeting and directed studies were held to best explore the applications for devising the toolkit. Not only this required a user friendly and intuitive GUI, it also needed to have an efficient database as well as a database management system.

Simulated and real cases for making decisions in post-occupancy design were selected to devise a model-base to test out the applicability of the devised prototype of the toolkit. The development of this prototype and its test stage in the third steering group and its concluding development into the design decision support toolkit will be reviewed.

The Platform

The status quo

Across the South East England, the local authorities in charge of capital projects for schools are using different databases and database management tools[2]. Although one might argue that different users (or user groups) within different regions may hardly reach to the point at which they wish to use each other's managerial systems, the fact that this multiplicity in tools and technologies not only calls for bigger deviated investment by the local and central governments, it also causes confusions and prevents from employing a common language between different user groups thereby limiting the sharing experience and abolishing co-creation of knowledge and value throughout a wider community of stakeholders.

[2] East Sussex County Council use 'C-Zone', West Sussex County Council utilise 'Grid for Learning' (WSGfL) while Brighton and Hove City Council have their own portal known as 'Wave', each of which has their own dedicated database and database management system.

The platform design

The core concepts deployed for designing this platform were knowledge/value co-creation and decision support systems (DSS). Figure 5 illustrates formation of this platform. It was designed employing the principles of knowledge and value co-creation. In that sense, rather than it being a system designed around standard solutions, it was formed in order that it can offer tailored solutions to unique client's problems and cases. To echo co-creation, it was decided that the platform should take shape through working with communities of practice within the education sector as opposed to by a group of design and system experts as consultants only. To elaborate on DSS, the decision mechanisms in school projects were investigated in steering group meetings. Furthermore, some external decision processes enforced by the funding bodies were elaborated on in the expert interviews with local authorities. To add the value of the existing knowledge though, experts' knowledge (in data collection and design stage) and standard DSS for post-occupancy (in toolkit development stage) were carefully employed.

As a result a three-segmented toolkit was designed which comprises of a database (DB) and its support database management system (DBMS), a model-base (MB) and its support model-base management tool (MBMT) and finally a graphic user interface (GUI). The DB formed an essential source of the toolkit where the data will be stored to be selectively retrieved respective to the queries as they arise. The efficiency of DBMS is paramount to carrying out such a task in the shortest possible time and with the most effective supports for the decision to be made. MB was simulated using the in-depth data/information gathered through the school visits. The MBs were case scenarios, which were used to work out the functionality of the toolkit as the design proceeded. Once the first prototype gestated, it was used as an MBMT to reflect on the success of design, to rectify its possible problems and to improve its functionality for a semi-future-proof application to be effectively and flawlessly used by school authorities. Although this part of the model-base might not be openly accessible for the end-users of the toolkit, its importance in a cross-sectional correlation between the three parts of the toolkit was essential to its successful development. It also remains as a powerful control mechanism as the toolkit begins to be used and for future developments. Moreover, presenting the model for school projects, the MB forms the foundations around which the GUI has been designed. Incidentally this structure is used whenever a new school is created, a new job package is put together or a new task is assigned.

Figure 5

The toolkit

The platform comprises of both standalone (desktop-client) and web-based (web-client) applications (subject to liability, copyright and patent of the toolkit, IP and confidentiality of the data and information involved). The toolkit, as developed for this research, stands as a basic multiple criteria decision making (MCDM) tool with possibilities to develop into an expert MCDM system for a more established application in post-occupancy decision making not only for school projects but across the building and construction sector. In this sense the architecture of the toolkit benefits from a modular structure providing opportunities for adding optional plug-ins both to develop the capabilities, performance and applicability of the toolkit for the school projects and to replace some of the existing modules with new ones to utilise the toolkit for non-education projects.

At this stage of development, the GUI consists of 4 interfaces. Each project starts with creating a school building. This forms the model-base and provides the users with possibilities to set up their schools, define different buildings in their school, create different rooms for each building and assign different components to each room (see Figure 6). This will then be used to attribute other specification to this interface and interlinks with the other interfaces. It also forms the main platform for the databases which proved to be different if the application is to be accommodated as a web-client, a desktop-client or both. This mainly governs how, by whom and from where the application is accessible and where the data is stored and who can access the stored data.

Figure 6

The second interface facilitates condition updates. This interface acts as the main data input interface for managing the property effectively. This means that once the buildings and spaces are set up in building interface down to the component level, each component, space and/or building can be attributed with a condition. The condition update interface utilises a normalised version of industry standard terms and definitions which have been developed using a number of condition survey reports for school projects (see Figure 7). This means the existing knowledge and the industry standards terms were optimised and utilised to prevent any future confusion. The condition update was determined by two different sets of variables: 'the condition' and 'the priority'. This was developed in order to be able to prioritise the tasks and allocate budget to them based on the discretion. In other words this mainstreamed and rationalised the human factor in the decision process of decision making for post-occupancy interventions.

Figure 7

The conditions are updatable down to the component level and this will cumulatively be reflected bottom-up, to the school level. Further to what was referred to as co-creation of values and knowledge in the development process of the toolkit, this interface also has an in-built capability to facilitate communication between different parties involved, in a transparent way benefiting from DART principles of co-creation.

Based on the condition, priorities and budget restrains, the next interface will help create job packages for different outstanding tasks. This has initially been developed to handle third parties as contractors who carry out maintenance, repair and upgrading jobs. But it can also be used for day-to-day operational and in-house maintenance tasks (see Figure 8). This interface provides the job packages for tender documents in different file formats but most importantly in pdf format. It also provides a database to keep the record of jobs, the performance of the third parties (i.e. contractors, builders, suppliers, etc.) involved in those jobs and the quality of work, materials and services provided. This can then be used for further reference by decision bodies in the same school, in other schools or in local authorities.

Figure 8

The scheduler assists in prioritising the jobs and tasks (see Figure 9). This can be done by setting a timeline for both operational and maintenance tasks and attributing a 'status' to each task. Each task in the scheduler can have one of two possible general statuses, namely 'open' and 'closed'. The scheduler screen summarises and visualises the information gathered on the conditions and jobs interfaces on a unified Gantt-style calendar using a traffic light system. This is in addition to more conventional text-based report formats in form of excel spread sheets to assist the user providing a visualisation tool. The Condition section creates an interactive 'live' condition survey in that it visualises the continuous effects of time on the condition of the managed site. The user can edit the data pertaining to displayed data by clicking on bars and handles on the scheduler or the school hierarchy. The context-sensitive properties view changes accordingly.

Figure 9

Within the initial status of each job and depending on its deadline, and its physical progress then the task can fall in one of the final status as follows:

Table 1

Discussion

The steering group came to an agreement that consensus on value is most likely to be achieved if the user team are effectively consulted and their knowledge of managing and maintaining the building is taken into consideration.

The study also found that POE for school project stakeholders is more than mere assessment of the quality or performance of design. The emphasis is on how design decisions and specifications affect operation and maintenance processes.

More importantly, the information gathered at the appraisal stages was considered vital. The group stated that the condition survey will be more useful if it is a living document, rather than something produced periodically. Some members of the group stated that documentation on the condition of their building is often 2-4 years out of date, which might be a long time depending on the building development plan. This confirmed a need for a real-time system reinvigorated by the timely feedback process, updatable and providing a common platform for sharing knowledge and information on alike or reasonably similar projects to support decision processes.

The most important finding of this study by the toolkit development stage was the pressing need for a system to assist in streamlining the information flow (particularly upwards, from the schools to the

LA) and management of knowledge to facilitate design decisions. A simple model was utilised to capture the findings from this study (Figure 10).

Figure 10

The model identifies the need for decision processes to be more integrated, collaborative and inclusive. It also acknowledges that decision making in post-occupancy processes, is an evolving process. Allowing sufficient lead-in time, information and knowledge gathering and also making the condition survey a live document, will help improve the briefing process and will ensure that user performance expectations are considered.

The prototype was showcased for the user groups in an actual setting in which they were able to experience the interface using provided guidance to perform a wide variety of realistic POE related tasks. As a result it was confirmed that although a graphical user interface is of great help to realise the overall state of the premises, by no means it can fully replace and serve the purposes of a table-based inventory of data and information, but should rather be used in conjunction with it. Furthermore, the transparency and ease of use of the prototype was highly appreciated but cautions were raised around confidentiality of sensitive data, level of access and openness of the system to the public for legal and liability issues that may arise at some point in future.

Modularity of the platform and its compatibility with existing DB and DBMS, already used at school and local authority level, was also highlighted if the proposed toolkit is to be successfully adopted by the schools and local authorities. Likewise and interrelated with the issue of compatibility, concerns were raised around the amount of extra work for training, if a system transition is to happen. In addition, once again this emphasised the main purpose of the proposed toolkit as a common platform for sharing and to enhance and encourage co-creation of knowledge and values. Modularity was followed both throughout the development process by selecting open-source and free-access applications, which provide the highest level of agility, and in the design process, where different compartments of the toolkit were combined using a standardised structure so that further developments and improvements can be made in the form of plugins to the existing database and model.

Conclusion

The paper reported on the findings of a study on the impact of design decisions on post-occupancy processes in schools with special reference to the development stage of the proposed toolkit. The principles of co-creation of knowledge and value, as suggested in manufacture and service industries, were investigated to inform the underlying design platform for the toolkit. The decision support systems for multi-criteria decision making processes were also established so that the toolkit can take a full account of the achievements in this area.

The qualitative and quantitative data from steering group meetings, confirmed that a real-time updateable support system for decisions is required for making the most reasonable decisions where multi-criteria/multi-agent decision is inevitable. Adding that, quality and competence of decision, is highly dependent on user-friendliness of the system, its offerings around the projects with as many different data-entry, querying, data-categorisation and data-mining tools and techniques as possible. This had a double-edged-sword nature as on one hand the simplicity of the interface was required to be adhered to very strictly and on the other, not only the comprehensiveness was not supposed to be compromised, but also a sensible variation throughout the toolkit was necessary to accommodate as many different categories of users as possible. A diagrammatic model that integrates the development strategy of this platform was presented and discussed in this paper.

This study provided clarification on the post-occupancy performance and practicable expectations of major parties in school projects. Based on the findings, of the previous stages i.e.:

- Including numerable criteria and possibilities in the briefing process
- Involving 'on-ground' staff in briefing process
- Identifying spatial relationships, cause and effect
- Guaranteeing knowledge and experience is passed on
- Conduct future projections based on up-to-date occupancy data,

The prototype toolkit was designed and developed to:

- Provide the right amount of information without it being burdensome
- Alert to pragmatic considerations
- Pin-point and deconstruct the exact (recurring) problem
- Look at what exists in order to make improvements
- Integrate necessary information needed to make decisions
- Seamless updating, not as a separate process, which will make the condition survey a living document
- Document product and material performance and durability for knowledge transfer (new technology means opportunities for new knowledge).

The developed toolkit provides an information management platform with different attributes for three categories of entities pertaining to school premises: buildings, processes and people; through the flow of data and information to create knowledge and value. The model-based approach used for developing the toolkit shares its principles with BIM applications in the most generic sense. However, the similarity ends right here. It differs from BIM in that PODIT is more human-driven and user-friendly. It is also developed specifically to help manage and operate school premises with the client, user, operator and their different level of access/authority in mind. Yet its web-client version makes it a live document accessible, usable and updatable by different users remotely and on a real-time basis. The other advantage of PODIT as a specialised application over mainstream BIM applications is that despite most BIM applications, which are heavily dependent on first 3 dimensions as a vehicle for 4^{th} and 5^{th} (and in some particular packages 6^{th}) dimensions, PODIT starts independently from the first 3 dimensions and provides them only as an additional visual aid. This will make PODIT much more appealing to the users with limited knowledge of IT, let alone any specialised knowledge of architectural or construction drawings, or even more unlikely of BIM applications.

The next level objectives for the project are:

- Demonstrate the developed prototype in the last steering group meeting
- Gauge the response of the users' while working with the toolkit intuitively or with the least possible amount of assistance
- Find out what might have been still missing and what could have been improved
- Document the findings for future development of the toolkit
- Consider the liability issues, IP, ownership and use terms
- Plan ahead for the next stage of development of the toolkit into a nation-wide application to be used by schools, local authorities and central government

Once the development stage is over the toolkit will undergo a 'beta test' stage. At this stage it will be installed in, and used by some partner schools and local authorities who agree in principle to participate provided that, confidentiality, IP and copyright liabilities should be met by all parties involved. This stage will provide a unique opportunity to test the application using a real set of data and in a real setting. The documented feedback then will be used to produce the first version of the application which can benefit both practice and research in the area of post-occupancy decision making in particular and facilities management in particular.

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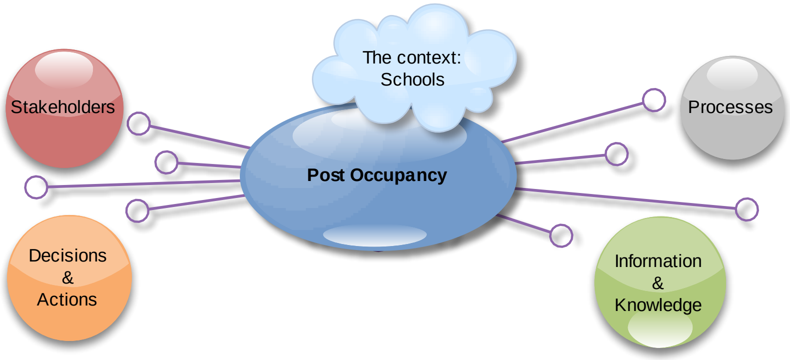

Figure 1: Areas and agents involved in post-occupancy activities

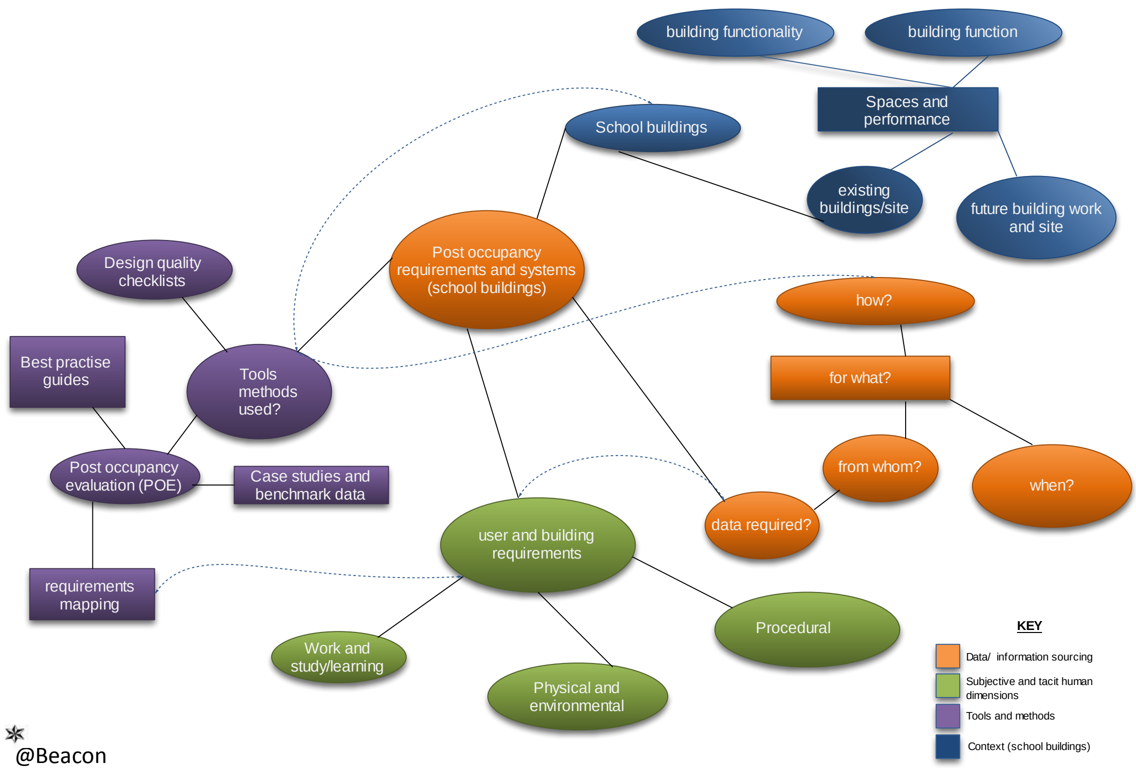

Figure 2: The scope of study

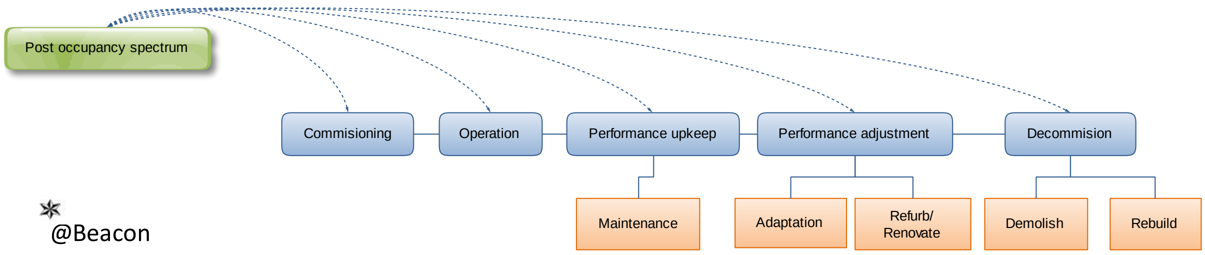

Figure 3: Post-occupancy spectrum

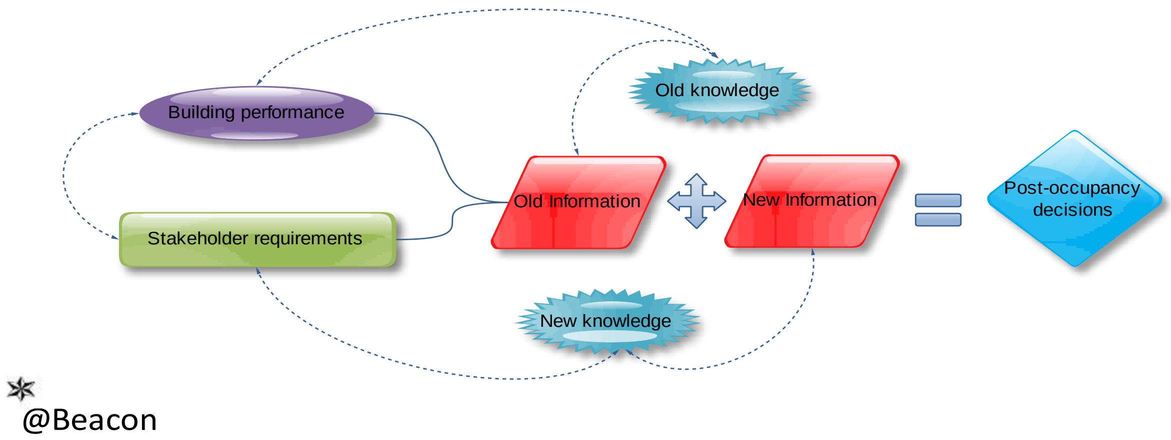

Figure 4: Information and knowledge processes

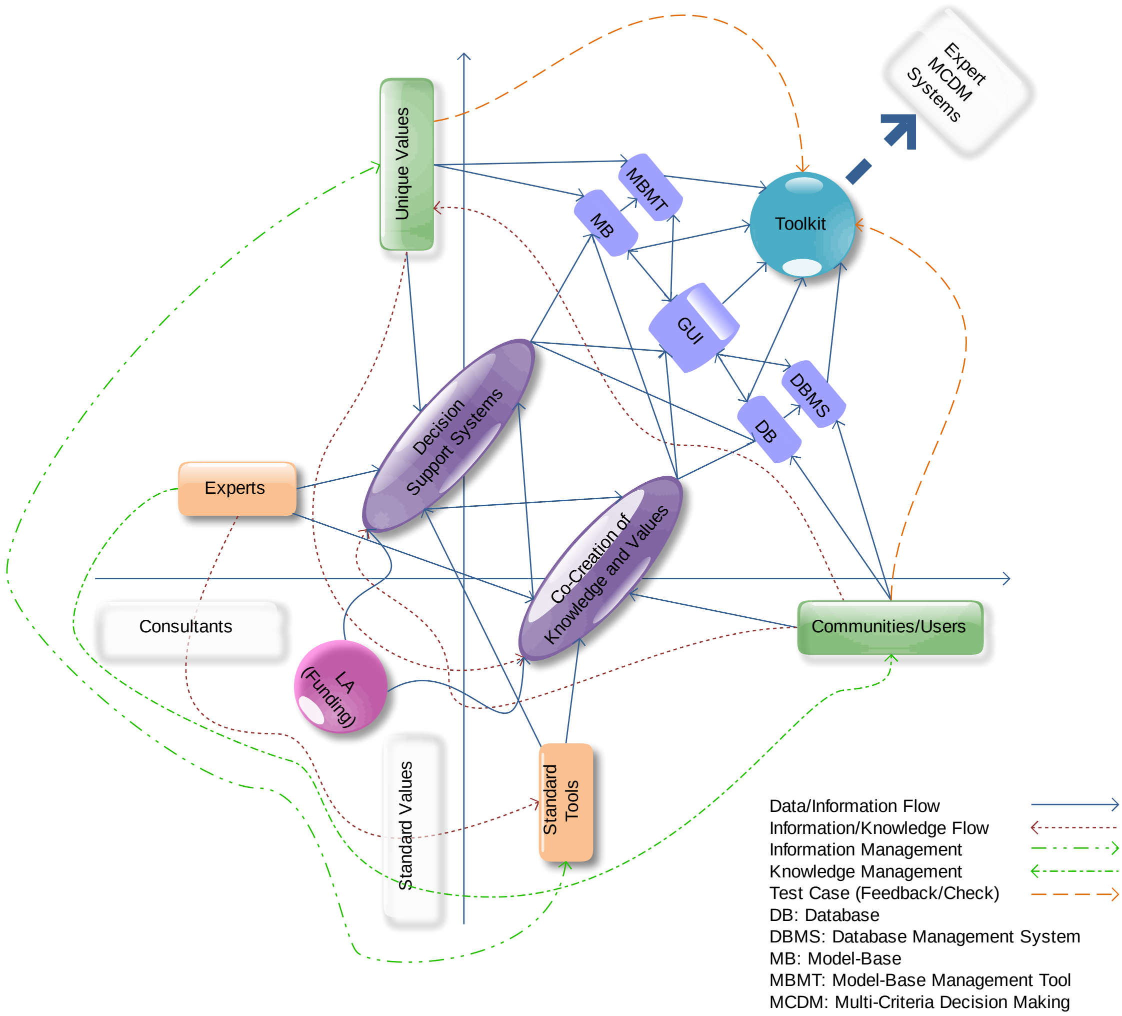

Figure 5: Development of the platform for PODIT toolkit design

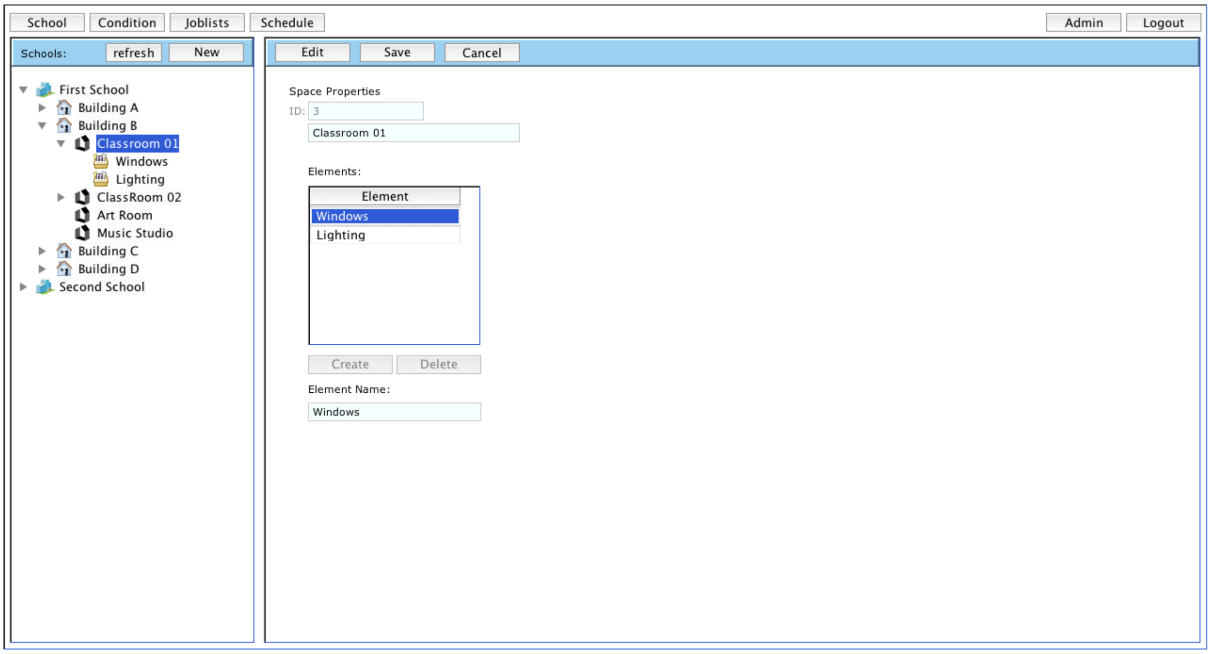

Figure 6: Model-base for creating schools, buildings, rooms and components

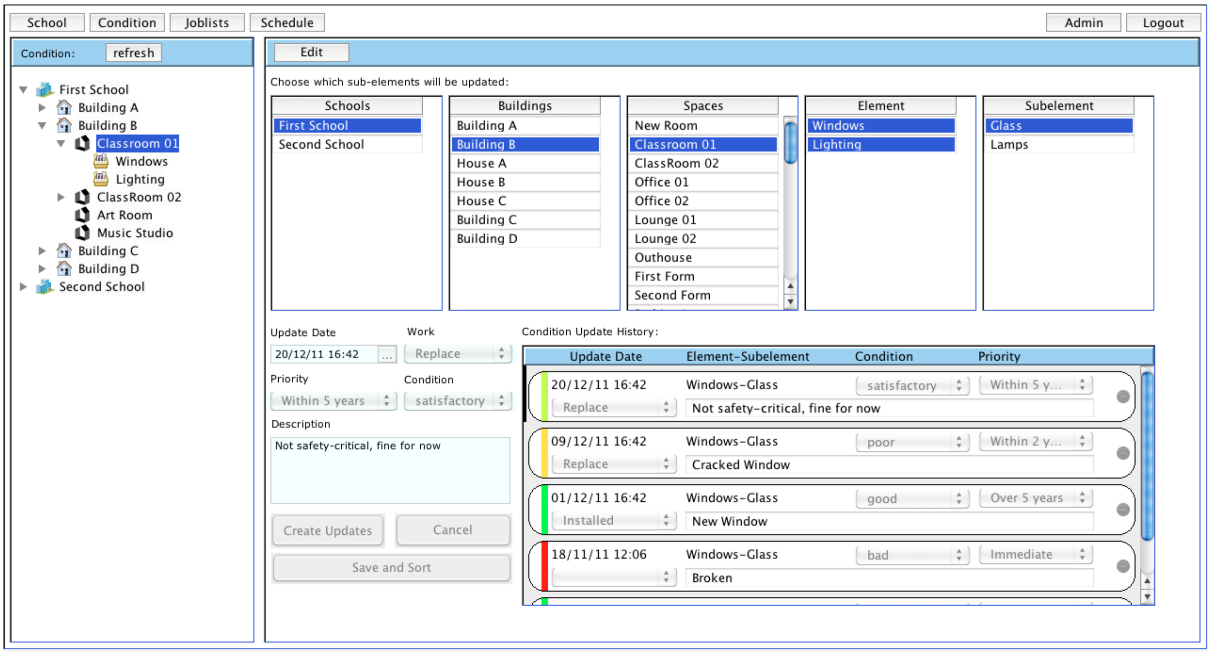

Figure 7: Condition update interface

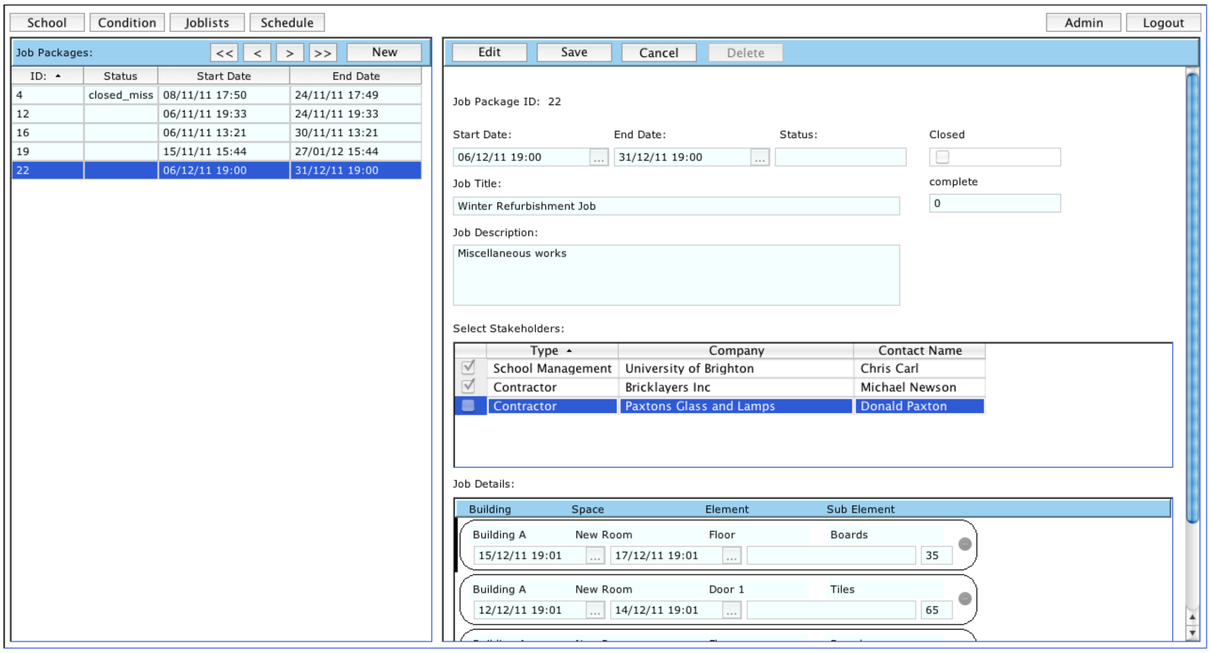

Figure 8: Joblists interface

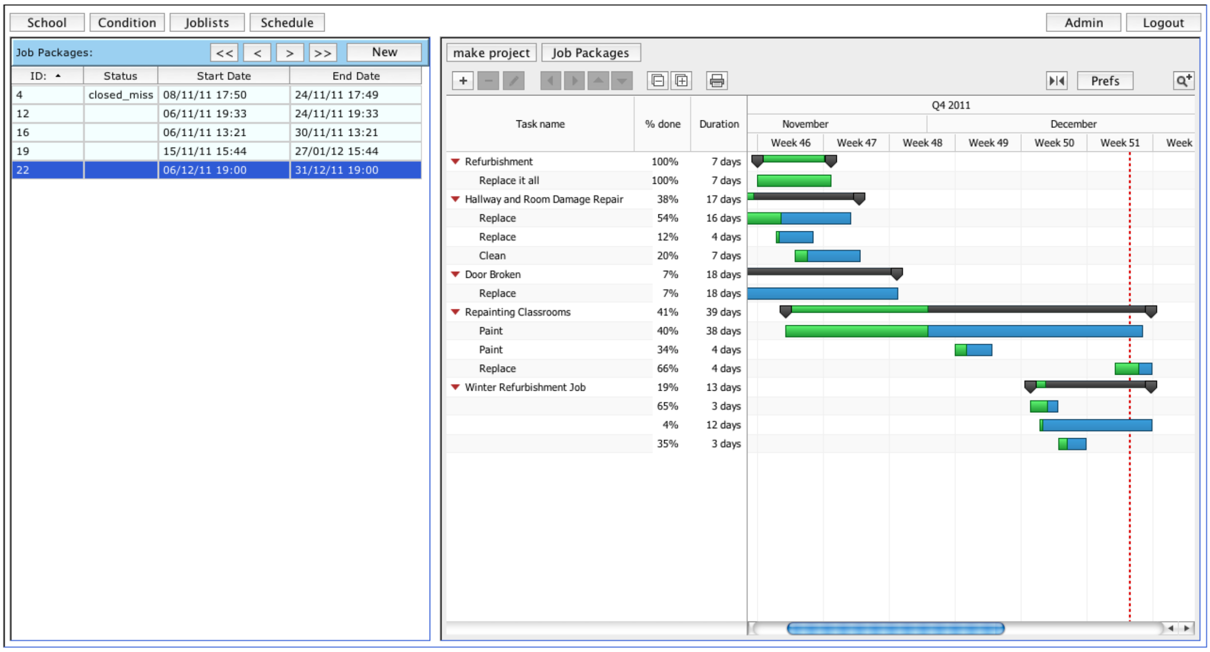

Figure 9: The scheduler

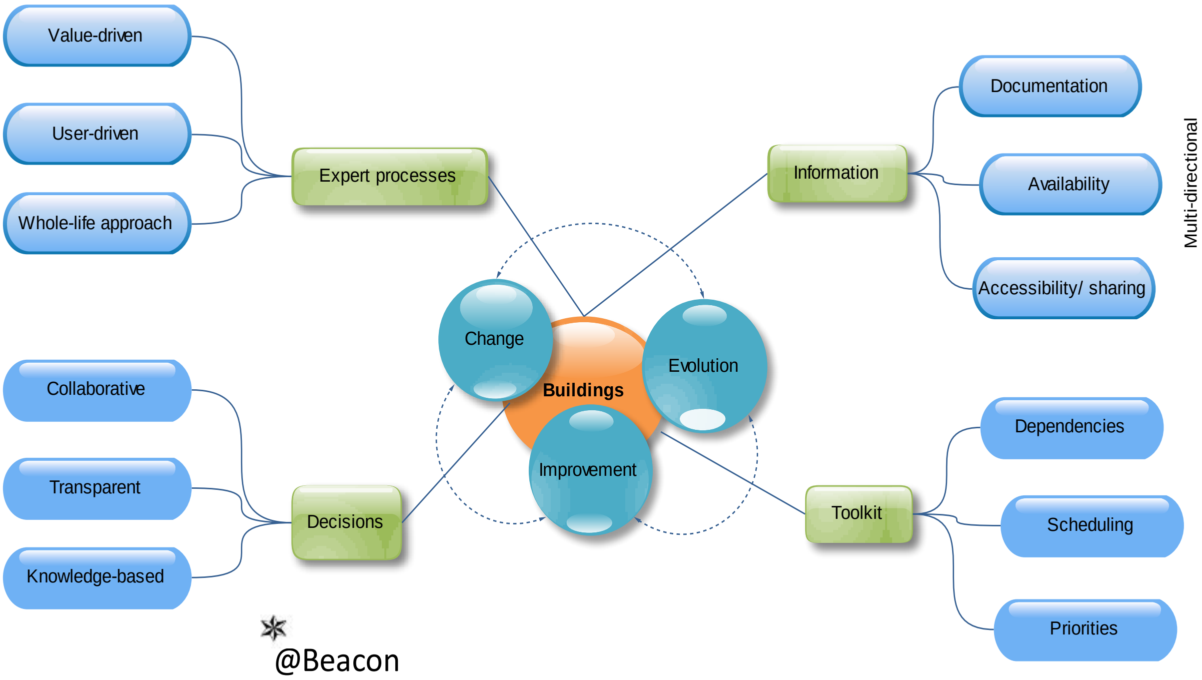

Figure 10: PODIT data/information/knowledge capture model

Open			Timing	Physical progress
	Planned		<S	=0
	In-progress		>S but <E	>0 but <100
	Overdue		>E	<100
	Done		Any	=100
Closed				
	Cancelled		<S	=0
	Incomplete		>S but <E	>0 but <100
	Missed		>E	<100
	Complete			
		Early	<S	=100
		On-time	>S but <E	=100
		Late	>E	=100

S: Start date; E: End date

Table 1: Job status based on timing and progress