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Sustainability by Information and Communication Technology: A paradigm shift for construction projects in Iran

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ABSTRACT

Anecdotal evidence refers to impacts of Information and Communication Technology (ICT) as an enabler of sustainable delivery of construction projects. This study aims to explore such claims through reflecting on and sharing the experiences of project managers in a developing country. It used a 'sequential exploratory design' (qual→Quan) mixed method approach containing sixteen semi-structured interviews followed by Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis of 101 survey questionnaires conducted in Iran using a hierarchical component model. The findings are presented as a model that quantifies the impacts of ICT on sustainability in delivering construction projects. Results show that process optimization, media substitution, and externalization of control are the means through which sustainability by ICT could be achieved. Having Iran, as the context, the study contributes to the field in two ways. First, the potential to use ICT as a vehicle to facilitate sustainable delivery of construction projects is quantitatively assessed. Second, several ICT-based solutions are proposed to assist in smoothing this transition.

1. Introduction

There is an enormous demand for infrastructure in Iran in order to sustain an accelerated economic growth. However, this comes at a very high cost to the environment (Banihashemi et al., 2017). Developing countries (including Iran) assign a high priority to economic development than sustainable development during delivery of construction projects (Zhang et al., 2014; Gan et al., 2015). Nevertheless, Iran has paid particular attention to adopting and implementing Information and Communication Technology (ICT) to enhance the productivity of construction activities (Alaghbandrad et al., 2012).

The use of ICT has resulted in cost savings, improved communication within project teams, and effective decision-making on construction projects (Sutrisna and Kumaraswamy, 2015). ICT has also resulted in process improvement, automation of project tasks, reduction of waste, and defects avoidance during construction operations (Bowden et al., 2006). Furthermore, researchers have claimed that ICT can help improve sustainability outcomes of projects (Hilty et al., 2011). This premise has triggered a new research direction known as "Sustainability by Information and Communication Technology" (SICT). SICT focuses on creating, enabling and facilitating production and consumption in a sustainable manner by means of ICT (Hilty and Aebischer, 2015) and represents an alternative means for construction projects to embrace sustainability (Inyim et al., 2014). This assertion seems a workable way of introducing sustainability on construction projects. However very little is known about the methods through which this could be achieved (Ikediashi and Ogwueleka, 2016; Diaz-Sarachaga et al., 2017). In essence, research on the interface between sustainability and delivery of construction projects is very limited (Martens and Carvalho, 2016, 2017). Particularly, no explicit

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body of knowledge from the Iranian context has been developed to investigate the impacts of ICT on sustainable delivery of construction projects (Banihashemi et al., 2017).

This study intends to fill these gaps in the body of knowledge. The paper is organized as follows. First, a literature review is presented to introduce the interface between ICT and sustainability, focusing mainly on their links to delivery of construction projects. This is followed by justification of the methods used to conduct the study. Consequently, the results of the study are demonstrated with a discussion followed by outlining the implications for research and practice.

2. ICT in the construction industry

ICT in the construction industry is defined as "the application of decision support tools, which uses electronic machines and programs for processing, storage, analysis, control, transfer and presentation of construction information during the whole life cycle of a construction project" (El-Ghandour and Al-Hussein, 2004, p. 85). In operational terms, ICT refers to the technologies engaged in collecting, transportation, retrieval, storage, presentation, visualization and conversion of information from various forms (Yang and Huang, 2016). ICT can bring about a wide range of enhancements on different areas of construction projects (Lu et al., 2014). These include supporting management functions, enhancing the quality of decision-making, optimization of resources and improving workers' efficiency (Bowden et al., 2006; Alaghbandrad et al., 2012; Alkalbani et al., 2013; Sutrisna and Kumaraswamy, 2015; Goodrum et al., 2016). Use of ICT improves coordination, communication and cooperation among project team members and assists on-site personnel with access to well conveyed data and information (Goodrum et al., 2016; Yang and Huang, 2016).

The construction industry has attempted to tackle a wide range of issues by harnessing the capabilities of ICT (El-Ghandour and Al-Hussein, 2004; Gajendran and Brewer, 2007). Of these, connecting the often fragmented processes of a project through automated and streamlined communication has remained the main application while productivity gains with digitized and standardized document management systems is another benefit (Sutrisna and Kumaraswamy, 2015; Mignone et al., 2016). Building Information Modeling (BIM) as a subset of ICT is a demonstrable example of a successful introduction of such improvements into the delivery of construction projects (Inyim et al., 2014; Mignone et al., 2016). Despite such great potential, construction projects still lag in fully embracing ICT (Fernández-Sánchez and Rodríguez-López, 2010; Goodrum et al., 2016; Ikediashi and Ogwueleka, 2016).

3. Sustainability and construction projects

In recent years, developing countries such as Iran have invested substantial amounts of money on construction activities, triggered by rapid economic growth and urbanization (Ghoddousi and Hosseini, 2012; Namini et al., 2013; Gan et al., 2015). To minimize the detrimental impacts of such massive upsurge of construction activities, these countries are promoting sustainable delivery of projects (Ugwu and Haupt, 2007; Shi et al., 2014). Sustainable delivery entails integrating principles of sustainability into activities throughout the whole life cycle of a project (Gan et al., 2015). This includes every actor involved in a project being committed and responsible for undertaking sustainable practices. Despite this strategic focus, challenges such as unstable economy, lack of transparency, corruption, and lack of awareness hamper the proposed shift towards sustainable practices (Gan et al., 2015). The problem of translating these strategic objectives into concrete actions at the project level has remained unresolved in these countries, with a similar problem affecting Iran (Banihashemi et al., 2017). As articulated by Ugwu and Haupt (2007, p. 678) "sustainability as a concept is not being effectively put into practice at the project level". Silvius and Schipper (2014) studied factors that hamper the implementation of sustainability practices on projects and lack of technology was identified as a major barrier. Shi et al. (2014) asserted that implementing sustainable practices relies on the use of modern technology that enhances collaboration among the actors involved. Researchers agree that ICT is highly effective in supporting sustainable delivery of construction projects (Bowden et al., 2006; Inyim et al., 2014).

4. Sustainability by Information and Communication Technology (SICT)

ICT is believed to have great potentials for supporting sustainable development on any production or services activity (Hilty et al., 2006; Klimova et al., 2016; Salahuddin et al., 2016). Hack and Berg (2014) asserted that ICT facilitates access to transparent information, enhances accountability, increases accuracy of data, enables automation and integration of activities, elevates the level of agility, and generates insights for better decision-making and optimization of processes. To link these two worlds of ICT and sustainability, several areas of applied research have emerged (Hilty et al., 2011). As illustrated in Fig. 1, the interface between ICT and sustainability combines methods from ICT-oriented disciplines (e.g. computing and communications) with the environmental and social sciences. This has resulted in establishing five fields of research shown as subsets of ICT→ Sustainability (see Fig. 1). These comprise "environmental informatics" in which ICT methods are combined with environmental management science for information processing. "computational sustainability" deploys techniques from computer science, mathematics and statistics to balance environmental, economic, and societal needs. The "sustainable HCI" field is a sub-set of Human-Computer Interaction (HCI) that considers interactions between humans and technology to serve sustainable practices. "green ICT" is comparable with Sustainable HCI, yet the focus on using ICT to support sustainability (Hilty and Aebischer, 2015). The premise of "ICT for sustainability" denotes that the transformational potential of ICT can be utilized to make any type of production more sustainable. This field is categorized into two subfields, these being "sustainability in ICT" and "sustainability by ICT" (SICT) as illustrated in Fig. 1. Sustainability in ICT operates with the aim of reducing material and energy consumption of a product over its life cycle to make it more sustainable. SICT, however, is aimed at "creating, enabling, and encouraging sustainable patterns of production and consumption by means of ICT" (Hilty and Aebischer, 2015, p. 21). The focal point of SICT in operational terms lies within the use of ICT to support sustainable lifestyle for products such as design of durable products and waste reduction. SICT also targets sustainable production processes through the application of ICT for simulation, spatial data processing, innovative data exchange, communication methods, networks, etc. (Hilty and Aebischer, 2015). SICT enables organizations to capture, process, manipulate and share data and information, improve transportation, use smarter automated methodologies, reduce energy and material consumption, and hence improve overall efficiency (Hilty and Aebischer, 2015; Añón Higón et al., 2017).

5. The conceptual model of the study

Despite construction's uniqueness, use of principles of production management to improve project delivery has been promoted by many researchers in the past (Koskela, 1997). Particularly,