A Conceptual Decision Making Model For Design Information Maturity

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Abstract

The efficiency of a design process has a close relationship with effective information management. However, the increasing volume of digital information makes effective information management in construction organisations more difficult, in particular on retrieving high value, high quality and more importantly mature design information when it is needed. There is an urgent need to develop a tool that can assess or indeed increase the maturity of any design information for the ease of storage, retrieval and reuse with suitable information management tools. The engineering industry has been striving for this for many years, they have been attaining success on capturing design rationale. The aim of this paper is to demonstrate how the concept on capturing design rationale from the engineering industry and its tool called design rationale editor (DRed) can be incorporated as a new tool called DRed-based decision making model that can be used in the design stage of construction. It can capture and evaluate design rationale and hence help designers to make better and effective design decisions through the increased design information maturity. The definition or concept of information maturity in construction has indeed yet to be explored and will be included as a major future work, others include to demonstrate how design rationale can be captured and edited along the digital life cycle through the use of real case studies, and to address any issues and limitations on its applications in the industry.

Keywords: Design, decision-making, information management, maturity, modelling.

1. Introduction

The challenge in a construction project derives from different organisations relying on a large number of various interrelated data sources, without a proper way or tool to manage these sources in a convenient, integrated and principle norm (Franlin et,al 2005). In other words, a clear and concise understanding on the data or information received between different stakeholders such as designers, engineers and other construction professionals at the conceptual design stage are one of the key element to a successful project, as good design decisions can be generated in an early stage of a project (Raisbeck and Tang 2009). Indeed, “Good design decisions at an early stage can demonstrate a constructive approach to planning requirements and greatly reduce the risk of costly later revisions.” (RIBA 2011). Kats (2003) proclaimed that a slight increase in the upfront cost of 2% is to support sustainable design, which on average, leads to a building life cycle saving of total

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construction costs approximately 20%, which is equal to the initial investment of the construction project more than 10 times. Throughout the life cycle of a construction project, key decisions made at the design stage of the whole design process can generate significant impact on the product the way to be produced and marketed. These design decisions to be generated at the design stage have become more complex within the contemporary construction projects because the solution sets and information flow are becoming highly dynamic. In addition, the “process of elaboration and refinement of issue, alternatives, and decision criteria itself is an important component of the problem” (Tiwana and Ramesh 2001), which concerns not only the conventional objectives (cost, time and quality) but also the issues of environmental management and sustainable construction. Early development of design support systems (Adeli and Hawkins 1991; Berraris and Watson 1994; Kolodner 1991) are therefore conducted with the aim of assisting designers in the management of this extensive and complex information, and of providing some autonomous problem-solving abilities in the early design stages. Emphasis had also been put on providing more accurate and high value information for building performance analysis and evaluation (Klashner and Sabet 2006).

In recent years, the 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 Building Information Modelling (BIM) breaks down certain information flow barriers and at the same time bridges communication between extended design and construction teams. It is recommended to adopt BIM to meet the demand on “new levels of quality in construction and new services in order to deliver the 40-year carbon reduction programme” (BIS 2010). However, within the BIM 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). “Extrapolating from US derived figures, the net benefits of BIM to the UK would account for between £1-2.5 bn p.a. in the construction phase.” Commercial data from the UK construction sector also showed a consistent reduction of 8-18% of cost associated with design stages C to E of RIBA Plan of Work, including concept, design development and technical design, while the upside potential of saving could be as high as 40% (BIS 2011).

The difficulties of retrieving high value, high quality and mature design information during the design process 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). During the design process of a construction project, stakeholders’ decisions become highly subjective due to the increased problem complexity and additional project objectives (Nemati et al. 2002). 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; any characterised immature information (Hanssen 1997; Helms 2000) can confuse designers and result in the possibility of rework in the design process, and thus causes an improper decision being made that could cause fatal consequences. On the contrary, the provision of mature information can help designers make effective decisions in avoidance of adopting any unstable, imprecise and incorrect information that can facilitate effective information management.

The capture and evaluation of design rationale in the engineering industry have proved to be efficient on assessing design options (Bracewell and Wallace 2003; Bracewell et al. 2009). This technique can find out the reasons of selecting one option over another. It is said that the implementation of this technique offers not just the evaluated decisions only, but also provides visualisation and justification of any arguments among immature design decisions, and can possibly make a significant impact on a collaborative design process. This paper demonstrates the use of capturing and evaluating design rationale in the engineering industry or its tool called design rationale editor (DRed), in particular on how they can be incorporated as a tool (a DRed-based decision making model) to assess the design information maturity at the design stage of a construction project, in the end helping designers and other construction stakeholders to make better and effective decisions in a digital environment. The three major research questions are:

- What is information maturity in a design process?
- How can it be increased through the evaluation and capture of design rationale?
- Why is it important to adopt this developed model on collaborative design in construction project e within design stage?

2. Nature of information in construction

Construction is a process which consists of several identifiable stages i.e. preliminary design, conceptual design, detail design and construction (RIBA, 2011). These stages are too broad and consist of many sub stages dealing with lots of information in order to achieve completion of every stage. Hicks et al. (2002) said information is defined in two classes in engineering design: formal information (provides a specific, structured context and measure) and informal information (encompassing unstructured context, measure and description). Tang et al. (2007, 2008) and Zhao et al (2008) defined that the hierarchy consists of three stages in two main levels: recorded and personal (See figure 1). In analogue to the "Iceberg model" defined by Quintus (2000) that illustrates knowledge as explicit, implicit and tacit. Tang et al. (2007, 2008) defined "knowledge can be explicit (recorded or codified in some way), implicit (in the mind) or even tacit (cannot be recorded and codified in any format). Explicit knowledge can be stored as information".

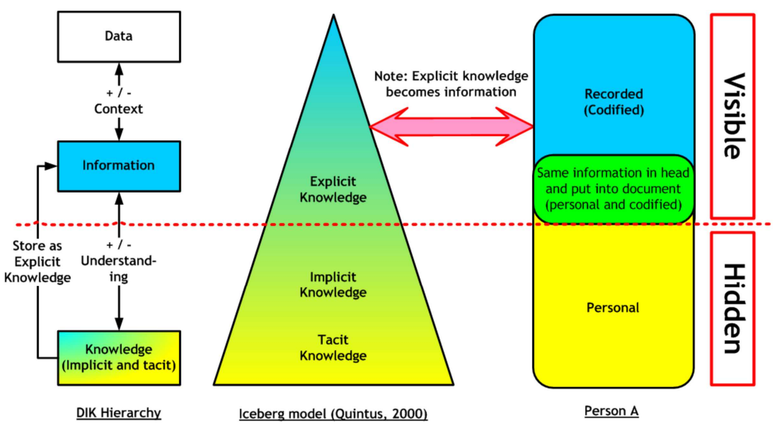

Figure 1 Codified and personal knowledge (Tang et al. 2007, Zhao et al. 2008)

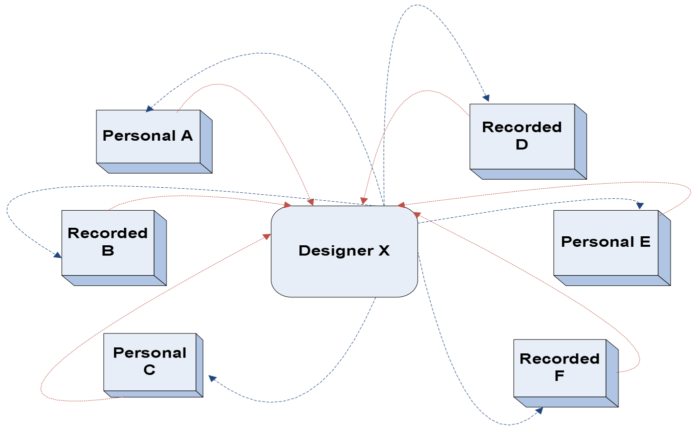

Figure 2 Personal and recorded information flow between stakeholders in construction

Designers are dependent on each other for information exchange: both recorded and personal. All design information is uniquely designed, structured and applied to complete a task in a project. Communication is a multidimensional flow of information exceptionally as shown in figure 2.

3. Nature of information in construction design process

Design is often described as a creative activity that is hard to support with exact science (Moran and Carroll 1996). A design process can be viewed as a set of inter-related activities, by different internal and external activities which are performed to increase knowledge, and increase certainty in relation to the design solutions. For example, designers need to cope with different requirements such as the size of beam, pillar, and space inside of the building to adapt different uses and scopes of the project. When a basic understanding of the task is achieved, designers have to choose appropriate methods. After that, when the decision on how to proceed is made, its evaluation will be taken place using tools, for example, BIM, CAD drawings and finite element analysis. Whether the design process is starting over again or not is subject to the decisions made satisfying the design requirements, otherwise a re-evaluation is necessary. Conceptual design process can be characterized by a series of actions including formulation, analysis, search, decision, specification, and modification. The actions characterised above at the early design stage of a project are shown to be highly interactive many years ago (Jense and Tonies 1979). In fact, the use of information management and technology tools on facilitating effective information management still need to be improved. The introduction of BIM helps address the iterations of redesign in order to refine or amend the functional requirements, design concepts and financial constraints of a project.

As the project moves on from conceptual design to detailed design, the design process becomes more structured. In the stage of detailed design, they are represented by specific steps with less random and uncertain design interactions. Since design problems are large and complex, they have to be decomposed to yield sub-problems in order that which the size can be solved. The integration of sub-problems often creates conceptual conflicts that must be identified and corrected. E.g. Darlington et al. (2008) discussed the foundations of a framework for information evaluation. It also identified and defined a number of important variables e.g. the objects of evaluation, the high-level operational contexts in which evaluation takes place, the motivations and post-evaluation actions associated with these contexts and how they and information entity attributes can be mapped on to the information life cycle. This leads to the questions of how good the value and quality (Tang et al.

2010) and more importantly how mature the design information is in order to avoid unnecessary design reiterations. A decision making tool is therefore needed to measure and increase design information maturity in a design process.

4. The concept of Information Maturity

“Right information needs to be available at the right time in the right format to the right person” (Winch 2002). The term 'right' highly relates how 'mature' the information is, which has a converse meaning against immature information (Hanssen 1997; Helms 2000; Grebici et al. 2006). There is little literature defining the maturity of information where immature information is defined as tentative, untested and possibly incorrect information. In construction, the lean management model proposed by Sacks and Goldin (2007) presented 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, the schedule of the finishing process should be done according to the maturity level of the client’s and designer’s changes to design. In construction production phase, maturity is measured according to the state of readiness of a work package or a task (Sacks et. al 2010). Watson (1998) stated that in construction the accumulated data becomes information when it is mature enough and ready to be passed on from one discipline to another. Immature information will be flown from one stakeholder or knowledge broker to another. In this paper, in simple terms, ***mature information is defined as 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.*** The demonstration of the idea of information maturity for decision-making derives from the design of “London tube map” which is shown in Figure 3 (a). The design of “London tube map” desperately is keen to provide the clearest information for passengers, no matter whoever originates, terminates or passes through from one stop, somehow a user can find out the fastest route to the venue easily with the least distance. In terms of the application of this “tube map” idea in assessing the level of information maturity for making the optimised decision, the design process as a whole will be fragmentised into a number of design packages, design options generated within each package will be assessed towards its information maturity level respectively, eventually the final optimised design decision will be made combined with the consideration of stakeholders’ preferences, project goals and expenditure. The concept can be interpreted in Figure 3 (b) about how the information to be assessed in relation to its maturity level.

The parallel coordinates plot as shown in Figure 3(b) provides an alternative view of the design space. The ranges of information maturity level for each design package are represented as a vertical axis (increasing from the bottom to the top). Each colour line represents a design option. As shown in the figure, the lines on the top over the red horizontal axis represent three design options (purple, red and blue) with relatively more mature information towards to the right hand side of this maturity map. Within all travel routes or design options, it takes into account all decision-making criteria that encounters certainly, uncertainty, risky, possibility and probability issues when assessing multiple design options. The point where each line intersects a vertical axis represents the level of the corresponding information maturity criterion of a particular design package. Visualising results in this form allows the designers to identify quickly the range of information maturity level. For example, it can see that the best designs at beam section have higher volume of information maturity level above the red horizontal axis. The best design option for instance varies after passing through the entire column section, of which its maturity level is going down obviously. It indicates that the design options for column have high influence on the design performance.

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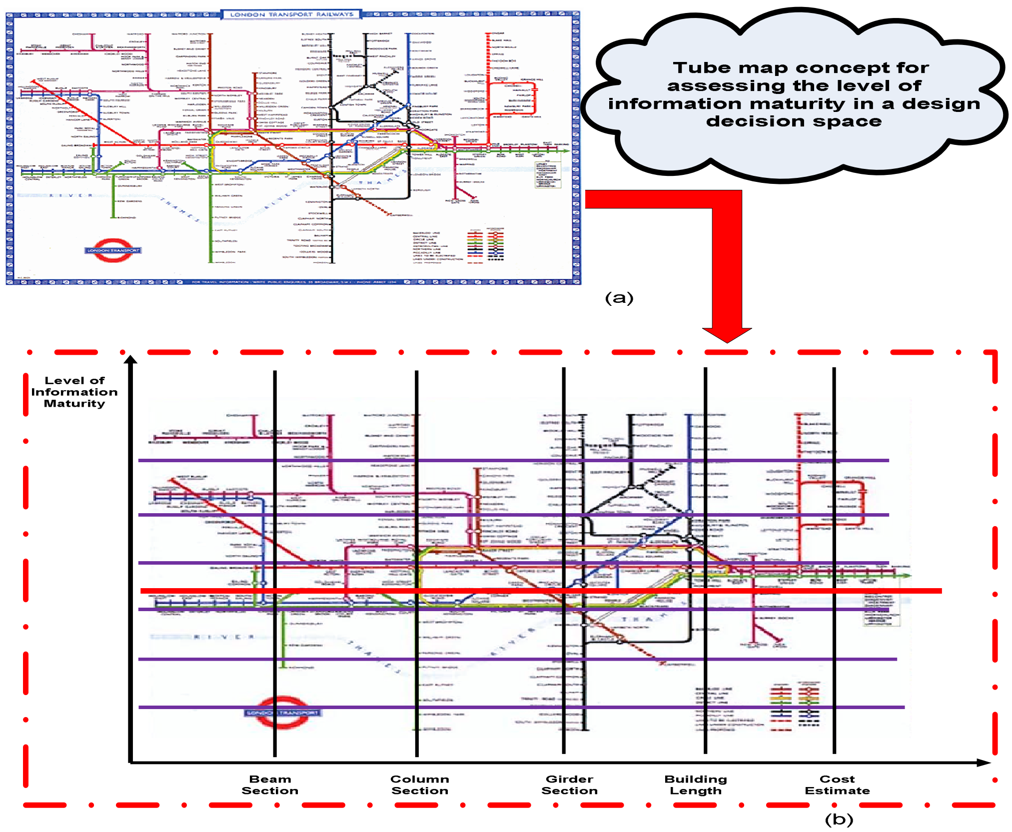

Figure 3 "Tube map" concept for assessing information maturity in a design decision space (Source from Google images: http://www.google.com/imghp)

In other words, the expected and targeted certainty among designers and other stakeholders on different design options (uncertainties) are lined up so that mature information is provided as an input certainty for the stakeholders in the next stage of the project life cycle. For instance, the optimised design option would be interpreted as the mature one with the highest level of information maturity.

5. Design Rationale Editor (DRed)

The advantage of an accurate design maturity assessment facilitates less re-design, the organisations can measure their designs' maturity in process (O'Brien and Smith, 1995). The understanding of designers' interactive processes and thinking should bring up methods for maturity assessment which allow decision-makers and stakeholders to forecast the level of risk on releasing a design option (O'Brien and Smith, 1995). Cambridge Engineering Design Centre has carried out the research into information capture, storage and retrieval for 20 years. Lee (1997) did a review about the advantages on the available of design rationale capture tools while the pioneering work dated back to 41 years ago by Kunz and Rittel (1970) who developed Issue-Based Information system (IBIS). A tool called Design Rationale Editor (DRed) has been developed to assist the designers to structure their design thinking, to capture their rationale, and to reduce the need for paper work (Bracewell et al. 2009). DRed has been popularly adopted in Rolls-Royce in the design stage of production. The aim of this paper is to propose the use of this tool as part of the tube map idea and extend the development of it in relation to the definition of information maturity in construction, not only to capture the design rationale but also to increase the design information maturity. Once the design rationale comes into the design process, which becomes an important factor when making a final decision on which design option works and what does not. The major difference on using DRed is to "understand design rationale for taking design decisions by weighting multiple aspects together" in three stages of the traditional design process in engineering. It is a linear process that consists of design task, its creation and evaluation (see figure 4).

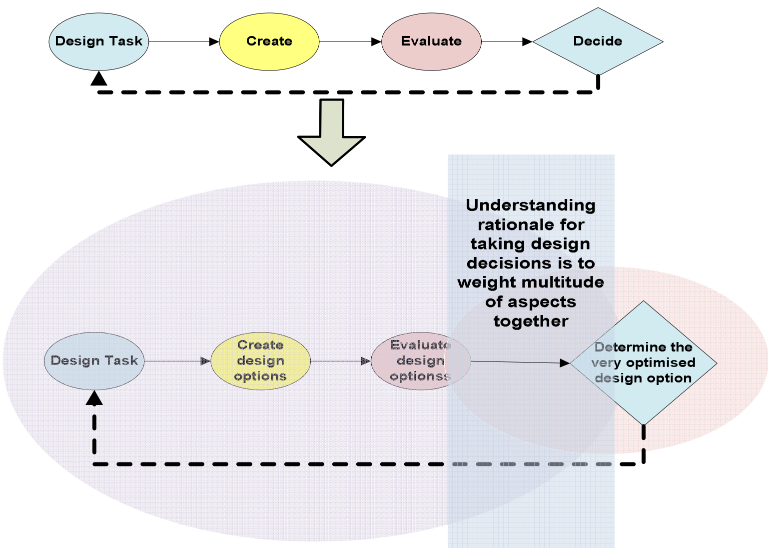

Figure 4 Traditional design process in engineering vs the use of DRed in a design process

DRed as a design rationale capture tool its potential has been proved to be able to improve the design process. Lee (1997) listed the advantages on using DRed that include the provision of better support for re-design, learning, reuse, maintenance, documentation, project management and collaborative work. It also allows "designers to record their design rationale at the time of its generation and deliberation". Functionally DRed can be complemented with the analysis of BIM, CAD tools, Office, web and communication applications of which designers use to support their day-to day activities. As DRed facilitates the creation of an optimised design portfolio which is structured according to the dependencies in the design rationale, through the capture and evaluation of design rationales, it can finally increase design information maturity routinely in a design process.

6. A developing DRed-based decision making model

The design of a new facility often begins with the search of most relevant information for a design. In order to support collaborative design between designers, this section shows how the DRed can be incorporated as a tool to evaluate and capture design rationale of designers and hence to increase the maturity of design information in a design process. Obviously the relationship between designers and other stakeholders, such as clients, engineers, contractors, can be realised as both information provider and information user, so information maturity must respond to an agreed level of certainty between designers and other stakeholders. Figure 6 shows this proposed DRed-based decision-making model. The design rationale is displayed in a document "as a graph of nodes linked with directed arcs. The user creates the nodes by choosing from a predefined set of element types. The key element types are: issue, answer, and argument" (Bracewell et al. 2009). Questions to ask include:

- What design rationale is worthy to capture?
- In what form is it after captured?
- Once the design rationale has been identified, captured, evaluated and stored, how to share it with other for reuse?

As for the application of DRed, designers start on the basis of forming theories against the causes of the potential problems, and are keen to find out the evidence to support and object them. DRed can be used to capture the track of this diagnostic activity during its proceeding, and figure 5 shows the resulting chart with the diagnosis of changing curtain materials by the use of 'traffic-light coloured' system. All the elements in DRed chart are given a colour which represent the elements in various statuses. Decisions are captured by manual changes on the colour, for instance from red to green. The element with green colour means the designers are satisfied with the diagnosis result, which is precise, complete and correct (that is, mature) such as the issue "Design simplification weight and cost reduction" as shown in figure 5. Conversely if an element is not satisfied by the designers, it is marked as insolvable, which is displayed as red colour, e.g. the issue of "Risk of increased maintenance cost" in figure 5.

A designer's diverse assumptions are captured and evaluated as answered elements, which go up along the upstream routine until the ultimate issue is eventually resolved. For a successful resolution to a design issue that relies on the number of answers of sub-problems being accepted, it is said that the more number of answers of sub-problems being sorted out, the higher percentage of the issue has been resolved. Hence the maturity of that piece of design information increases until it reaches its optimised level (see figure 6).

Through visualising the design rationale, the developed model can:

- monitor the design behaviour through assessment and capture immediate design thinking,

- and improve the 'richness and clarity' (Bracewell et al. 2009) of recorded information non personal as shown in figure 1 and hence increase the design information maturity. It helps line up and liaise the targets and expected certainty between designers and other stakeholders (see figure 6).

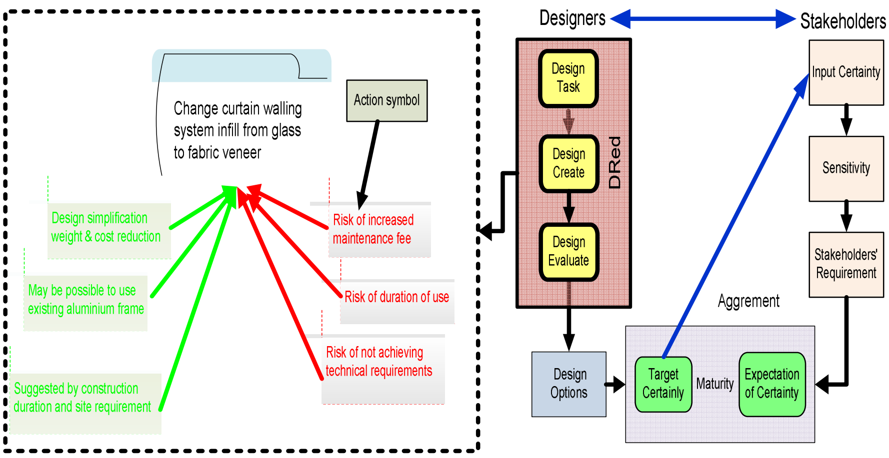

Figure 5 A demonstration of a DRed-based decision making model for changing curtain walling system in conceptual design stage

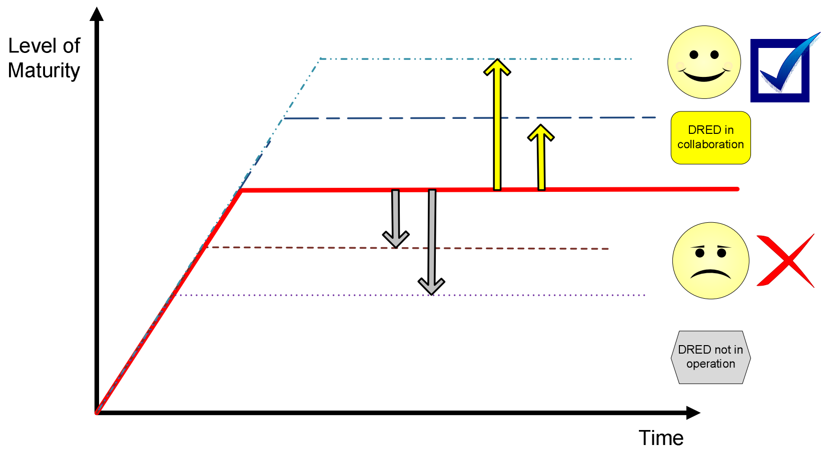

Figure 6 The impact of collaborative DRed on the information maturity of a design process

7. Future works

In this paper, the definition of design information maturity in construction has yet to be explored and will be included as the major future work, others include demonstrating how design rationale can be captured and edited along the life cycle in the BIM environment (e.g. through the pre-construction, construction, post-construction and facility management), by the use of real case studies. There is a need to address any issues and limitations on its applications in the industry, in particular:

- How should the design descriptions (in terms of richness of the recorded information) be associated with the levels of information maturity?
- Which attributes of mature information in each description should be included in the model?
- How can the measurement of future values of the information maturity be carried out?
- How should the design rationale evaluation be carried out with multiple designers?
- Which barriers have limited the application of this developed model, and how can they be overcome in the construction context?
- How does the model impact the design thinking and behaviour of designers?

Furthermore, acting too early or too late can turn a good decision into a mistake. This untimely information flow has been proved to affect the quality of decision-making in a design process (Whelton and Ballard 2002). The time of capturing design rationale needs to be explored in a greater extend. McKenna (1994) realised this kind of decision-making model as bounded rationality and suggested that it should include three investigation processes: sequential consideration of alternatives, using heuristics to identify the most appropriate alternatives, and choosing on the basis of the identification of the first acceptable solution.

8. Conclusion

Information is getting increase in the volume of digitalisation, while some of the intrinsic characteristics e.g. value, quality and as a whole the maturity of it needs to be explored in a design process. Particularly there is a need for a state of art construction form to maintain construction firms' competitiveness through assessing/increasing the productivity of designers or the costs and benefits of a design in a digital environment such as BIM. This paper shows that it is highly possible to develop a collaborative Design Rationale Editor (DRed) decision-making tool to facilitate designers in making effective decision in the design stage of a construction project. Through understanding the nature of information in construction reveals that the identification of mature (i.e. high value, high quality, least possibility and probability on design re-iterations or other associated uncertainties) information should be beneficial to bring out effective design decisions in the design stage of a project. However, the concept of information maturity in construction has not yet been explored. In particular, when facing uncertainty and design changes among designers and different stakeholders, the developed DRed-based decision making tool shows that it provides a systematic and informative way to show the optimised design decision through capturing and evaluating design rationale of designers, which is a concept adopted from the engineering industry. In conclusion, there is a need to apply the proposed model in construction to be embedded in the digital working environment, and hence to increase the information maturity level of design information among designers in order to facilitate effective information management.

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