Migration from an individual to an enterprise computing model and its implications for AEC Research

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Introduction

Some commentators have emphasised the 'structural' difference between construction and other industrial sectors (construction is low tech., one-off, other manufacturing industries can amortize R+D costs over long production runs, etc). Others have considered the organisational aspect of the industry, focussing on issues of discipline specialisation, organisational fragmentation and adversarial contractual structure.

This paper's focus is to consider the construction industry as essentially an information processing system. In its ideal form, practitioners (each with an individual internal representation of design intent) interact with other practitioners by first interacting with an information processing system that manages various shared external representation of design intent. The underlying assumption (from an information technologist's perspective) is that design data is held in a sufficiently complete representation, and that changes to this representation are transactions that move the representation from one consistent state to another consistent state. We might call this 'enterprise computing' for construction.

A research agenda built around this concept of 'enterprise computing' for construction might pose the following questions:

- what are the existing uses of IT in the construction industry and their advantages and limitations?
- what assumptions are being made about the benefits of moving to an enterprise computing model?
- what aspects of an enterprise computing model indicate that it will actually address the special requirements of the construction industry users?
- what organisational and operational changes are associated with the adoption of an enterprise computing model?
- what 'use-cases' and field trial could be constructed to indicate how this type of system might perform in practice and to refine appropriate deployment and training strategies?
- how are the costs and benefits of using an enterprise computing model going to be quantified?
- to what extent would the adoption of an enterprise computing model facilitate the wider deployment of other innovative design tools?

Historical perspective

We are still a long way from realising this type of system. For example, it was recently reported that the design and construction of the new Hong Kong airport involved the use of over one million documents. We can imagine that most of these documents (certainly all the drawings) where created and edited with computer applications. This observation implies no criticism of the organisations involved in this project. These practitioners used the latest available technology in a way that the vendors suggested it should be used. However, from an information technologist's perspective, this observation should be cause for concern.

We need to ask why, after so many decades and millions of dollars of research and development in Construction IT, has one of the most prestigious and successful construction projects required a million documents to manage its design and construction. This observation tells us quite a lot about:

- how the construction industry currently uses information
- the characteristics of currently availability of IT tools and their suitability for this scale of project
- how the construction industry perceives what is an appropriate use of information technology.

It is as if the construction industry exists at the fault line between individual and enterprise computing.

To adopt an enterprise approach requires (or provides the opportunity for) the re-engineering of the whole information creation and usage process and also the wider business context. Certainly, in the process plant sector there are more examples of enterprise computing which may be due to a combination of factors (fewer organizations involved, high contract value, use of standard parts, etc.).This can be compared with the fragmented nature of the building construction industry and its pre-existing use of incomplete representations (such as drawings) which has historically worked against the successful and widespread adoption of an enterprise approach. However, we should not forget that such systems as BDS and RUCAPS[1] were commercially successful in 1980's. These were effectively an enterprise wide construction computing system. Although these system pre-dated 'object orientation', they provided some impressive functionality, essentially allowing multi-user access to a single 3D and fully attributed building model, with parametric components and 'graphic' reports in the form of rule based 2D drawing extraction.

This type of system made a clear distinction between definitive 'model' data and derived data (reports, such as drawings). This had the added advantage that a set of drawings derived from a model at a given moment were at least known to be consistent. It required the practitioners who worked at the early conceptual phase had to create possibly a more complete representation of the design (before any drawings could be extracted) than would have been the case without this system. However, other members of the design team, working 'down-stream' benefited from this approach. It also required that one member of the project team was responsible for maintaining the integrity of the model. These requirements created winners and losers and it was difficult to adjust existing contractual arrangements to compensate for the extra effort required of some team members and the advantages offered to other team members. We can conclude that the technology of enterprise computing for construction was viable, but the supporting (and necessary) process re-engineering was never really established.

In one sense this early enterprise approach failed economically when confronted with the emergence of the PC. But there is another more important reason for its demise. The PC adopted the 'desk-top/document' metaphor. Word processor applications could replace typewriters, 2D drafting applications could replace drawing boards without any of the process re-engineering, training and contractual re-negotiation required by the enterprise approach. With the limited automation offered by 2D drafting systems, drawings could be produced in the traditional way, which split the recording of design intent across multiple incomplete representations, each of which could be independently edited without reference to other documents.

An additional consequence of 2D drafting systems was there was no comprehensive computable model of design intent (as had previously existed in the early enterprise systems). To run any kind of analysis (for example, an energy analysis) which was dependent on room volumes, required the re-assembly of geometric and attribute data from multiple 2D drawings. I think we could argue that this manual 're-assembly' process was a major obstacle to the use of these analysis tools. Having funded the development of energy and other analysis and simulation tools, it must have been disheartening to the research funding agencies that the potential of these tools in practice was not being realised, in part because design data was dis-aggregated and recorded with an inappropriate "dimensionality".

The result of adopting the 'desktop/document' metaphor was that the clear distinction established by the early enterprise computing systems between a single 'definitive' building model and derived data (in the form of drawings and reports) was lost.

On the one hand, the PC software vendors could argue that the 'popularity' of (personal) computers owes much to the selection and promotion of this 'desktop/document' metaphor, because it provided an essential transition from the pre-computer world where physical documents were the only option.

On the other hand, as a professional computing environment, the 'desktop' metaphor perpetuates the myth of the 'discrete' document (with its physical implementation as a file) as a suitable and logical unit of data. As the Hong Kong Airport example indicates, much of the construction industry is trapped within the desktop/document' metaphor, which we could argue is wholly inappropriate to multi-user collaborative workflows, found in the construction sector.

Present opportunities

Conditions are changing. Many practitioners have gone through the 'desk top' experience and realise that the productivity gains from a limited form of automation (of electronic drafting) are exhausted. Both the advances in computing technology and changes in business conditions suggest that the building construction sector has the potential to reconsider the use of an enterprise computing model. In the context of this seminar, it is neither the technology of enterprise computing nor even the migration from an individual to an enterprise computing model which are research issues, but rather the effect of this migration on the construction sector. For example, how will the associated process re-engineering be handled and how will the use of more complete design representations and management tools effect the use of applications for energy analysis, cost estimation, and construction planning.

While the migration from 'individual' to 'enterprise' computing is not a research issue, it is most probably one of the key challenges to both the software vendors and practitioners. We have to remember that 'discontinuities' (particularly of IT systems) are simply not tolerated in the construction industry, so this transition has to be extremely gentle.

One example of an enterprise computing system, which is especially designed for construction industry data, is Bentley's ProjectBank data repository[2]. A particularly important facility is that it allows practitioners to retrospectively build a single comprehensive construction data set from multiple legacy CAD models or drawings, thus supporting a smooth migration from a traditional file based system. This migration is further supported because the user can interact with design data via what appears to be a drawing (or other traditional document formats, as approprriate). Essentially, the user is given the illusion that he is editing a local 'virtual' document, when in fact his edit actions are being used to update the data repository. The visual feedback he sees on the screen is a new consistent report which is derived from the repository and sets his edits in the context of other changes made by his co-workers.

The use of this shared data repository by a project team facilitates the parallelisation of design by enabling multiple users to modify similar regions of the model concurrently. The system supports multi-user optimistic long transactions, an audit trail of changes to all components, facilities to merge compatible changes made to the same components by different users, and facilities to identify and resolve conflicting changes.

Intuition suggest that the facilities offered by enterprise computing will have a beneficial effect on the construction sector. However intuition is not enough. Obviously a system such as ProjectBank is based on a number of assumptions which the software developers have made about how practitioners might work with a shared, transactionable data repository. It might be beneficial if these assumptions were more rigorously tested. In addition, there could be benefits from an independent research initiative that investigated the consequential organisational and deploymnet issues and the quantification of benefits.

Another area where enterprise computing intersects with research, is its potential to be the context for the development and deployment of innovative research design tools.

One of the motivations for research (and indeed an important test of the research concepts) is to deploy research tools (specifically software) in practice. Without a proper 'software infrastructure' it becomes increasingly complex to deal with additional applications (both commercial and research tools).

Potentially we could have multiple users applying different analysis tools to the same design project, with each user potentially revising different aspects of the project in the light of his particular analysis. After the individual revisions are complete there is the issue of how to merge these different revisions back into a single model in order to assess whether the changes are compatible or in conflict. Multiple iterations of analysis, model revision and merging of changes with associated inter-disciplinary negotiations might be required to establish the appropriate interaction of all the design and performance variables and to arrive at a consensus within the design team about an agreed design configuration.

Although it is possible to develop and test individual analysis tools in isolation, it is going to be problematic to use of these tools concurrently without an appropriate enterprise scale computing infrastructure to help manage the consequential merging of changes and conflict resolution. The whole essence of this type of highly engineered multi-disciplinary design process is that there should be no inhibitors to 'another iteration cycle'. The ability to create a new 'consensus' revision that can combine selective elements for previous (individual) revisions, allows the enterprise computing system to support negotiations between design team members. We can envisage some interesting research scenarios being developed where the enterprise computing system is effectively being used to 'instrument' this inter-disciplinary negotiations process.

An enterprise computing system can become an essential 'framework' for the development of research tools and for the early deployment of these tools in practice. These advantages include:

- it saves valuable research resources by avoiding individual research teams from having to create their own computational infrastructure
- it enable different application plug-ins (developed by different research groups or commercial third party developers) to be used together
- the framework is already deployed in practice, and therefore gives practitioners access to research tools and gives researcher the opportunity to observe their tools in use under realistic conditions.
- in the case of ProjectBank, it provides tools to manage the use of multiple design and analysis tools
- the audit trail facilities in ProjectBank allows a complete multi-user design process to instrumented, replayed, and analysed by a research team.

<u>Conclusions</u>:

- Due to its fragmentation, the construction industry generally perceives its use of information technology in terms of multiple discrete 'individuall' systems (with the resulting proliferation of discrete documents) rather than as an enterprise systems.
- The drawing tradition, which represents building in 2D, with different representations of the same design split across multiple independently editable documents inhibits consistent management of design and the use of analytical tools.
- There are new object oriented and data management tools emerging from some software developers that are designed to address the specific needs of a 'construction enterprise', namely geometric generality, multiple application semantics, multi-user access, and transaction management. These systems also address the scalability and reliability issues required for deployment in practice.
- However there are still significant issues in deploying enterprise computing models to what is still an essentially fragmented industry. An independent research initiative could be instrumental in investigating these issues.
- An enterprise computing system can provide a framework for the development and integration of diverse research tools and as a delivery mechanism for deploying these tools in practice.

We need to set this in a wider context. The role of both the researcher and the developer in Construction IT is to harness language features (and other computational devices and resources) to satisfy the issues which are of concern to the practitioners. Additionally, the researcher and developer may find it necessary to construct, what we could broadly term, 'usage metaphors' to enable the practitioners to interact with the implementation.

Here are some of the issues which may concern the 'strategic' practitioners:

- Semantic completeness: building a sufficiently complete multi-disciplinary representation of design intent
- Data integrity: where any intelligent components are used, these should not become 'orphaned' by becoming detached from the data
- Data longevity: data integrity should be maintain for the life-time of the building, across new hardware platforms and operating systems. Upgrades to the application and any intelligent components should not disrupt or invalidate existing data
- Parallelisation of design: individual designers or engineers should be able to work in parallel, and then be able to synchronize their work with co-workers
- Expressibility: architectural design and construction engineering are an opened ended domains. Additional functionality or intelligent components should be capable of being added on a per project basis.

While the implementation of computer systems to support these requirements is the responsibility of the software vendors, we wish to be constructively engaged with the research and user communities, both to ensure that we are addressing the appropriate issues and that our implementations match the needs of the construction industry.

To this end, Bentley has and is currently participating in a number of research projects with both academic and industrial partners (MIT 'House of the Future' project, Carnegie Mellon University + US Army Corps of Engineers Research Lab., Georgia Tech + Portman Associates, University of Cambridge + Oscar Faber, University of Salford + Building Design Partnership).

Our objective is to be a catalyst between researchers and practitioners, by creating the software infrastructure and enterprise computing systems which can facilitate the development and deployment of innovative design tools.

Reference

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2. Bentley, K. "ProjectBank White Paper", www.bentley.com (1999)