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The use of interorganisational ICT in United States construction projects

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ABSTRACT

In recent research, the use of ICT applications in real time construction projects have been documented and analysed extensively. However, there is a need for identifying and analysing in-depth the mechanisms influencing the use of interorganisational ICT applications and for solutions to eliminate potential barriers to the successful use of ICT. A model is developed providing insights in these mechanisms. Based on this model and expert interviews in the United States construction industry directions for solutions to barriers to the successful use of interorganisational ICT — document management applications, workflow management applications, and product modelling applications — in construction projects are formulated. These solutions focus on stimulating the personal motivation to use ICT, the external motivation to use this technology, and facilitating conditions in terms of knowledge and skills and acting opportunities to use ICT.

1. Introduction

The application of Information and Communication Technology (ICT) stimulates a more standardised communication between different actors in construction. ICT is also creating many opportunities for a more efficient and effective project execution. Argyres [1] showed how the use of interorganisational product modelling applications in the aviation industry supported the coordination of design and production activities and allowed the design and production of a high-technology aircraft (B-2 "Stealth" Bomber), which might have been impossible without the use of this application. Numerous scholars have discussed the opportunities and potential benefits of these ICT applications for the construction industry too [2–6]. Boland et al. [3] showed that the implementation of interorganisational 3D CAD in construction projects was a driving force for technological and organisational innovations. The use of interorganisational ICT in construction projects, however, still seems quite limited and not as effective as it could be (e.g., [7–12]). Designing, engineering, and constructing parties all speak their own languages and all have their own approaches. The underlying problem is the constantly changing coalitions of firms working on different projects. Therefore, investments in ICT-applications that formalise interorganisational communication seem to have limited added value in construction projects and have failed to meet expectations.

Several investigators documented and analysed the use of ICT applications in real time construction projects (e.g., [4,8,9,13–18]). Harty [13] suggested that social and organizational aspects need to be taken in account to understand the adoption of interorganisational ICT. Taylor [16] showed that the introduction of 3D CAD in construction requires addressing regulatory, technological and organisational issues. In other words, there is a need for an analysis of mechanisms influencing the use of ICT applications across organisational boundaries and how these mechanisms influence usage over time. Bouchlaghem et al. [4] suggest that organisational and human issues in particular stand in the way of realising the potential benefits of these applications. Potential benefits of ICT-applications in the future can be realised when these mechanisms are understood and solutions found to eliminate potential barriers to the successful use of ICT. The first objective of our research is therefore to develop and validate a model providing insights in mechanisms influencing the use of interorganisational ICT in construction projects. The second objective is to formulate directions for solutions to barriers to the successful use of interorganisational ICT in construction projects.

Based on a discussion of the literature on ICT-adoption and characteristics of the construction industry, a model is developed providing an understanding of mechanisms influencing the use of interorganisational ICT in construction projects. The mechanisms address technological, organisational, and human barriers and drivers to the successful use of these applications. Based on expert interviews, the robustness of our theoretical model is validated in the context of (1) the interorganisational use of ICT in construction projects in the United States, and (2) document management, workflow management, and product modelling applications.

In this research, we define interorganisational ICT as a digital coordination and collaboration tool used for communicating and sharing project information between participating organisations in a

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construction project. We focus on document management applications, workflow management applications, and product modelling applications. Document management applications are used to store, organise, and manage a collection of documents within construction projects in a digital way. Workflow management applications are used to manage the flow of documents and information and to monitor and record the progress of tasks in construction projects. Product modelling applications (e.g., 3D modelling, 4D modelling, building information modelling) are able to support interorganisational cooperation, coordination, and communication as well. These applications can be used to make a graphical model (i.e., representation) of a building object. 4D applications add a further dimension (i.e., time) to 3D applications. Product models can store both graphical and non-graphical data.

The article unfolds in the following way. First, we develop a model of mechanisms influencing the use of interorganisational ICT in construction projects. The second section presents the research design of our study. The third section describes the results of our study in which the interorganisational use of document management, workflow management, and product modelling applications in the context of the United States construction industry is examined. In the fourth section we present directions for solutions based on the analysis of interorganisational use of ICT in the United States' construction industry. We conclude this study by discussing and assessing the contributions of our findings, our research limitations, and the implications.

2. Interorganisational use of ICT in construction projects

In our study, we focus on the key mechanisms that influence the way actors use interorganisational ICT in construction projects. Three influential models about the adoption and use of ICT are the Technology Acceptance Model (TAM), the Theory of Planned Behaviour (TPB), and the Unified Theory of Acceptance and Use of Technology (UTAUT). TAM is considered to be the most influential and commonly employed theory about user acceptance of ICT [19–21]. TAM was designed to predict ICT acceptance and use and has been widely applied to a diverse set of technologies and users [22]. Core constructs of TAM are the perceived usefulness of a particular technology and the perceived ease of use. TPB is a general theory of human behaviour (see e.g., [23]) that is often applied to the adoption and use of ICT [24–26]. The basic idea of this model is that the decision to perform or not to perform a certain behaviour depends jointly on motivation (intention) and ability (behavioural control). UTAUT integrates several existing models about the individual acceptance of ICT [22]. In this model, the intention to use ICT is determined by performance and effort expectancy. Usage behaviour is determined by this intention and facilitating conditions.

In this section, we confront constructs of these models with characteristics of the construction industry. Based on this confrontation, a model is developed consisting of mechanisms influencing the use of interorganisational ICT in construction projects. These mechanisms are related to the personal motivation to use ICT, the external motivation to use this technology, and facilitating conditions in terms of knowledge and skills and acting opportunities to use ICT. In this section, we will discuss these mechanisms.

2.1. Personal motivation to use ICT

A central construct in the three existing theoretical models is the individual's *intention* to perform a given behaviour. Intentions are 'indications how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behaviour ([23], p. 181). The personal attitude or motivation determines the intention to use ICT. Personal motivation refers to the extent to which actors are willing to use interorganisational ICT themselves. Personal motivation influences both the willingness of the actors to use ICT and their willingness to invest resources to overcome barriers to the intended use of ICT. This motivation is in particular influenced by the perceived benefits and disadvantages of ICT use. Analysing the perceived benefits and disadvantages of the different actors involved provides a rich picture on personal commitments and rewards as motivation to use ICT. Individuals are not only motivated by financial incentives or the 'carrot and stick' approach but by a number of other factors as well (see for this discussion also Bresnen and Marshall [27] and Allen et al. [28]). All three models on ICT adoption and use pay therefore attention to perceived benefits and disadvantages of ICT use.

Second, in construction perceived time pressure is a dominant mechanism influencing personal motivation to use ICT. Temporary relations and the short time frames in a project based industry as construction [29] influence personal motivation to use ICT. Two important constructs of the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Technology Acceptance Model (TAM) deal with the factor time pressure: effort expectancy and ease of use. This construct is related to the time investment needed to learn to use ICT. The perceived time pressure and perceived benefits and disadvantages are important factors influencing personal motivation and thereby the intention to use ICT in construction.

2.2. External motivation to use ICT

One important characteristic of construction projects is the importance of interorganisational relations and contractual arrangements. Tendering, in combination with the one-off nature of the work, means that several bilateral contracts are negotiated between participating organisations (e.g., the client, the architect, the engineering firm, and the contractor). Different interpretations of what is included in the contract, also in terms of ICT-applications to be used, gives rise to many conflicts between parties during the building process [30]. Therefore, contractual arrangements are an important factor explaining the use of interorganisational ICT in construction projects. Another important characteristic of construction is the way power is distributed among project participants in a project [13,28,31]. Power can be considered as distributed, but also as something that can be accepted or resisted, especially in case when an actor inside or outside an organization requests another actor to use a particular ICT-application.

So, in construction projects contractual arrangements and the presence of a requesting actor may force other actors in a construction project to use a particular ICT-application. Management of firms in the construction industry often reacts to external factors and do not have a strategic vision on state-of-the-art IT solutions [3,32]. These actors are often forced by *other* actors or external factors to use ICT. This external motivation influences both the use of ICT and the efforts made by actors to invest time and money to overcome barriers to the use of ICT. Both the Unified Theory of Acceptance and Use of Technology (UTAUT), and the Theory of Planned Behaviour (TPB) include a construct that is related to the presence of a requesting actor, but a construct similar to contractual arrangements about ICT use is not included in the models. This can be explained by the context in which these models are developed and used: a student context, or an organisational context, but not an interorganisational context.

2.3. Knowledge, skills, acting opportunities and the use of ICT

Construction is a highly fragmented industry compared to other manufacturing industries [29,31]. In construction projects, often many participants from different organisations have to collaborate on a temporary basis. Each organisation has its own working practices, resources and objectives. As a result, working practices needs to be aligned and interorganisational ICT has to be set up for the course of only one project. The short time frames available to change working