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ASSESSMENT OF INFORMATION MATURITY DURING DESIGN, OPERATION AND MAINTENANCE STAGES WITHIN BIM USE ENVIRONMENT

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ABSTRACT

In construction, there is a prevalence of application of BIM (Building Information Modelling) involving in the processes and activities to contribute to a better output of lean production within construction projects, but there is still little emphasis on its application during the operation and maintenance stages. This paper proposes to discuss how the use of BIM can capture in use knowledge through the provision of a new information capture and visualisation tools for design, operation and maintenance stages in construction. In order to investigate this, a review of numerous literatures spanning multi-sectors has been undertaken by authors. The paper addresses the issues of uses of knowledge during design, operation and maintenance stages, and BIM's application at those stages and the limitations during its applications. Finally, this paper introduces the concept of information maturity and its form of visualization, through which its use can facilitate a better information management, regarding the generation, capture, use and retrieval of information, as well making optimized decision with provision of reliable, accurate information throughout design, operation and maintenance.

Keywords: design, operation and maintenance, decision-making, information management, information maturity, BIM

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1 INTRODUCTION

Building Information Modeling (BIM) has implications for all processes and activities related to construction supply chain and can thus make significant contributions to lean construction. It can be argued that BIM as a design-centric technology, with emphasis on sharing and collaboration, can be the ultimate solution to multiple challenges faced by the construction industry by improving and coordinating construction supply chain. The existing dimensions of BIM not only attend to most aspects of the construction work and processes, the technology also has the potential to add further dimensions to respond to other existing or future challenges. Most stakeholders with different BIM definitions endorse the centrality of design and the use of BIM as currently an appropriate design technology. Furthermore, it also needs to be recognized that all these processes and applications can work efficiently and effectively. In construction, such effectiveness associates with many other dimensions of work by reducing design errors and by better information management, thus controlling cost, delays, and damages.

In particular BIM acts as "the design information for different stakeholders along the construction supply chain to support sustainable design decisions for the life time of a built asset". This has extended the work and responsibilities as well as influence of the designers, requiring greater communication and higher collaboration among different actors and key stakeholders (e.g. owners, surveyors, constructors engineers, facilities managers) for achieving desired outcomes which are cost-effective and efficient, at the same time, meeting other project requirements – time, quality, environment, logistics, buildability and safety" (Dwyer et al., 2013).

The paper discusses how the use of BIM can capture in use knowledge through the provision of a new information capture and visualization tools for optimized design, operation and maintenance decision-making throughout building lifecycle. This paper has the following 7 sections: (i) to address the issues of in use knowledge, (ii) to explain the fact: construction industry, a highly fragmented sector, (iii) to highline the barrier between design and end-users, (iv) to demonstrated how BIM relates operation and maintenance, (v) to discuss the limitations of BIM on optimized decision-making, (vi) to demonstrate the concept of information maturity and its visualization form, and finally (vii) to conclude the study.

2 IN USE KNOWLEDGE

The focus on life cycle performance including the operational and support costs, which could be a significant proportion of the initial asset costs, means that there are more incentives for companies to collect and analyze the information from the in-use phase. Information and knowledge concerning the on-going aspects of in-service operations and maintenance such as maintenance requirements, performance and reliability of the product should be captured and reused to aid design decisions. Arguably, one of the most important understandings is the user interactions and equipment reliability but such understandings tend to be tacit and subjective. If information is to be retained for use in the wider context, it needs to be captured formally and in a useful manner. Previous experience suggests that although realization of reusing in-use knowledge is increasing in companies, the extent and methods to support this tend to be *ad hoc*. There are many reasons for this, including the nature of the service business that is geographically distributed, for instance, teams may be stationed away from their companies' main offices to be closer to the install base. Some products may be installed in remote locations or may not have fixed positions such as on aircraft or ships. Due to the amount of time spent away from the main office, service teams often find it difficult to share knowledge through traditional face-to-face contact. In addition, there is pressure for the service engineers to resolve issues and to bring the systems up and running as soon as possible. Hence there is much reduced priority in producing detailed documentation of their work. In isolated cases, technological and communication difficulties on site may also prevent service engineers from accessing and logging information into company's information systems. As a result of such motivational and technological barriers, feedback from service is found to be less than optimal.

In the context of integrated products and services, Jagtap et al. (2007) conducted a series of questionnaire and interviews with designers and service engineers to determine the most important and common life cycle information design engineers seek from maintenance documents. They arrived at categories of information designers find useful, such as information related to component failure, operating conditions, maintenance, life cycle cost and reliability. They also noted that in-service information required by the designers is highly heterogeneous and disparate. Companies can use insights gained from use and in-service to adapt their on-going support activities and also to feed-forward this knowledge into new design projects. This former is known as single-loop learning and the latter as double-loop learning.

As service contracts demand for ever shorter time for responses (to reduce overall downtime) from engineering companies, learning from use is important to enhance the on-going maintenance and service activities (real-time decision making). This type learning, also known as single-loop learning, results in knowledge that is not embodied in the product (Maidique and Zirger 1985, Argyris 1999). The single-loop learning may be seen in terms of changing maintenance schedules or operating modes, developing workaround solutions etc. in order to avoid recurring in-service issues. Márquez and Herguedas (2004) analyzed the maintenance records for earthmoving equipment in order to determine root causes with the objective to improve the current maintenance processes. Although feasible, they noted a number of challenges such as ineffective maintenance data management and reduced knowledge in data processing techniques.

On the other hand, a number of literature papers have identified the importance of in-service knowledge to the improvement of design. Doultsinou et al. (2007), from a series of semi-structured interviews conducted in the UK manufacturing industry, identified the types of service knowledge related to tooling, spares, serviceability, maintenance and training. In studying the feedback of reliability information into development process of high-volume consumer products, Sander and Brombacher (2000) found that reactive loop between operations and development team does exist. However, they could not identify pro-active learning loops from the interviews conducted in a company. They noted a number of issues related to the culture and organizational structure that do not encourage, and worse still, may impede aspirations of continuous improvement. They suggested improvement to business processes through promoting communication and improving closed-loop information flows between departments. From case studies with three companies, Fundin (2003) also found that none of the companies actually learn from feedback information to inform new product developments. The feedback systems (customer feedback systems and codified and personalized information provided by service personnel) at best were used to improve current product development processes. Busby (1998) conducted both structured and semi-structured interviews on feedback in design and identified problems associated with it. Their observations included informational, motivational and organizational factors that make feedback problematic and difficult. Although opportunities for learning have been recognized in addition to business advantages (Tan and McAloone 2006), methods for utilizing information and knowledge feedback from the later life cycle phases to impact the engineering activities have been limited in the literature. A number of observations that are critical to the effectiveness of information reuse have been made (Goh and McMahon, 2009):

- *Incentivize the people to capture information effectively.*
- *Points of capture and reuse must be embedded within work processes to ensure effectiveness.*
- *Adoption of formal taxonomies (or controlled vocabulary) and standardized information structures and representation to improve reuse.*
- *Improved retrieval and organization of information to add value to intellectual asset.*

Information reuse occurs when information is assimilated and used in a new application and also, subject to some processing, yields useful new insights and knowledge. In developing approaches to facilitate reuse of in-service records in an aerospace company, our experience shows that greater use of structured records, controlled vocabulary and taxonomy is fundamental. For example, (Wong et al. 2007) employed an ontological approach to organize service information to support the ability to make inference between design and in-service outcomes. A number of statistical and data mining techniques can be employed to analyze and reuse data or information collected from in-service to make useful inferences (therefore to facilitate knowledge discovery). The next section of this paper will discuss how BIM could be used to facilitate information reuse to support life cycle decision making, against the fragmentation of construction industry that leads to communication barrier to the retrieval of design information between designers, clients and facility end-users or Facility Management (FM) personnel.

3 CONSTRUCTION INDUSTRY FRAGMENTATION

In construction industry, since early 90's it has been becoming highly fragmented (ILO 2001) with a diversity of increasingly specialised roles. The nature of a construction project that consists of thousands of companies working independently, which inevitably can cause some negative impact for end users and the industry mostly (Eastman et al, 2008). An essential example of a fragmented industry is the rare involvement of FM during design. The FM often inherits the building only after completion of the project, despite possessing valuable knowledge and experience regarding end use (Wu and Leifer, 2006). This often results in overlooking valuable knowledge and experience and missing the opportunity of transferring these knowledge and experience as important information to key stakeholders at design stage, such as clients and architects. The design stage of a project is noted as the most important life cycle phase, however in effect the fragmented nature of the industry often prevents collaboration with FM (Wu and Leifer, 2006). A significant aspect relating to fragmentation, is the 'over the wall' syndrome (*Figure 1*), "*whereby professionals who are involved in downstream activities (e.g. contractors) are usually not involved in 'upstream' decisions (design) that are passed onto them over the 'wall' of separation between those disciplines*" (Kamara et al., 2002)

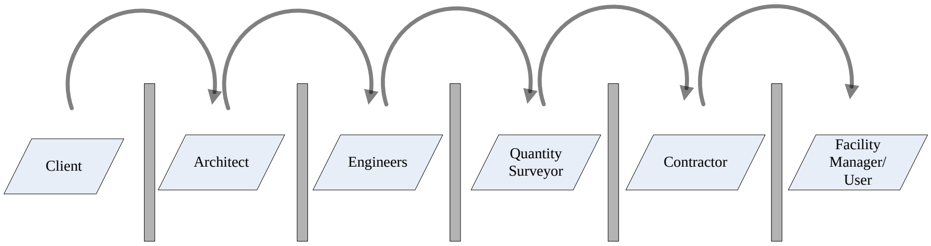

Figure 1 Over the wall' syndrome

The high level of fragmentation within the industry often leads to inadequate communication and a lack of data interoperability, which is regarded as inadequate information/ knowledge management during the inconsistent construction process. Though there has 25 years development of digital design system, such as CAD (Computer-Aided Design) , 71% of documentation of building project is still recorded or presented on paper-based (Lorenz, 2006). Although the lifecycle of a building, very much linear process, paper format documentation has become a problem for communication in contemporary construction projects, where project deliverables are handed 'over the wall' with a lack of integration or collaboration between disciplines in each phase (Eastman et al., 2008). The interoperability of data allows critical information to be exchanged seamlessly between relevant participants (Lorenz, 2006). The technology exists for the interoperability of data, however the short-term commitment of relevant professionals to the life cycle of a building proves to be a significant hurdle (Lorenz, 2006). The underlying trend amongst these major limitations is a lack of collaboration, communication and data standardization.

3.1 Communication gap between design and end-use

The collaboration and communication between designer and client is central towards ensuring that the distinct interests of both parties are met and that successful project outcomes and client satisfaction are achieved. In various studies carried out in the early 90's (Kaya, 2004), researchers criticised the lack of thoughtful consideration in regards to the requirements of end users. Kaya (2004) suggests that little has improved since the early 90's and highlights the communications gap that still exists. *Figure 2* demonstrates the communication gap between user clients, paying clients and designers. The gap between the designer and user client often leads to a lack of occupancy consideration (Kaya, 2004).

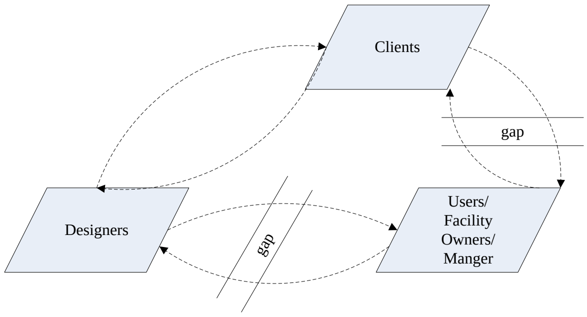

Figure 2 The Communication gap between FM and designers and clients

Furthermore, uninformed predictions of occupancy requirements for buildings result when “the end users are taken out of the demand-supply and user chain” (Kaya, 2004). Through a number of case studies Kaya was able to demonstrate the importance of occupancy involvement during briefing, claiming that the use of space becomes more predictable. The communication gap between designer and end user seems to be a problem that has been entrenched within the industry for many decades. The importance of end user participation seems to be apparent, however a level of fragmentation between various professionals seems to exist that helps create this gap.

In summary, the gap of communication between the designer and end-user/ FM often results in the barriers to designer capturing useful information from FM/ end-users for developing design information and to end-user/ FM retrieving design information for improving operational and maintenance service. Up to date, computer aided design technology has been developing with the aim of filling the gap and breaking down the barriers, including Building Information Modeling (BIM).

4 BIM FOR OPERATION AND MAINTENANCE

BIM (Building Information Modeling) is changing the way buildings are designed and constructed, in other words, this technique is changing the way buildings are operated and maintained. BIM is intended to be “a breakthrough in individual and industry transformation that embraces and facilitates "innovation, integration and collaboration. Our challenge is to integrate a collaborative innovation culture” (Tang, 2012). There are substantial interests in the construction industry revolving around the use of building information for facilities management; however, there are also some concerns of how it really works and how the benefits of application of BIM bring to facilities management.

The application of BIM facilitates storage of semantic information about a facility, which have been well identified by designers, engineers and constructors. Although the opportunities for BIM leveraging the benefits of facility management are attracting industry attention and interests, its application during building operation and maintenance stages are far lagging behind its implementation at the design and construction stages. Recent research and studies in the AEC (Architecture, Engineering and Construction) industry show they are experiencing savings at the early stage of building facility lifecycle, along with fast-track in delivery and much less change of orders through the application of a virtual building modeling and analysis (Smith 2007; Valentine and Zyskowski, 2009). Therefore similar opportunity for greater saving should be extended to the operation and maintenance stages (Smith, 2007).

Establishment of BIM proposes to provide a reliable facility information database and integrated views across all facility systems, through which facility personnel can retrieve and analyse information at every individual process and at the whole building level. BIM, compared with traditional data representation format (e.g. paper, 2D drawing, 3D CAD), provides all building information in one model, the storage of information in this manner helps integrated views among multi-discipline stakeholders, such as owner, architect, engineer, quantity surveyor, contractor. The capability of BIM providing 3D spatial information of a building and its systems enables it to bolster visualisation and spatial analyses of numerous maintenance activities taking place in a facility. This scope is hard to be performed with a traditional data representation approach.

The functions of BIM also support capturing and transferring facility information from design and construction stages to operation and maintenance stages. Currently, some commercial building management systems have been developed, such as CoBie (Construction-Operations Building Information Exchange), where allows facility information to be transferred automatically from BIM system to other Computerized Maintenance and Management Systems (CMMS) or Computer Aided Facility Management Systems(CAFMS). Basically, CoBie creates a platform for architects, engineers, contractors and manufacturers to input data with a computer interpretable format at the early stage of a building lifecycle when it is established. By this means, information users who are applying the same data at downstream that do not need to recollect or recreate the necessary facility management information (East, 2007). Furthermore, COBie supports facility information export from BIM, such as maintenance plan and system instructions with a spreadsheet format, and then importing to other computerized systems, like CMMS or CAFMS (East et al., 2009). Through the application of COBie during operation and maintenance stages, it mitigates necessity of recapturing, recreating the facility information by architects, engineers and contractors, it minimizes the needs of converting information formats for diverse information users (Gallaher et al., 2004). As a result, it creates a potential of a huge savings during operation and maintenance stages.

Currently, BIM as a building information processing tool, its benefits for facility operation and maintenance are compelling, but as the key component of BIM- “Information”; which is rapidly expanding demands of “data everywhere” or information overloads have led to a field consisted of interesting and productive efforts, but without a central focus or coordinated agenda (Franlin et al. 2005). The application of digital design tools, such as BIM breaks down certain information flow barriers and at the same time bridges communication between extended design, construction and operation and maintenance teams. However, during its application it is found that there are still some communication barriers among the stakeholders such as the designers, developers, planners and civil engineers on the deficiency of generating reliable information within and across project teams, when a mechanism for the justification (e.g. costs and benefits) on using BIM has to be provided (BuildingSMART 2010). Since a part of information, being used during operation and maintenance stages is inherited from design and construction stages. In other words, it is lacking of reliable information that can be provided to carry out an accurate cost estimating for facility management, which will be useful during operation and maintenance stages of a building lifecycle.

5 THE LIMITATIONS OF BIM ON OPTIMISED DECISION-MAKING

The understanding of the level of uncertainty in the available data, such as a cost estimate, is a significant factor in making optimized decision (Thunnissen, 2005), such as when the operators or users are choosing the solutions offered by various suppliers.

Thus, decision-making tools need to include uncertainties in predicted costs that arise during the building lifecycle (e.g. owing to technical, financial, timescale, and quality factors). Currently most of available decision-making tools are developed deprived from general probability theory, which propose to be suitable for particular scenarios in estimating uncertainty and its associated risk.

An understanding of uncertainty and risk was stated by Frank Knight and John M Keynes, social scientists, who differentiated the definitions between risk and uncertainty. In 1921 Frank Knight defined risk is concerned with the loss that might arise (e.g. cost, time, or performance) relying on whether a given case may or may not happen. Uncertainty is relating to cases which are sure to take place (obsolescence of equipment) but whose effect is hard to predict (e.g. the number of obsolescence cases over the lifetime of the building in service). In fact, uncertainties in cost estimating have been proved more difficult to manage (e.g. owing to obsolescence and supply chain disruption), if there is a lack of supply of the reliable information (e.g. complete, precise, correct information) as the input to be considered in a decision-making tool.

A major weakness of current digital decision-making tool in managing uncertainties for optimised decision-making during design, construction and operation and maintenance stages is due to the difficulties of retrieving high value, high quality and mature design information during the design process. These difficulties can sometimes be considered as a major insufficiency of existing digital decision tool, which leads to the disparity between the reality and the prediction or simulation of any digital building models (Moffatt and Kohler 2008). In other words, the capability of designers to retrieve and utilise information is critical to the outcome of a project in a design process. The volume of digital information has indeed been increased substantially; abut the existence of immature information (Hanssen 1997, Helms 2000) can confuse operators at operation and maintenance stages, and thus causes an improper decision being made that could cause fatal consequences. On the contrary, the provision of mature information can support designers make effective decisions in avoidance of adopting any unstable, imprecise and incorrect information that can facilitate effective information management.

6 THE CONCEPT OF INFORMATION MATURITY AND ITS VISUALISATION FORM

As mentioned previously, the generation of informed decisions at every individual stage is critical for the success of a construction project. The generation of informed decisions cannot be done without a good understanding and management of uncertainties existing at each stage of a project lifecycle. The concept of information maturity was developed by Zou and Tang (2011) with the purpose to satisfy this need. This concept highly promotes co-operative design and design collaboration at conceptual design stage, and is greatly functional on this basis and on the ground of application of modern digital design tool such as BIM.

6.1 The interaction and information flow between/ among the project stakeholders

Design collaboration and the associated characteristics may help to bridge the gap between the design and end-use of buildings. Building Information Modeling (BIM) and collaborative briefing are both recognized as collaborative platforms as discussed at the early part of this paper. The process of collaborative concept can assist BIM's application to collect and analyze information for the purpose of accurately communicating and documenting the clients' needs and requirements (Kelly et al. 2005; Yu et al. 2006).

Traditional approaches of briefing design often are not able to accommodate clients' need, generally lead to a lack of consideration about the end-users and the lifecycle of the building (Kelly et al., 2005; Sanoff, 2000, 2006). One of the main reasons this insufficiency is the fragmentation characteristic of construction industry throughout the construction process (Kaya 2004). Kelly et al., (2005); Sanoff, (2000, 2006) also claimed that if building end-users are more actively involved in the design and management process of the project, the more support of built environment can be provided to occupants. Kelly et al., (2005) moreover stressed that the involvement of FM during concept design is critical for the facility's adaptability concerning future change, in this paper which inevitable for the accommodation of the interaction of concept of information maturity on this ground (see Figure 3). As the development of the communication of mature information on the basis of this ground, it inspires the project participants to contribute to the project design at concept stage, in particularly, it takes value on the end-users' need and the contribution of FM's expertise and knowledge. It is an approach distinct from the traditional approach, high interactive between multiple participants and working on the same platform using the same lens to look at a project. With addressing this, it supports effective information exchange for collaborative design, it is beneficial to the design and the stages after, such as the construction and the operation and maintenance stage.

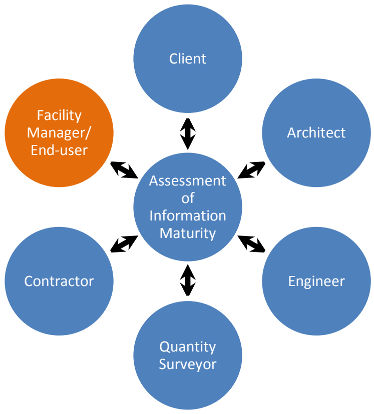

Figure 3 the interaction and information flow between the project stakeholders under the concept of information maturity

6.2 The characteristics of advanced information

There are various descriptions from diverse fields in terms of good information that have been identified, which information facilitates effective information management, enables to undertake the most advanced decision, management and planning. In recently, during the application of existing Information and Communication technology (ICT) system (e.g. internet, intranet, collaborative tool, Building information Modeling), it has exposed little or more problems regarding the credibility, quality or reliability of information contained in the systems.

In Autodesk Building Solutions Whitepaper, it stated that there is a need for well-developed practical strategies among the BIM model components for the purposeful exchange and integration of "meaningful information" (Bernstein and Pittman, 2005).

In design management, as the need of delivering the design concept to the end product in the order of satisfying clients' requirement, for which need it requires "the provision of accurate, fully co-ordinated and complete information" (Gray and Hughes, 2002), which information must be transferred to or exchanged timely between the specific project stakeholders who will be in charge of making decision on a particular part of a project (Gray and Hughes, 2002).

The UK Government's Office of Government and Commerce stressed the importance of provision of "firm information", whose well prepared in design brief is the basis of the subsequent project actions, making significant influence on the results of the outputs of these actions, i.e. Production Information, Tendering and construction work etc. In the BSI BIM Strategy Report-BIM Task Group 2011, it emphasizes in a design non-prescriptive the "timely information" must be made available during its creation, exchanging and transferring within BIM's implementation to enable correct decision to be made. The design decision made by the exploitable "timely information", as a key driver, can help improvement of the building performance, in terms of two variables identified: Whole Life Cost and Carbon Performance. This is important, as by the provision of these information, a more effective and transparent design decision making process can take place by removing the needs of making assumptions which mostly produce uncertainties and additional risks for the project during and after design stage (BSI BIM Strategy Report 2011).

In summary, the good information can be characterized as reliable, quality, credible, "meaningful", accurate, co-ordinate, complete and timely information. These are the characteristics that information maturity should include.

6.3 The working definition of information maturity

In construction, there is an urge of "Right information needs to be available at the right time in the right format to the right person" (Winch 2002). The terms "right" highly equate to the level of "mature" information, which has a converse meaning against immature information (Hanssen 1997, Helms 2000, Grebici et al. 2006). Immature information has been defined as tentative, untested and possibly incorrect information (Hanssen 1997, Helms 2000, Grebici et al. 2006). In construction, the lean management model proposed by Sacks and Goldin (2007) suggested that this method facilitates the replacement of a fixed activities network to be scheduled for the purpose of works' completion dynamically. In order to achieve this goal, decisions being made during operation and maintenance stages should be carried out according to the maturity level of the client's, designer's and facility manager's to various options. The definition of information maturity was defined by (Zou and Tang, 2011), which is concerned with certain information (e.g. stable, precise and complete) that can be passed on to the next stage of a design process with the least possibility and probability of re-iterations and/or other associated uncertainties, which can cause significant impact on the collaborative design decisions among different designers. This definition was shaped not under a scope of design process only, but also it is a term that can be extended to other stages within lifecycle of a building and it benefits the design decisions being applied at operation and maintenance stages, e.g. it enables the level of information maturity at cost estimate among various design options to be assessed at the early stage of a building lifecycle. For such benefits, it exposes a need to develop an information evaluation tool, in order to assess the associated information maturity level of decision options over a building lifecycle.

6.4 Rationale of assessment of information maturity

The proposed Information Maturity Evaluation Assessment Tool (IMEAT) is an information evaluation assessment tool, based on a number of information attributes, was firstly developed with the use of Bayesian Network Theory and conditional probability statistical data (Zhao et al., 2008). This assessment system impacts on existing practice from different stakeholders' perspectives (designers, engineers and information managers) on the determination of high value information so that the maintenance cost of archiving large amount of information can be decreased in both sectors. An in-depth comparison between leading engineering and construction companies was undertaken to understand the issues and challenges of information evaluation in these two sectors (Tang et al., 2010).

6.5 Presentation of information maturity in "tube map"

One of the critical development of information maturity is its unique demonstration approach, by which it visualises and interprets its meanings to users. As an example, Figure 4 demonstrates the idea that information maturity for decision-making derives from the design of "tube map". The design of the "tube map" is created to provide the most stable, precise and complete information for passengers to make their journeys easier. It is a visual format providing information for the passengers; no matter where their journey commences, terminates or passes from one stop, the information on the "tube map" provides the information enabling users to decide on the fastest route for the journey with the

least distance to the destination. In reliance with this principle, design of the “tube map” aims to help decision makers generate optimised decisions, different components of a building are divided into a number of packages, various design options within an individual package are to assess on their information maturity separately. The final decision will be taken in accordance with the one whose level of information maturity is high beyond the acceptance line (the horizontal red dotted line) as well as consideration of stakeholders’ preference, project goals, and expenditure (life cycle cost).
In other words, the optimised design decision should be selected according to which has the highest information maturity level, concerning highest Probability of Certainty, least Uncertainty and Risk, the most importantly, the presentation of Probability of Certainty should have taken the participants knowledge and expertise into account.

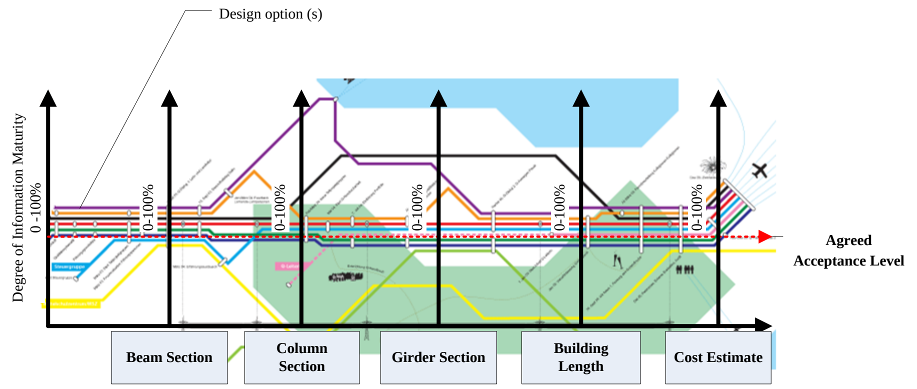

Figure 4“tube map” concept for assessing information maturity during lifecycle of construction project

In figure 4, the horizontal axis places various building design packages, such as beam, column, girder and so on; the vertical axis shows the variation of information maturity level, whose volume is increasing from bottom to the top. Each colour route represents an individual design option. Every design option within each package has an intersection between its route and the light blue dotted line of each package, this point has a related reading on the vertical axis which represents its level if information maturity. For example, in the Cost Estimate section, there are two lines beyond the red horizontal dotted red line, over the minimum information maturity level to be accepted. One of them is orange, the other one is green. It shows that the orange route has a 99% information maturity level higher than the green route which is with a 80%. This means the orange option has higher probability and certain than green one, and less possibility and uncertainty than green one as well. Additionally the level of information maturity is concerned with the orange option that has high information quality and value than green. Therefore, it reflects that the result of cost estimate for orange option is more reliable and accurate than the green option.

7 CONCLUSION

With the provision of an information maturity map that provides a more comprehensive information visualization to show the in-service knowledge for operations and maintenance, the costs and benefits analysis could be done a lot easier. Moreover, the development of BIM applications over the life cycle of a building should not be dominated by a single professional institution or representative body - instead these standards and protocols should emerge from a true cross-industry discussion. Leadership must be provided from the top-down, from public and private sector clients, from government, institutions and from leading-edge organizations to ensure that the inherent intelligence in BIM is fully exploited in future buildings to deliver truly effective virtual information models.
The development of the concept of information maturity, it has the potential to break down the communication barrier to information flow, information exchange. Its employment can provide the decision making support for multiple participants in construction project at concept design, in particularly while applying state of art digital design tools, such as BIM. This concept not only increases interaction between participants, which assures the top-down information flow that Clients’ requirement can be addressed in the end product, but also encourages bottom-up information flow, which enables the needs of end-users and the expertise and knowledge of FM to be considered while a conceptual design of the project is developing. These both are reflected while the presentation of a design optimised decision as Probability of Certainty by assessing information maturity, which is

consisted of input of knowledge of diverse specialized parties and more importantly, a consensus made between participants toward the final design option selected.

The concept of information maturity with end-users and FM involvement in the project at early stage will bring the following benefits:

- The concept of information maturity provides a platform for the communication between Clients and FM and architects and FM, breaks down the barrier to information flow between them.
- FM and end-users' requirement and knowledge can be engaged in design process while developing a concept design
- The presentation of information maturity is an envisioned approach, which provides convenience and increases accuracy of the information exchange.
- By this open communication platform, FM can realise the changes incurred during the construction process, capturing their design information maturity, which enables associated solutions or plans against the changes to be carried out accordingly at the earliest time.

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