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The impact of emerging information technology on project management for construction

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ABSTRACT

Changes brought about from advances in information and communication technology for the architecture, engineering, and construction industries (construction ICT) are not purely technical, but must be accompanied by changes to the management processes. Elsewhere, we have discussed a framework for project information management in construction. This paper addresses changes to the practice of project management as a whole. Broadly, it suggests a unified approach to project management that involves defining a set of widely-applicable common views of the project information, explicitly defining the inter-relationships between the information in these different views, and modifying project management tools and procedures to work with these integrated views.

1. Introduction

Current trends in *information and communication technology (ICT)* are yielding a wide range of new computer-based tools to support the *architecture, engineering, construction and facilities management* industries (collectively referred to simply as "construction" in this paper). These tools—particularly those associated with building information models (BIMs) for project modeling and integration—promise great increases in the effectiveness and efficiency of designing and managing construction projects. However, these improvements require more than just technical solutions; their full potential cannot be realized without corresponding changes in the work tasks and skill sets of the project participants. We are exploring the relationship between emerging ICT and project management and, in particular, how project management should evolve to fully exploit the emerging ICT potential. Elsewhere [1] we have discussed a specific sub-discipline of *project information management* and the role of a *Project Information Officer*. This paper considers adaptations to the overall practice of project management to more explicitly recognize, represent, and manage the interdependencies between different project views, presenting a conceptual framework for a *unified approach to project management.*

1.1. Emerging construction ICT

We have categorized trends in construction ICT into three eras [2]. The first era of construction ICT (now more than four decades old and continuing) focused on developing stand-alone tools to assist specific work tasks such as CAD, structural analysis tools, estimating, etc. These tools are well established within current practice. A more recent second era (from the mid-1990s) of construction ICT has focused on computer-supported communications such as E-mail, the web, document management systems, etc. This is a less mature field, with new tools and core features still emerging, and business processes still adapting. Much of the construction ICT research and development over the past decade has pursued a third era of construction IT focused not on individual applications or transactions, but on the potential for uniting all of these as a cohesive overall system through integration, building modeling, etc. This emerging ICT has seen some impressive innovative use in industry but has yet to reach mainstream application.

1.2. Types of impact on project management

We have defined three broad ways in which these ICT trends impact construction project management. First, the trends in construction ICT are leading to information systems that are increasingly complex, increasingly central to the management of the project, and require increasingly specialized knowledge and work practices. As a complex and critical project resource, the project information and information systems must be explicitly managed. We have addressed this issue of project information management as a specific sub-discipline of project management [1]. Second, we argue in this paper that current project management practice de-emphasizes the interdependencies between project tasks as a necessary mechanism for dealing with project complexity. While not a problem for the "stand-alone" first era ICT systems, the second and third era ICT systems assume and require a relatively high degree of integration and collaboration across project tasks. Because of this difference, emerging ICT often has difficulties fitting into current practice, and current practice is not able to take full

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advantage of the potential of such systems. This paper suggests that project management practice, enabled by emerging construction ICT, could more explicitly recognize, represent, and manage the interdependencies that are pervasive throughout construction projects, thereby fully exploiting the potential of the ICT to improve overall project performance. Third, a major thrust of third era ICT (typified by technologies such as BIM, IFCs, virtual design and construction [3], and nD [4]) suggests fundamental changes to construction projects in which the project team comes together to produce comprehensive, computer-based, virtual prototypes of all aspects of the construction project as the central activity for the design and management of the project. A full virtual design and construction approach (which would indeed involve significant changes to project management practices) is outside of the scope of this paper, but the issue of addressing project interdependencies through a unified approach to project management (as discussed here) is fully compatible with, and an essential element of, a virtual design and construction approach.

The ultimate objective of the work described in this paper is to produce practical guidelines for modified project management processes. However, this paper focuses on the early phases of research on this topic: developing a conceptual framework for understanding the issue of multiple views and interdependencies in project management, and suggesting a general approach for how project management practice and emerging ICT might exploit this framework. As such, the paper is largely conceptual in nature. Future work will include further development of the proposed solutions and industrial experimentation and validation.

2. Characteristics of views and interdependencies in project management

2.1. Complexity and interdependencies in construction projects

Construction projects are often described as large and increasingly complex. A greater understanding of the nature of this complexity can point to the areas where the need for improved management is greatest. Studies have identified the following characteristics as generally common to any type of complex system [5]:

1. Complex systems are comprised of a multiplicity of things; they have a large number of entities or parts. Generally, the more parts a system contains, the more complex it is.
2. Complex systems contain a dense web of causal connections among their components. The parts affect each other in many ways.
3. Complex systems exhibit interdependence of their components. The behavior of parts is dependent upon other parts. If the system is broken apart, the components no longer function (like the parts of the human body).
4. Complex systems are open to their outside environments. They are not self-contained, but are affected by outside events.
5. Complex systems normally show a high degree of synergy among their components: the whole is more than the sum of its parts.
6. Complex systems exhibit non-linear behavior. A change in the system can produce an effect that is not proportional to its size: small changes can produce large effects, and large changes can produce small effects.

To some extent, all of these features can be observed in construction projects. Construction projects are made up of components such as the physical elements in a building, the design or construction activities, the people and resources utilized, etc. In many cases, the individual components are not complex. Yet the number of components that make up the project is vast, and the causal connections between these components are numerous. For example, a change in the intended use of some space in a building could affect the heating and cooling requirements for that space, which could affect the design of parts of the mechanical system, which could alter the elements of the electrical system, which could change a purchase order for material supplies, which could delay a material delivery, which could influence the construction schedule, which could reduce the productivity of a work crew, which could increase a work package cost, which could affect a sub-contractor's financing, and so on.

Furthermore, the complexity is increasing—aside from the technical complexity of the facilities themselves, trends such as ISO 9001 quality management, public–private partnership financing, sustainability concerns, etc. have increased the number of important interrelated issues that must be simultaneously addressed. Construction projects, then, are justifiably described as complex, largely because of the quantity and interdependence of the components that make up the project. (Here, we have developed the notion of complexity to better understand the issue of interdependencies in construction—yet a deeper mining of complexity theory may well yield many other concepts and techniques beneficial to the construction industry. As Merali and McKelvey [6] describe, "The compelling argument for complexity science is that it provides a wide and powerful lens to define and move around the multi-dimensional 'problem' and 'solution' spaces in a dynamic way, at multiple levels of abstraction.")

The two concepts of *components* and *interdependency*, as two important characteristics of all construction projects, correspond to two concepts that are important characteristics of the way that people manage and carry out construction projects. These are, respectively, the notion of distinct project *views* (incomplete, partial perspectives of the whole project), and *integration*, the degree to which distinct views are explicitly perceived to inter-relate with one another.

2.2. Views and integration in project management approaches

One of the fundamental mechanisms that the construction industry has developed for dealing with complexity is the approach of decomposing project work into well-defined work tasks and assigning each work task to a specialist group. Each group works with the subset of project information that is relevant to their work represented in a form suitable to their particular task, thereby creating a specific view of the project. These tasks are then carried out, to a large extent, as if they are fairly independent from each other. To be sure, each participant has some notion that their work must follow certain work and must precede other work, and that certain actions or outcomes of their work will influence others. Also, a few individuals in the project have explicit responsibility for overall coordination (e.g., the project manager). By and large, however, participants adopt a view that focuses primarily on their individual tasks, with any concerns about these interdependencies addressed in a very ad hoc and reactive way. Most participants try to optimize their own work while the few people responsible for managing the project as a whole have little opportunity to optimize the entire system.

Clearly, it is beneficial to organize work in such a way as to minimize interdependency among work tasks. However, we contend that a weakness of current project management practice is that it tends to treat typical construction work tasks as being far more independent than they actually are. Instead, project management approaches should strive to make the interdependencies between work tasks more explicit. This does not increase interdependence and complexity, but it does make the existing interdependency and complexity more visible, and therefore more manageable. In summary, construction projects are complex because of the quantity and interdependency of their components, and project management techniques should strive to make these interdependencies explicit by increasing the level of integration among the project views.

2.3. Views and integration in project information

All design and management tasks work with information rather than physical resources. This information all describes or models the