Capturing Histories of Design Processes for Collaborative Building Design Development

Field Trial of the ADS Prototype

Cristina Cerulli, Chenghzi Peng and Bryan Lawson
University of Sheffield

Key words: Design Rationale, Design Support Systems, Usability Evaluation

Abstract: The ADS Project - Advanced Design Support for the Construction Design Process - builds on the technological results of the *previous* COMMIT Project to exploit and demonstrate the benefits of a CAD based Design Decision Support System. COMMIT provides a system for storing knowledge about knowledge within the design process. It records design decisions, the actors who take them and the roles they play when doing so. ADS links COMMIT to an existing object-oriented CAD system, MicroStation/J from Bentley Systems. The project focuses on tackling the problem of managing design information without intruding too much on the design process itself. It provides the possibility to effectively link design decisions back to requirements, to gather rationale information for later stages of the building lifecycle, and to gather knowledge of rationale for later projects. The system enables members of the project team, including clients and constructors, to browse and search the recorded project history of decision making both during and after design development. ADS aims to facilitate change towards a more collaborative process in construction design, to improve the effectiveness of decision-making throughout the construction project and to provide clients with the facility to relate design outcomes to design briefs across the whole building life cycle. In this paper we will describe the field trials of the ADS prototype carried out over a three-month period at the Building Design Partnership (BDP) Manchester office. The objective of these trials is to assess the extent, to which the approach underlying ADS enhances the design process, and to gather and document the views and experiences of practitioners. The ADS prototype was previously tested with historical data of real project (Peng, Cerulli et al. 2000). To gather more valuable knowledge about how a Decision Support System like ADS can be used in practice, the testing and evaluation will be extended to a real project, while it is still ongoing. The *live case study* will look at some phases of the design of a mixed

residential and retail development in Leeds, UK, recording project information while it is created. The users' feedback on the system usability will inform the continuous redevelopment process that will run in parallel to the *live case* study. The ADS and COMMIT Projects were both funded by EPSRC.

1. INTRODUCTION

1.1.1 The ADS project

The ADS Project (Advanced Design Support for the Construction Design Process), funded under the Innovative Manufacturing Initiative by the EPSRC, aims to exploit and demonstrate the benefits of a CAD-based Design Decision Support System. The project builds upon earlier work on the more theoretical information management concepts developed in the COMMIT (Construction Modelling and Methodologies for Intelligent Information Integration) project, an earlier EPSRC funded project.

ADS develops naturally from COMMIT by incorporating the advanced information management and decision support techniques of the COMMIT project into an existing object-oriented CAD system (Microstation/J from Bentley Systems), and applying this tool to the management of design information and decision making in a real life project provided by Building Design Partnership (BDP), a large construction design practice.

In implementing the COMMIT approach in a real design situation, the emphasis shifts towards learning and understanding more about the decision-making process within design activities. The motivation behind the COMMIT and ADS projects is concerned with defining mechanisms to handle the proactive management of information to support decision-making in collaborative projects.

ADS focuses on how to provide designers with tools for recording and managing the group dynamics of design decision-making in a project's lifetime, with the explicit intention to minimise any intrusion on the design process itself.

The deliverable of the ADS Project is an advanced CAD tool that facilitates capturing designers' rationales underlying their decision-making throughout the design and construction development. The system also enables members of the project team (extendable to all the actors involved in the process, including clients), to search and browse the recorded project history of decision-making, during and after design development.

1.1.2 Commit and beyond

As mentioned above, the ADS project was set up to bring forward the developments from the COMMIT project which was concerned with the management of information to support decision making in multi-actor environments. It addressed six primary issues that are central to information management:

1. The handling of ownership, rights and responsibilities;
2. Versioning of information;
3. Schema evolution;
4. Recording of intent behind decisions leading to information;
5. Tracking of dependencies between pieces of information;
6. Notification and propagation of changes.

Many of these are distinct issues, but they have been found to be closely inter-related, making it difficult to address them individually. During the COMMIT project, the Salford group has employed object-oriented technologies (first in C++ then in JAVA) to implement an information management framework that addressed the problems indicated above (Brown, Rezgui et al. 1996).

COMMIT does not impose a decision making sequence, leaving it to the design team, but provides an infrastructure through which all members of the team have the opportunity to be aware of what decisions were made, who made them and when as well as why. The way in which this is achieved is described elsewhere (Rezgui, Cooper et al. 1998).

1.1.3 ADS: aims and objectives

The key aim of the ADS project is to develop a system that is adequate to demonstrate an object-oriented approach to managing design decision-making across the whole building life cycle.

The ADS research project also offers an opportunity to investigate a number of issues concerning computer-mediated collaborative design processes such as the integration of recording/capturing design intents/rationales into a general CAD platform.

With ADS, designers are provided with the tools to record any information related to a particular design decision-making process. That information can then be recalled and accessed by other actors involved in the process such as clients, other designers, contractors etc.

At any point in time the actors involved in the process are enabled to make informed design decisions in the light of the information about other design decisions related to the *current* one, that are being or have been made

by other project actors. The system supports and facilitates the collaborative asynchronous decision-making process.

1.2 ADS field trials

Following a pilot Case Study in which ADS was populated with historical data (Peng, Cerulli et al. 2000), ADS is currently being tested on live projects with the collaboration of the Manchester office of BDP. The projects used for the trials are: the *Round Foundry Residential and Retail Development* in Leeds and the *Deansgate Hotel* in Central Manchester. ADS is being used to record design decisions as they are made over a 3-month segment of the design process. Currently two of the designers involved in these projects are using ADS.

During the field trial every attention was paid to avoid any interference with the design development as well as any imposition regarding the frequency at which to insert data in the system. Designers regularly e-mailed the updated ADS project database and the model dgn files; short meetings were periodically held to gather feedback about system and interface usability and for post hoc interviews about the data analysis.

One of the main objectives of the ADS field trials is data gathering. Populating the system with real data gathered in real time, in anger, without any artificial simplification of the design development process.

Associated with this objective is the intention to explore the potential of ADS as a tool for carrying out research on design processes as an unobtrusive way to monitor real design processes, without significantly interfering with the observed process. Lawson identifies five methods of investigating design processes: speculating about design, laboratory observation of designers under rigorous empirical conditions, observing designers at work in the studio, listening to designers telling about the work they do, either by interviewing them or reading what they have written about their process and simulating the design process (Lawson 1997). All these ways of researching design processes have been tried and each appears to have some flaws. Either the events studied do not reflect real events or the analysis is bound to be biased by the investigator's personal perceptions or the experiments deal with artificially limited phases of design or the fact that knowledge about the process often remains implicit in the designer's head. Despite the ADS system was originally developed as an innovative tool for supporting decision making in design (Cooper, Rezgui et al. 2000; Peng, Cerulli et al. 2000) the research group realized that it could also offer a fundamentally new methodology for studying the design processes by capturing design development events in a relatively unobtrusive way.

Other key objective of the ADS field trials is the evaluation of both the ADS System and the User Interface. This objective partially clashes with the previously stated aim of non-obtrusiveness in data gathering, but is seen as a necessary stepping-stone towards a more usable system. It has to be pointed out that these field trials are regarded as a tool to support the system development: user feedback and evaluation, as well as results of the project data analysis will feed back directly into the development that runs in parallel to the experiment. Incremental changes to the system will be continuously implemented and released for testing and evaluation. A few development cycles will be iterated throughout the duration of the case study.

The project data gathered by the designers through ADS is being analysed as it is produced, and post-hoc interviews are held with the participants to confirm any interpretations of the data that arise from the analysis. For an account of the completed ADS Live Case Study see (Cooper, Rezgui et al. 2001).

1.3 ADS Field Trials - Phase I

1.3.1 Description of the ADS prototype as currently released

Designers were given the ADS tool to work on the Round Foundry and Deansgate Hotel Projects and they were asked to generate ADS Design Decision Records as a result of design decisions.

An ADS Design Decision Record is a complex dataset formed by many types of data: CIMM management attributes; ADS taxonomical attributes; CAD transaction; description of design intents/rationale; affected and pending design decisions; and hyperlinks to other related documents. For a detailed account of the ADS Decision Record please refer to (Peng, Cerulli et al. 2000).

In this phase of the live case study the system was capable of recording only the following data types:

– The CIMM management attributes. The CIMM Manager deals with the information regarding "people" involved in a building design project. Members of the project can generate a member profile by addressing the following attribute: Actor (Title, Name, Phone, Email, Fax, etc.); Role (The roles as played by the members of the project team); Default Authorities (Object Type, Role, Methods); Specific Authorities (Object Instance, Role, Methods).

- CAD transactions. All the identities of the CAD elements or components involved in any transaction as recorded by the ADS Event Listener. The transaction can span over many work-sessions and across multiple files.
- Description of design intents/rationale. Input of textual descriptions in a natural language (English) of what the designer thinks are the reasons behind a design decision or design changes. Intent representation promotes the Actor's understanding of the reasons for project changes, which in turn reduces problems arising from misunderstanding intentions.

The decision record generation process can be summarised as follows: the designer logs on her client workstation and gets access to a project CAD design file stored in the project's server workstation. When a number of changes have been made as the result of a design decision, they may be committed as a single transaction, with a brief explanation of the rationale for that decision. This has some resemblance to filling in a change box in a paper drawing, but it can encompass a change that would be represented on more than one drawing, and, most notably, there is total freedom of choice regarding the granularity at which this information is recorded.

Before committing a decision the system checks to see which previous decisions may have been affected by the current changes (by inspecting the changed elements). The *Commit* Decision Browser displays as highlighted the past decisions that have been affected by the changes in the current transaction (*Figure 1*) and it is possible to browse information relative to those previous decisions such as actor, time, rationale, CAD objects involved etc. For objects that are able to be represented graphically in the CAD tool, this facility also allows the user, by means of the *Select Objects* button, to view the different versions of an object graphically in context within a window of the CAD tool.

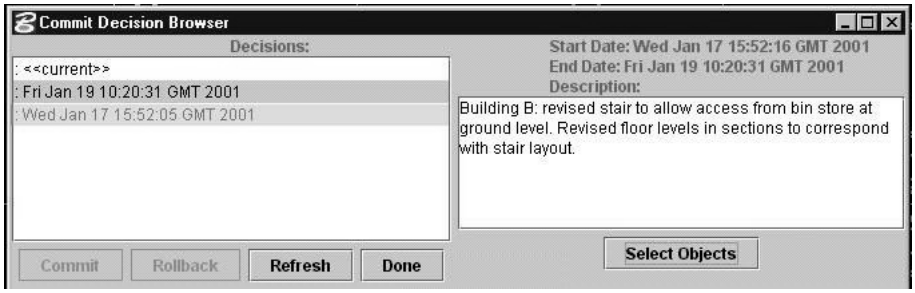

Figure 1. The Commit Decision Browser

1.3.2 Data gathered

A number of design decisions were recorded into the system. To illustrate the type of data gathered let us consider one of the decisions recorded during Phase I (*Figure 2*) committed by the actor *Garrett, S.* in her role of *Architect,* to which the *rights* of creating/deleting/modifying the model had been assigned.

The user was left totally free to determine at what point to commit a decision, the amount of information to insert and the number of design changes to be included in a single decision or transaction. The rationale for that decision was input in an unstructured form in a free-text box, and, for the decision in examination, reads as follows: "Building B: revised stair to allow access from bin store at ground level. Revised floor levels in sections to correspond with stair layout". The system also stored information about the CAD elements (dgn objects) involved in that decision. They belonged to two different dgn files: ap0120_02.dgn; a plan, and ascc20_02.dgn; a section (the relevant portion of those files is shown in *Figure 2*). The *Select Objects* button allows highlighting the CAD object involved in the decisions when one of the files containing them is open (MicroStation does not allow having more than one dgn file open at the time).

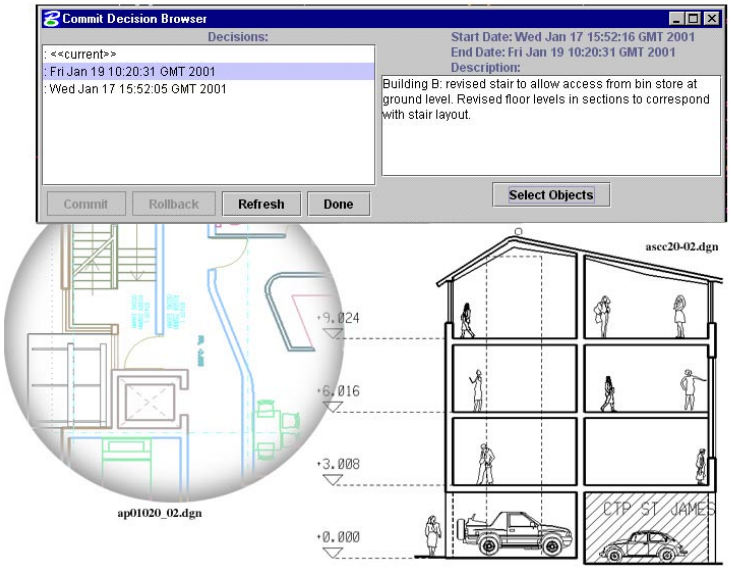

Figure 2. Illustration of a design decision

1.4 ASD field trials - phase II

Throughout the field trials the software development proceeded in parallel with the use of the system. Features that had been previously designed have been implemented and the feedback on system and interface usability gathered from interviews and e-mail communication between designers and researchers was taken into account. A new version of ADS is about to be released and it will mark the beginning of Field Trials - Phase II.

1.4.1 Description of the ADS phase II prototype

The main features of the Phase II ADS release are an improved User Interface, based on the results of evaluation, and the implementation of extra data gathering functionalities. In particular the additional data types that can be gathered and displayed through the *Commit Decision Browser* are hyperlinks to related information and rationale taxonomical attributes.

1.4.1.1 Hyperlinks to related documents

A design decision may be made in relation to other information that is stated in other documents such as minutes of a project meeting with the client, a WWW page showing a building component product, etc.

Gruber and Russell observed that rationale explanations are often inferred from information that is stored, rather than being stored as exhaustive explanations (Gruber and Russell 1996, p. 330). The possibility to hyperlink the decision record to related documents will therefore enrich the contextual information about that decision, reducing the amount of information that need to be input s for that decision.

1.4.1.2 Taxonomical attributes.

The idea of establishing a *taxonomy of design decisions* emerged from our research into the possible ways of capturing design rationales from designers' actions performed on a CAD platform and into what type of design information is more likely to be useful once it's been captured. Gruber and Russell, from a protocols analysis of designers talking about design, derived a taxonomy of categories of information requested about designs (Gruber and Russell 1996, p. 326). It seemed to us that we might experiment with a generic classification scheme that may cover most, if not all, kinds of design decision-making in the processes of building design. As a research hypothesis to be further verified, we consider that a taxonomy of design decision is useful because for:

a) Post Analysis. Design intents or rationales entered by the designers through the taxonomical interface can generate data records that will allow for further analysis after a project is completed.
b) Data Gathering Efficiency. A well-defined and designed taxonomy can enrich the user interface so as to help the user to think about design rationales at the time of making those decisions. A taxonomy can provide efficiency in recording design rationales if the designer does not have something specific to start with at the time of making the decisions.
c) Data Structure: Each attribute of the taxonomical structure (template) can be used as a data entry to index and characterise design decisions so to improve the organisation and search of recorded decisions.

The provision of a taxonomy of design decisions within the ADS framework is therefore mainly to facilitate the generation and use of design decisions during and after design development. It has to be pointed out, though, that the taxonomy provided could only be an open-ended scheme in which the end users can define and extend the scope at any one time to reflect the demands of the project as it develops. We also understand that design decisions may not be attributed in simple or general taxonomical terms, and the system should aim to preserve the "context" as much as it can.

The decision to build the ADS taxonomical attributes in the data gathering interface was encouraged by the findings from the analysis of the free text description of the rationales for decisions committed in Phase I and by interviews with the designers.

2. CONCLUSIONS

The ADS system as a recording tool is still under testing and under development. The data structure proved to be versatile, easily accommodating changes and developments in the software architecture.

Minimum intrusiveness is crucial to the success of any decision support and design rationale-gathering tool. With ADS the granularity of decisions is determined entirely by the designer using the system. Obviously the benefits deriving from recording design rationale are proportional to the quantity of data gathered and, possibly, inversely proportional to the granularity of events/decisions/transactions. A potential impediment or deterrent to the data gathering is the fact that it is likely that the main beneficiary of such activity is not going to be the very person that is requested to input the data into the system. But there is also a cultural dimension of the construction design process that determines the success of design rationale and project information capturing. It is possible to envision a gradual increase in the

amount of information recorded into the system as the designers become more aware of the real potential benefits of recording design rationale.

The user response was very sympathetic towards the overall objectives of the system. Frustration was occasionally expressed towards the limitations of specific implementations. In particular limitations in processing speed were pointed out as disruptive and intrusive. These issues are currently being addressed to be included in the next release of ADS.

In this phase of the field trials, fine-tuning to the user needs the system data recording functionalities necessarily shifted the focus on the ADS system as a data gathering tool rather than a design aid tool. In the next phase of the field trials and development, still ongoing, more emphasis will be placed on improving the retrieval of information. Extra functionalities will be implemented like the notification of changes to potentially affected objects, mechanism for mapping relationships between decision (affected and pending decisions) and the nesting of design decisions.

An account of the completed ADS Live Case Study and a critical evaluation of the system will be published in (Cooper, Rezgui et al. 2001)

3. ACKNOWLEDGMENTS

The Advanced Decision Support for the Construction Design Process project is funded by the UK Engineering and Physical Sciences Research Council (EPSRC), Innovative Manufacturing Initiative (Ref#GR/M42398). Building Design Partnership participated in the Field Trials and provided documentation about the Round Foundry Project in Leeds and the Deansgate Hotel in Central Manchester. Bentley Systems provided Microstation/J CAD software and support for integrating the ADS system into the CAD tool.

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