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An Information System for Design Decisions in Hybrid Projects

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Abstract
Hybrid projects refer to existing buildings that are altered through major works to accommodate and/or enhance value, function and use. The result of this process is more than an extension but a complete hybrid building. A recently completed study on the effects of the lack of as-built information for design decisions in hybrid projects led to the development of an integrated information tool based on a requirements framework. The Hybrid Project Design Decision Tool – HybridDt was developed to integrate spatial and performance information and refocusing the value stream to enhance the making of design decisions for hybrid projects. This paper presents the information protocol which forms the basis of the tool and discusses an important functionality within the tool i.e. information acquisition, storage and use. Feedback from industry practitioners on the efficiency of the tool is also briefly presented.

Keywords
Collaborative design decisions, Hybrid projects, Hybrid buildings, Integrated information system

1. Introduction

A Design Decision Tool – HybridDt was developed based on the Hybrid Project Process framework. The purpose of the tool is to facilitate the acquisition and storage of as-built information as well as to provide an environment for proposing, monitoring, and implementing design decisions made collaboratively during hybrid projects. The proposed hybrid process framework defines eight important but reiterative milestones; outline appraisal and development plan, core team procurement, building performance evaluation, briefing development, design activity, planning and logistics, construction, evaluation and operations. The process commences by examining the existing building on four levels; spatial, organisational, productivity and use. This examination is carried out to acquire quantitative (measured) and qualitative (perceived) information that will influence decisions made throughout the building process. Actual building performance inevitably declines over time owing to a number of influences such as wear and tear, user abuse or misuse, climatic conditions, inadequate maintenance, and so on (Douglas, 1996). The examination should therefore include considerations prevalent in hybrid projects; the complexity of existing building and site (Petzold and Donath, 2004), the need for up-to-date quantitative 'as-built' information (Leslie and McKay 1995), feedback on existing and proposed building use, issues of constructability and layer interface (Nicolini *et al.*, 2000), distinguishing between function and functionality, conflict between value and resource, and increased risk and liability (Graves *et al.*, 1998). Each of these factors and sub-variables will influence what is measured and the level of implementation needed to achieve a lean and effective construction process.

The collaborative Design Decision Tool - HybridDt was created to provide a single view of the truth, based on the premise that ‘blind’ decisions will not be made if relevant information are in place. This translates to mean more information, less uncertainty and therefore, less risk. Findings from research on which this tool is based demonstrated the importance of *both* qualitative and quantitative information for making design decisions about hybrid buildings. More importantly, it was found that design information has to be contextual and of suitable quality to be beneficial to the design process. However, information systems currently used for design collaboration and management fall short of successfully defining relationships among various strata of information. This shortcoming is mostly because the manner in which design information is presented (often graphically), does not readily support the making of qualitative design decisions collaboratively. At least, not without the need for further intuitive, representational or presentational techniques. Hence, the need for a functional tool that promotes integrated and collaborative approach to making design decisions among the project team.

The ability to store, locate and transfer information from a singular source is not sufficient for making design decisions; an information system to help correlate this information is needed. For hybrid projects, information is more beneficial if a relationship is defined. Stacey (2005) suggested that in the late 20th century, the role of the architect had arguably been eroded by fragmentation and specialisation. However, the same author stated that creating architecture is not just problem solving, it is about invention and interaction. The HybridDt tool promotes this by presenting integrated information in an open and accessible manner. Integration is achieved by displaying how each drawing, detail or report relates with design and performance criteria or variables. Design priorities are then pre-set using opportunities and constraints presented by the existing building.

Making requirements relationship visible to the project team, including the client, during the evolution of design concepts will aid informed, yet collaborative decision making by all parties. Conflicts will immediately be visible and corrected before design is finalised. An ongoing dialogue among all the parties will also encourage cooperation and less adversarial relationships among the project team. Compared to collaborative tools that were designed to improve processes and flow of information, the design decision tool integrates information to further aid interpretation and use. Effort was also made to make design and construction activities seamless, with the need for design improvement and related change management reduced as the project progresses.

This paper presents an overview of the development process. It also describes important functionalities of the tool including; information – acquisition, integration and storage, task management – allocation, support, logs and monitoring, collaborative decision making, process efficiency – risk and value identification, monitoring and delivery.

2. The Design Decision Tool – Development

The objective of the design decision tool is to provide multiple functionalities without direct intent. Capabilities of extranets, data warehouses and other collaborative tools are therefore inherently provided. In addition to these, information is relative and integrated, thereby minimising the need for tacit, intrinsic processing of information. Instead, it promotes open communication among team members and transparent decision-making, which will be beneficial to the design process as a whole.

2.1 Choice of Information Systems for Reuse and Integration

A number of data management systems were explored during the development of the tool. The first step was to examine practices in the information sciences, most specifically, information reuse in software development. HybridDt is an information management system, which stores and visualises multiple data formats rather than translate and utilise them. Therefore, the focus of the tool was more on information integration and management systems rather than software applications.

Table 1: Correlating Requirement Management with HybridDt Functions (after: Kamara *el al.*, 2002; Lee *et al.*, 2005)

Requirement management Process	Description	Typical Design and Construction Activity	'HybridDt' functionality
Requirement definition	A careful assessment of the needs that a building is to fulfil and involves context analysis (justification for a building project), functional specification (what the building is to be) and design constraints (specification of how the building is to be constructed)	Briefing	Existing building information, Building performance evaluation, Briefing documentation
Requirements analysis	The processes of understanding and recording (or representing) in a clear form, the requirements or needs to be met by the design and construction of a building. It involves the interpretation of customer needs and deriving explicit requirements that can be understood and interpreted by people. Requirements analysis results in specifications that are represented in documents, drawings, and contextual data	Briefing	Building performance evaluation, Briefing documentation, Design activity – Data repository matrix, Project Manager, Design proposal and design review
Requirements tracking or traceability	The continuous interchange and negotiation within a project team regarding conflicting and changing objectives (Fiksek and Hayes-Roth, 1993). It also refers to the techniques used to represent relationships between requirements, and the design of the building		Design activity – Project Manager, Data repository matrix, Design proposal and design review
Requirements verification	The procedure for determining whether a product design complies with a designated set of requirements.		Design activity – Project Manager, Design review

With the understanding of a typical life-cycle information system and armed with concepts from software reuse systems, an information integration and management system based on the principles of Requirements Management (RM) for hybrid projects was developed. This system, as described by Lee *et al.* (2005), was integrated with Product Data Management (PDM) capabilities (Svensson and Malmqvist, 2001). RM ensures that customer wants are defined precisely, and that the solution determined efficiently meets those requirements (Dick, 2004). RM stems from requirements engineering. Like other product or manufacturing database systems such as product data management (PDM) and enterprise resource planning (ERP), a requirements management (RM) system integrates information on a product (or building), defines relationship among key factors and presents this information for decision and action.
Kamara *et al.* (2002) defined requirements in the construction industry as the vivid description of the facility that satisfies the business need of the project initiator. Enumerating further that requirement in this context includes client requirements, site requirements, environment requirements, regulatory requirements, design requirements and construction requirements.

A RM process consists of four main functions performed in an iterative fashion (Table 1) - requirements definition, requirements analysis, requirements tracking and traceability and requirements verification (Kamara *et al.*, 2002).

3. Integrated Information Acquisition, Storage and Use

Integrated information within HybridDt operates by interpolating principles of mixed reality modelling with that of a Requirements Management (RM) and Product Data Management (PDM) system. The system architecture comprises a series of databases, which support hypertext, and hypermedia, object representation formats as well as context/relationship representation matrices or frameworks. Hypermedia provides powerful mechanisms for structuring and navigating large quantities of information. An additional advantage of hypermedia is the fact that it provides an appropriate mechanism for storing the users' actions using history/path mechanisms (Romero and Correia, 2003). This functionality combined with RE and PDM structures is consolidated in a systemic manner to process requirements in a more efficient way.

The user functionality in a PDM system includes; a data vault or repository, work flow and process management, part and component management as well as project management capabilities. Each of these capabilities is duplicated within HybridDt. The user updates a data repository in the form of a matrix as the process progresses. Within the tool, each building is decomposed into design layers; site, structure, façade, services, internal space and performance factors; space, comfort, accessibility, energy efficiency, safety and security, maintainability, adaptability and durability. These represent parts and components within PDM systems and the 'ProjectManager' represents the project management functionality as the name stipulates.

The RM functions within the tool comprises (after: Svensson and Malmqvist, 2001); Requirements import: Possibility to read requirements from documents created with word processors etc. or through forms completed within HybridDt. Product structure management: Instead of hierarchical structures, relationships are defined to link different information types. Requirements allocation: Allocate functionalities to the data prior to storage. Allocate tasks, actions and decisions to data through ProjectManager. Requirements tracing: Trace the requirements that comply with a function, trace inheritance of requirements and trace the source document and paragraph of a requirement object using design repository matrix, design proposal matrix and ProjectManager. To ensure better traceability between the final parts structure and the requirements, integration between the systems is needed. This is achieved by transferring structures from the RM system to the PDM system. This strategy permits a more accurate and detailed traceability of the requirements. Performance calculation: Communicate the performance and functionality of the design options using the matrix within design activity.

In the tool, RM and PDM systems are linked to allow transference and retrieval of information between both systems. The tool itself is a stand-alone, project based web application with a central data repository located within an internet server. Making it web-based offers advantages such as a flexible, scalable platform where users are not restricted to a singular work-site. It is developed to accommodate multiple hybrid building projects, multiple teams and multiple users. The web tool is also fully flexible and can be modified and deployed for immediate benefit of users without much disruption.

In order to maintain software independence within the decision-making tool, key characteristics of information, including compositionary data, had to be considered so that the functionality of HybridDt is not compromised when used by users with varying computing systems. These characteristics are as follows:

1. REPRODUCTIVE INTEGRITY. In HybridDt, the key concern is reproduction integrity; expected and achieved, for the display of each data format uploaded into the data store. Considerations include the integrity that is lost through storage and retrieval or through viewing, modification, storage and then retrieval. There is no simple solution to multiple format interoperability; the simple solution employed is to phase information activity into two; simple and complex. The simple stages include information acquisition, storage, update and review. As-

built geometric information is acquired externally and uploaded into HybridDt. The tool facilitates the acquisition of non-geometric performance information and prompts for integration of non-quantitative and quantitative information at the end of each section. Information viewing and reviewing is with a universal viewer. This is to ensure that every user has the same 'data view'. The complex information stages are carried out by specific team members i.e. the designers using specialised software independent of HybridDt. The resultant information from specific design activity is then fed back to the team through the simple information loop (Figure 1). This option is viable because for design creation is as vital as the decisions made before and after. Therefore, the design options are viewed in the objective context of design and performance criteria and not in the subjective context of spatial representation alone.

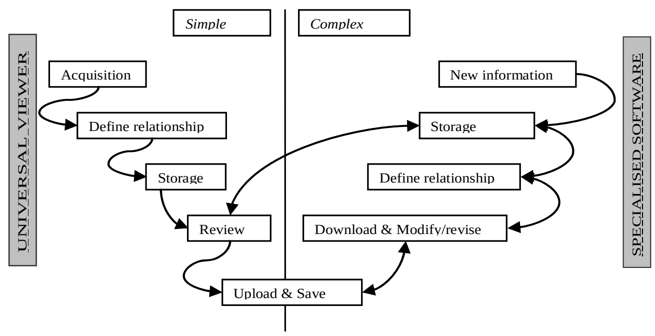

Figure 1: HybridDt's Solution to Maintaining Reproductive Fidelity for Users

2. PRESENTATION. The format in which information is presented within HybridDt de-emphasises the focus on spatial representation alone and seeks to integrate information within documents so that it presents a singular view. It supports this through information layering, generating design models from historical information or original building data. Each permitted user is allowed to revise information in a manner suitable to them, which is most effective for communicating requirements. The architect is therefore likely to use visual methods such as sketches, drawings and 3D renderings to communicate concepts to the client and rightly so. On the other hand, the client is more likely to respond using text based instruments. The tool supports this multiplicity while ensuring that duplicity of information is discouraged.

3. STORAGE - MAINTAINANCE, FILTERING AND ERROR MANAGEMENT. Information within HybridDt is stored and retrieved from a network of complex databases. Constraints are defined within these databases to ensure that the user conforms to the tool's working protocol. The filing convention is as defined in the BS 1192:2007. Users can access a simple version in the 'Help' section. Prompts and pop-up messages are used to notify the user of non-conformity and errors. In addition, the data store maintains a history of tasks, actions and decisions for future review. The user can also search within relevant databases to find specific information.

4. COMMUNICATION. Ease of communication within HybridDt is first implemented by making it web-based. The information and decision matrices within the tool also present an integrated view of all the data within the data store and their relationships to key design and performance priorities. In addition, notifications can be generated within ProjectManager whereby recipients are advised of changes, tasks, actions or decisions required by email. Effective and traceable communication among the team can be traced through logs.

5. IMPLEMENTATION AND PERFORMANCE. HybridDt is designed to be intuitive with the processes within it designed to follow a defined work flow The generic explorer interface is maintained and functionalities within this interface are similar to those used on most computer applications. Nonetheless, the implementation and performance of the tool has to be monitored within the context of each hybrid project. This task has been allocated to the project administrator (the architect by default).

6. FEEDBACK/ UPDATING SYSTEM MODEL. HybridDt also has inbuilt design flexibility which allows its capabilities to be modified or customised depending on project requirements, thereby enhancing system performance. This is demonstrated by relative ease by which validation comments have so far been implemented within the tool. The resulting integrated information protocol is as shown in Figure 2. The key attributes of the system are the compiled data store, input and output functionalities and the project RM system.

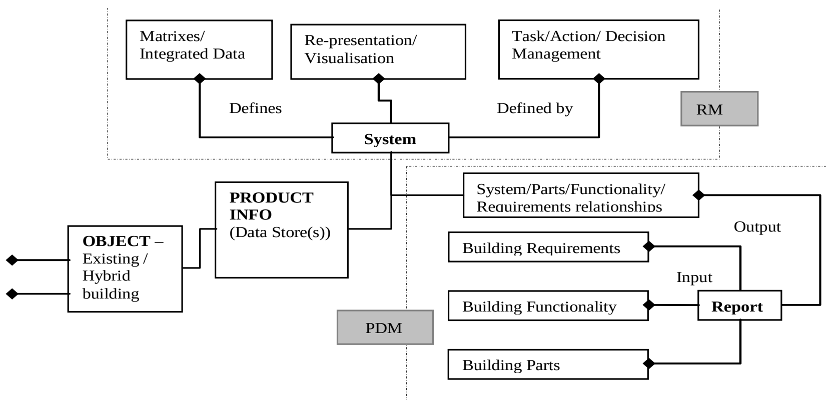

Figure 2: HybridDt Integrated Information Protocol

Importantly, as suggested by Björk (1999), the HybridDt protocol provides the four levels of information processes required typically in any hybrid project. These are; person-to-person communication characterised by virtual networking and collaboration, answering questions and queries and feedback, creation of new information by building on the old, ability to search and retrieve information and robust tools to make information available and easily accessible when required.

3.1 Systemic Information Layering

Design information is integrated through a process of systemic layering based on information required and design need (Table 2). This is implemented using a workflow format. Historical data available at the projects inception are uploaded at the first stage of the tool under the ‘Existing Building Information’ section; this information will include drawings, details, maintenance reports and all other information relevant to the building project. Storing and uploading convention within the tool is according to the BS1192:2007 standards.

Table 2: HybridDT: Information Integration Through Layering

	Layering		*Decision/ action tools*
1:	Historical drawings/details	Upload into HybridDt	Hotpoints/ Hyperlinks/ annotations
2:	2D/3D survey data (drawings/details)	Integrate with existing design information	
3:	Superimpose 1&2	Correct for errors (see chapter 7)	
4:	Superimpose proposed design and details	Identify constraints/ problem areas/ design decisions	(retain/revise/remove)
Advantages:	Relational yet single information view for making design decisions		More information means increased accuracy
	Less time creating drawings & models from scratch		Integrated design and design decision-making
	Visualisation in more enhances (Quick MR)		Early and easier clash detection

HybridDt provides a workflow structure for carrying out a high-level survey using the Building Performance Evaluation (BPE) section of the tool. This section is further divided into two sections; design (spatial) factors and performance factors. Users are then prompted to update historical information (drawings etc. already in the repository) in light of the new information rather than create new ones. This concept is termed layering. Layering in this context is the practice of updating existing information rather than creating new ones. This is easily achieved within current computer and CAD/CAM applications; therefore, there was no need to prescribe new computer tools. This is the first stage of information integration, the second stage occurs with the matrices and during design activity. At the end of each section, the users are required to upload modified files into the tool. A report on information provided in each section is also logged.

Information generated from this section are forwarded to the next stage; briefing development. The briefing development stage employs the same protocol to acquire, store, integrate and categorize information.

At the end of this section, it is also possible to revise files or update new ones as prompted. A report that incorporates the findings from the Building Performance Evaluation section is then produced at the end of this section. This report is the briefing documentation upon which contracts and consequential design and construction activity is based. It provides an informed guide for single-minded design decisions because it incorporates the opportunities and constraints provided by the existing building with client, user and statutory requirements. It is good practice to index as the project develops rather than leaving it until the end. Records also need to be maintained to satisfy requirements of the Construction (Design and Management) Regulations 2007, ISO9001:2000 and in order to meet conditions of contract (Townsend-Rose 2006). An index of documents is automatically created after a file is uploaded into HybridDt. A history of activities related to each file is also kept, as a result, data modifications can be tracked in the order of date, time, user etc.

4. Evaluation Feedback

Eleven experts comprising architects/design managers, engineers, collaboration and construction managers participated in evaluating the design decision tool. Each participant also had direct experience of building adaptation projects especially hybrid projects. During the exercise, each participant was briefly introduced to the research project as well as the process framework prior to being asked to evaluate the tool. At the end of this exercise, each evaluator was asked to complete a questionnaire as well as provide additional comments and feedback of their experience using the tool. The session generally lasted between 1 hour 30 minutes and 2 hours.

According the evaluators, the benefits of HybridDt are that it provides clarity of information and transparency in design. It facilitates programming of work and provides a record of work requested and completed according to that programme. It is also useful for sharing information and forces input of project information for collaborative design, planning and implementation. It enables project management of tasks on one hand, while it ensures survey for existing information on the other. This multi-functional system was considered advantageous because it is process driven first, with information technology support, rather than the other way round. Another positive was that the tool provides a life cycle view of the project, thereby giving a comprehensive perspective to everyone involved in the project. For technical or construction issues, the tool provides a means for early conflict resolution because everyone is communicating and sharing information early. One evaluator also said the tool could help to de-risk contracts and minimise cost implications of information-related risks.

Evaluators however mentioned the potential difficulty with having to tick too many boxes especially at the early stages, which could then become time consuming. Efforts have been made to minimise this. There were concerns raised about cultural resistance to its uptake and the challenges and steps necessary to overcome it, especially as the tool relies on partnering/collaborating in order to be efficient. Practically, users will need manuals and help files, and regarding filing conventions (BS1192:2007) - buildings cannot always simply be classified all the time. Final comments were that the tool 'looks like a very useful tool for future application, that is both very well developed, considered and process driven'.

5. Conclusion

The paper presented the Hybrid Project Design Decision Tool (HybridDt) by highlighting its functionalities for information acquisition, storage and use. A summary from the evaluation of the tool by a number of industry experts was also presented. The benefit of the tool is principally to monitor the delivery of important process-led requirements. It also meets the need for accessible, homologous and structured information. This functionality is provided within the information protocol earlier described. The tool also provides a simplified format for the integration of flexible, adaptable real and virtual information. In integrating information for design decision making, it represents space, location and time with particular emphasis on change and value processes rather than the passage of time.

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