An Empirical Investigation on Construction Companies' Readiness for Adopting Sustainable Technology

M. Foroozanfar[a], S. M.E. Sepasgozar [b] and H. Arbabi[c]

[a] Department of Construction Project Management, University of Tarbiyat Modares, Iran
[b] Faculty of Built Environment, University of UNSW, Australia
[c] Department of Construction Project Management, University of Tarbiyat Modares, Iran

Abstract

New digital technology has the potential to decrease the environmental footprint of construction activities, while they increase the productivity and safety involved in major construction projects. Digital technologies such as web-based building information modelling (BIM) and sensing technology are emerging technology that can be widely employed in construction projects in developing countries. However, the construction industry tends to be slow in adopting new digital technology to meet their objectives in developing countries. This paper aims to investigate construction technology readiness for utilization of digital technology in construction projects and to identify the factors that can potentially facilitate construction stockholders' application of digital technology.

A questionnaire is designed, and an empirical investigation is conducted to collect data from construction companies including industrial and infrastructure construction companies. Regression analysis was utilized to analyze the data to measure the relations of latent factors through significance values using SPSS. The findings show the importance of a series of factors influencing construction stakeholders' intention to use a new digital technology. Based on the extensive review on the relevant literature, few empirical studies have been conducted to examine the proposed constructs including innovativeness and optimism for emerging digital technology. The results are also expected to provide a guidance to broaden understanding of adoption behavior within this context and thereby increasing the chances for successful adoption of sustainable technology and develop activity-level.

Keywords

Construction Industry; Digital technology; Sustainability; Technology Adoption.

1 Introduction

The construction industry has been under pressure to move toward the sustainability because different governments have legislated regulations for protecting the environment [1]. A large number of organizations tend to increase their sustainable practices to save their resources and competitive advantage [1]. The intention for implementing sustainability concepts in construction projects has increased uncertainty and complexity and created many challenges for construction stakeholders [2]. On the other hand, organizations need to make decision about the utilization of new technologies to be competitive in the industry. That is why construction stakeholders tends to apply different technological tools to meet the requirements sustainability in all phases of projects [1].

One of the most effective information technology toward sustainable construction is digital technology which its influence on construction industry has become greater. The digital technique cover the entire process of building program from design to construction [3]. In today's digital world, innovative solutions for projects managers to solve problems of coordination and delivering projects on-time, on-budget and according to its scope and sustainability specifications are presented by digital technology such as web-based technique; however, there is no comprehensive understanding on how this technology is implemented in construction industry [4]. In addition, the construction industry is slow in up taking digital technologies and there are challenges during the implementation phase [5].

To address this challenge, the aim of this study is to empirically examine the factors affecting construction stakeholders' adoption of digital technology and to investigate the research question in this study: what are the effects of the organizational, social, technical, and individual factors on adoption behaviors as related to digital technology by construction stakeholders?

The paper first systematically reviews the literature. It follows with presenting how the literature of digital technology applications is growing while the number of publications which presents green technologies has been constant in the last three years. Second, the research design and approach are presented. Finally, the results of

the study are discussed following with an agenda for future research.

2 Literature review

This section systematically reviews the most recent literature in both green and digital technologies. Figure 1 presents the process of the technology transfer in the construction industry from technology development to implementation. This paper focuses on the adoption phase referring to the process which a company make decision to utilize a modern technology.

In order to systematically analyses the most recent literature three journals were selected such as Journal of Information Technology in Construction, Building Research & Information and Journal of Construction Engineering and Management then their papers were reviewed. Each of journal is devoted to a different special topic, so by choosing them a wide range of articles were reviewed. Regarding green technology, we classify papers in to four non-green specific non-technology, green specific non-technology, non-green specific technology and green-based technology categories. Figure 2 illustrates the number of papers in two non-green specific technology and green-based technology categories in three recent years. It shows rapid growth in non-green specific technology papers in 2016, accordingly it can be predictable that by improving of the technology, this increasing trend will continue in the coming years. However, the figure shows despite of the increased sense of responsibility to sustainable development, the researchers neglected focusing on green technology adoption. Figure 3 demonstrates that green specific technologies are reviewed less than non-green specific technologies, and it shows that researchers should be encouraged to pay more attention to the gap of green specific technology adoption in construction.

Based on the current review, four main themes were identified: 1) Off-line digital technologies; 2) BIM based technologies; and 3) web-based technologies; 4) Green technologies. Each theme is reviewed in the following sections. The most recent technologies intend to address sustainable concerns and therefore tend to identify new applications for decreasing the environmental footprint of construction activities.

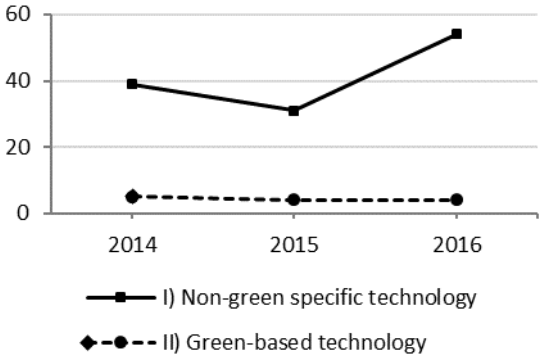

Figure 2 total technology related publications in three mentioned journals in tree recent years

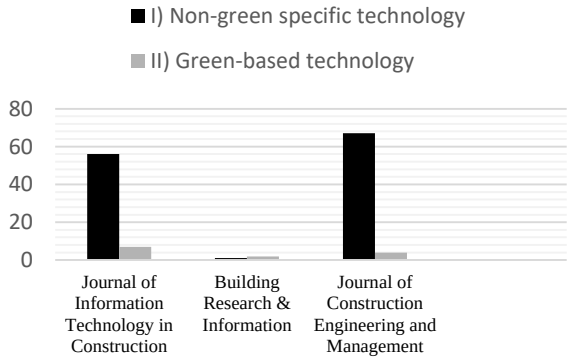

Figure 3 technology related publications in each of the three mentioned journals

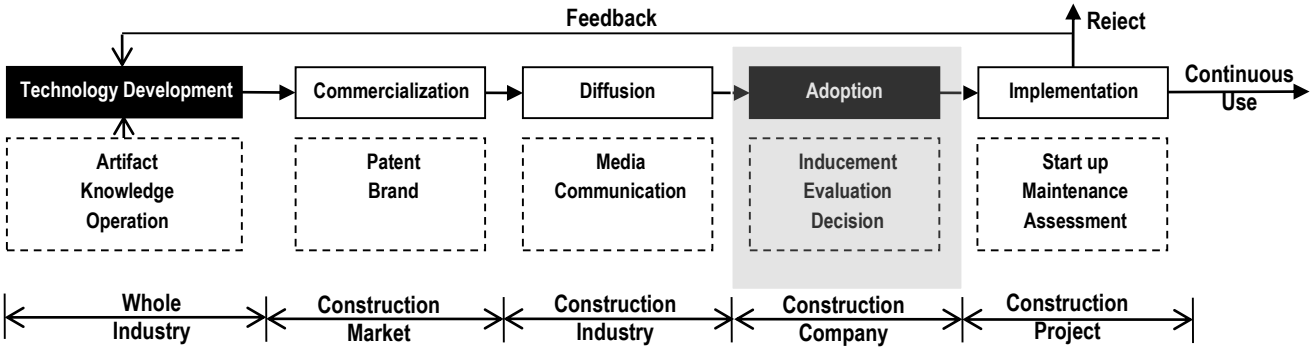

Figure 1 The process of technology transfer in the construction industry

2.1 Theme 1: Off-line program

Construction digital technologies such as digital leveling devices, building information modeling, 3D printers, smart roads, transparent solar panels, smart helmet and anti-collision software are increasingly being used in the construction industry as a new trend. For example, drone is an aerial quadcopter that is armed with video cameras, in construction industry drone enables project managers to monitor the site, maintain the asset and capture images and videos from different positions throughout the worksite [6, 7], and virtual reality contains real life images which helps us to analyze building structures in different environmental status or to promote construction safety [8, 9]. This paper refers to a Construction digital technology as any type of electronic device that is used for visualization, process, monitoring, tracking and etc.

Construction digital technology in construction industry use for different purposes such as management and delivery of projects [10]. Construction digital technology is used in all of the phases of the life cycle of the construction projects from project design to construction for different purposes [3]. Such as building lifecycle management, digital representation of information using different visualization and modelling techniques and software applications or coordination and management issues around digital delivery of projects. Although offered definition focuses on the technical aspects of construction technology, it contains practices and processes that support technology [10]. These technology include tools and technology which are independent, integrated and web-based and apply to capture, store, process, display and communicate data and information in different phases of construction [11].

2.1 Theme 2: BIM based technologies

Building information modeling (BIM) has been developed recently in the construction industry. By using BIM we can increase project quality, schedule timetables accurately, and reduce total costs of the project [12]. BIM is a technology which is used in construction industry to generate and manage a parametric model of a building to decrease document errors and rework, and reduce the time of the design process Son, et al. [13]. Using BIM enable project team to create and use digital models, to design construction and to manage operation of the construction process and finally to achieve the project life management [14].

2.2 Theme 3: Web-based technology

The character of the construction industry's organization is unique because the nature of its projects is one-off in planning and operation. Each project has its own challenges, risks and problems which are different from others but experiential knowledge and information data are important to solve these problems and challenges. Besides, each construction project is a temporary organization which is the combined of several organizations, it has a multi-participant feature; there for, exchanging information is critical for it. In each phase of project and for solving the problems, relevant organizations should collaborate with each other to obtain solutions and determine appropriate concessions [5].

One of the construction innovations is in the area of IT which is developing rapidly, such as several tools software with different usages including, quantity calculation software, cost evaluation software and quota management software. One of this applications that has an upward trend growth is in the field of communication networks, which enables the involved stakeholders to exchange information and data. These web-based communication networks can enhance the coordination and cooperation among team members [5]. Web-based platform solution apply latest progression in computing technologies, using it enable us to access to sustainability resources in the form of interactive, dynamic, and user-oriented services seamlessly (Petri, Beach, Rezgui [1]. There are several applications of information and communication technology in construction industry as are shown in table 1. Table 1 shows different types of technologies that are introduced or implemented for construction purposes. In addition, it shows that the recent information and communication technology products are more complicated and may need specific considerations for utilizing in construction projects.

2.3 Theme 4: Green-based technology

One of the most critical factors in reaching the goal of sustainable construction, is using the new technology in this field, but most of these technologies have their own complex nature and operational challenges that prevent the successful use of them or reduce their application. Therefore, to achieve sustainability objectives, relevant technical considerations must be investigated. For example, alongside the development of new sustainable construction technology, the efficiency and effectiveness of existing technology must be improved, so their weaknesses should be known; besides, access to technical standard procedures, suitable guides and adequate and reliable data about the performance of sustainable construction technology can encourage participants to use these technology [15].

One of the modern technology with increasing usage for sustainable construction is digital technology. Some studies indicate that IT and digital technology and software are so significant in reaching environmentally

friendly features into construction projects helping in analyzing the sustainable building performance such as daylighting, energy efficiency and sustainable materials [16]. Digital technology enable stakeholders to cooperate and communicate with each other effectively to equilibrate the artistry and function of buildings, it provides the condition for related participants to carry out various analysis about energy consumption, carbon balance, lighting and noise. On the other hand it enables experts to simulate physical environment which will be helpful to design and built a building with low energy consumption and carbon balance [3].

Table 1 Example of technology applications for all identified themes

Theme	Non-Green Specific Technology	Theme 4: Green-Based Technology
Theme 1: Off-Line Program	Computer Aided Architectural Design (CAAD) to integrate different applications of Architecture Science, Artificial Intelligence and Graphics [3]	physical environment simulation software to analyze energy consumption [3]
	Analyzing information of the construction and managing the documents in digital form [17]	Sustainable Construction Modelling evaluate sustainability of the construction by the system [18]
Theme 2: BIM Based Platform	Integrating the project management and cost estimating with three-dimensional (3D) model [12]	Determination the orientation of the building, studying daylight to determine buildings position on the site and Calculation of the carbon emissions and usage operational energy [12]
	preparing a more simplified business process and provide solutions to decrease costs and increase productivity and efficiency through effective communication in remote construction projects [19]	Advanced simulation of energy, realization of the design problem regarding to energy, such as thermal comfort [14]
Theme 3: Web-Based Tchnology	Web-based Enterprise Resource Planning to manage construction supply chain [11]	BMS system for doing energy management initiatives [20]
	Using video cameras to control and monitor construction sites remotely [21]	web-based self-assessment prototype tool to manage sustainability at the strategic level of corporate [2]

Most of the construction stakeholders are familiar to web-based services such as e- mail, network news, remote login, and file transfer, these new opportunities help them to move toward improved sustainable construction processes because by using them construction stakeholders can achieve accurate project information in needed formats, anywhere and anytime without delay across the world. Even they can have a live vision of site location happenings if they aren't able to be there which is really critical for sustainable construction goals. By these web-based applications, virtual online design studios are available that enable stakeholders to interact and discuss applying auditory and pictorial conferencing, online electronic bidding systems helps us upload, download and update the documents online and reduce the paper usage, time and cost of bidding, using on-line project administration systems can help us to access the on-time information project status and specifications, control reports and submit on-line change orders. Web-based catalogues are building product information sources which include numerous information about products such as their performance data, standards, and instructions of installation which enable us to order on line; therefore, we can save time and energy. Moreover, web-based technology provide the opportunity to monitor and control the project via web cams [21].

2.4 DCT concepts and adoption barriers

The literature shows that current DCT application and practices can be divided into three types of studies: a) technology development, b) technology adoption, and c) technology implementation.

The first group of studies are based on field experimentations to develop new prototypes to introduce it to the construction industry or improve a current technology in terms of accuracy and quality.

The second studies present or use models that are drawn from the established body of knowledge predominately such as socioeconomic or psychological models. For example, Son, et al. [13] showed that two distinct constructs (usefulness and ease of use) are positively associated with an individual's behavioral intention to utilize a new technology in construction. Some other studies tend to understand the adoption process through an exploratory process which is mainly case based study. For example, Mitropoulos and Tatum [22] investigated factors affecting the adoption of information systems in construction, and the results of such exploratory studies are not necessarily tailored or adjusted with classic models in information systems.

The third group of studies focus on the way of operating an innovative technology to resolve a specific problem in construction. For example, Wang and Cao [23]

review main project-level factors which influence IT implementation and analyze how these factors effect IT implementation in construction industry. In other paper the implementation of user-based innovative construction technologies in Australia is investigated and it's studied if the construction industry environment is supportive for innovation or not [24].

One of the important points of interest in the investigation of influencing factors on construction stakeholders' decisions for application of digital technology is recognizing the challenges of them. These challenges can be divided to the challenges of the own technology and the problems of the digital technology' application. The following table is a collection of well-known own technology challenges.

Table 2 The application of digital technologies in two major groups: a) green-based; and b) non-green specific technologies

	Technology Theme	Focus and Current Direction	Limitation and Suggested Improvement
Green-Based Technology	Theme 1: Off-line program	To develop a simulation tool for predicating carbon emission by virtual prototyping technologies [25]	The current tools cannot monitor construction mechanisms and evaluate the sensitivity of planning schedules
	Theme 2: BIM based platform	To generate documentation necessary required for green building certification [26]	Limited to only a group of the BREEAM materials and compatible with ArchiCAD® software
	Theme 3: Web-based technology	To develop BIM-based web platform for green building services such as energy simulation and code checking [27]	Technically limited functions are delivered and cannot cover critical qualitative factors such as human comfort
Non-Green Specific Technology	Theme 1: Off-line program	Computer Aided Architectural Design (CAAD) to integrate different applications of Architecture Science, Artificial Intelligence and Graphics [3]	The function of the technology is limited to design and architecture. The technology should be compatible with other information available in construction sites
	Theme 2: BIM based platform	The design process is improved, because values are generated through waste control and management [28]	The linkage between the project design information and the project support information should be improved for sustainability purposes
	Theme 3: Web-based technology	To develop a web-based performance management system for supplier selection and monitoring their performance [29]	The system should be integrated with the current systems (e.g. project databases, tender documents) considering their green practices

The main reasons of the slow technology uptake are cost, too many functionalities, rework problems due to data entry, difficulty in learning and complexity in usage, requiring computer knowledge, less user-friendly characteristics and low efficiencies. Lack of ability to use some of these technology in the early stages of design reduces its performance in this field and lack of integrity of some of the analytical tools with key software, uncertainty and distrust in data sources, persistence to making change in lifestyle of the project, industry and organizational realized barriers, can prevent its widespread application [1, 3, 30].

It is proposed that a construction company should seek for possible solutions for a need or to improve the current situation. For example, to boost the productivity of construction in restricted areas, mini-equipment as new technologies used extensively [31]. On the other hand, vendors correspondingly support the potential adopters in several stages. For example, the vendor support the customer by know-how knowledge Hommels, et al. [32] and awareness Frambach and Schillewaert [33] as crucial stages to the success of a technology innovation.

Several innovations are used in construction industry for different purposes such as increasing speed or reducing the time but some of them are related to sustainability, for instance for suit sustainable construction and energy efficiency we can use improved design, for reducing energy consumption in old buildings we can retrofit solar passive principles to them, new building materials can be used for insulating or improving environmental efficiency. Thorpe, et al. [34], argue that these innovations are used because they are 'good ideas' and key drivers for business which increase the competitiveness as the point of difference and using them causes the improvement of reputation, prospects, productivity and profit.

3 Research Method

3.1 Participants profile

Construction stakeholders who use digital technology in their projects with the aim of sustainability are studied in this paper. A total number of 60 construction project participants from different construction companies were

selected for the survey. In these companies considering the principles of sustainable construction is a priority. The survey was conducted using a questionnaire for data collection. Sufficient description is provided to prevent the misinterpretation by respondents. All of the respondents had experience using sustainable construction digital technology. Of the respondents in the survey, about 40% were men and about 60% were women. 100 %of the respondents had university degree. They were aged between 27–47 years. The sample demographics are listed in Table 3.

3.2 Measurements

The survey is divided into two parts. The first section solicited demographic information including gender, age, education level, job title, and tenure with the company. The second section asked the respondents to indicate their level of agreement with 42 different statements (the measurement items) on a five-point Likert type scale, with 1 displaying "strongly disagree" and 5 displaying "strongly agree." the measurement items were adapted from previous studies and reworded to render the items relevant to digital technology usage. Measurement items are grouped according to the six main constructs (organizational facilitating conditions, expected performance, expected efforts, innovativeness, optimism, and user performance), for each construct 5-8 questions were designed to assess the impact of 4 independent variable (Table4) on dependent variables (perceived usefulness and perceived ease). Regression analysis was utilized to analyze the data to measure the relations of structures through significance values using SPSS. Finally, respondents were asked to express their opinions in the form of a number of open ended questions.

Table 3 Demographic attributes of the respondents

Characteristics	Number	Percent
Gender		
Male	24	40
Female	36	60
Education		
University	19	31
Graduate school	41	69
Age		
20-30	12	20
30-40	42	70
≥40	6	10
Job title		
Consultant	12	20
Designer	14	24
Supervisor	9	15
Contractor	10	16
Client	3	5
Workshop manager	6	10
Project manager	6	10

Table 4 Definition of independent variables

Abbreviation	Independent variables	Definition
UP	User Performance	The user's efficiency for performing a duty, which refers to the conducted act's accuracy and race in the period of a task [35].
OFC	Organizational Facilitating Condition	Availability of different technological and organizational resources, such as opportunities, science, and resources which can enable employees to eliminate the obstacle of applying a system [36].
O	Optimism	A positive belief that by technology application and people can have more controllable, flexible, and proficient life which cause people have a positive opinion about technology [37].
I	Innovativeness	Innovation is carrying out new or current operations by a new method which has been defined in respect to new production, new operations, new materials, new organizational structures [38].

4 Results

In this research, to recognize the key factors that facilitate the digital technology implementation in construction industry an analysis was carried out. To achieve this aim, the relevant literature was reviewed to identify the associated factors with the adoption of digital technologies in the construction industry. Accordingly, researchers such as Davis [39] proposed that two internal factors -perceived usefulness and perceived ease of use determine the intention to use of the technology and some external factors influence on these two internal factors. In this paper, the effects of the four independent variables such as organizational facilitating conditions, innovativeness, optimism, and user performance (which are described in Table 4) on the internal factors are studied.

Firstly, for testing the internal consistency as a measure of reliability for each sub-scale, the Cronbach's alpha was assessed. According Nunnally [38], alphas above .70 for group analyses are acceptable. In this research, the Cronbach's alpha is .706 which indicates it is acceptable and no item shouldn't be excluded. Regression analysis was conducted to estimate the relationships among dependent and independent variables, in model summary, R factor shows the intensity of the correlation between two variables while the conditional expectation of the dependent variable given the independent variables is determined through R^2. The results of ANOVA illustrate if Regression model can significantly predict dependent variable changes, if Sig. in Coefficient is less than 0.05, the correlation is meaningful. The Beta analysis shows the amount of dependent variable impact on independent valuable.

Table 5 Results of the Regression analysis of Independent variables and perceived ease of use

Model Summary	
R	R Square
.668a	.447

ANOVA					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	6.010	4	1.502	9.890	.000b

a. Dependent Variable: perceived ease of use

b. Predictors: (Constant), UP, OFC, I, O

Coefficients					
Independent variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
OFC	.255	.129	.247	1.982	.004
I	.282	.074	.508	3.821	.000
O	-.011	.141	-.012	-.082	.935
UP	.131	.097	.161	1.348	.184

The results indicate that there is a significant correlation between the four mentioned variables and both internal factors although the correlation intensity for perceived ease of use is greater; also, the results demonstrate that the four independent variables can explain perceived usefulness for 33% and perceived ease of use for 44%.

Table 6 Results of the Regression analysis of Independent variables and perceived usefulness

Model Summary	
R	R Square
.577a	.333

ANOVA					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	10.261	4	2.565	6.110	.000b

a. Dependent Variable: perceived usefulness

b. Predictors: (Constant), UP, OFC, I, O

Coefficients					
Independent variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
OFC	-.356	.214	-.228	2.200	.005
I	-.099	.123	-.118	-.806	.424
O	.501	.234	.346	2.140	.004
UP	.601	.162	.485	3.708	.001

Table 5 and 6 show that these 4 structures can significantly and appropriately predict the two dependent variables and among the independent variables, user performance is the most significant variable for perceived usefulness that can explain it is up to 48% and innovativeness is the most effective variable for perceived ease of use that can explain it is up to 50%. Following tables illustrate the result of Regression analysis.

According to the results, positive relationship between user performance and two dependent variables shows that if the efficiency of a user is improved by using a technology, he or she recognizes it more useful and if it could enhance his or her efficiency it states that using the technology is easy.

The positive relationship between optimism and two dependent variables indicates that optimistic individuals toward the technology find it more beneficial and easy to use.

The relationship between organizational facilitating conditions and two dependent variables significantly positive which implies that if fewer obstacles in the use of technology prevent users for adopting technology and needed technological and organizational resources are available, they will recognize it more useful and easier to use.

The positive relationship between innovation and two dependent variables suggests that if a technology causes innovation creation in the process of company which results in competitive advantage, individual finds it easy to use a technology and has a positive opinion about the efficiency of it.

5 Conclusion

The paper was aimed to identify key factors influencing the companies' decisions in terms of digital technology implementation. The current literature is paid enough attention to the process of technology adoption in construction; however, none of them evaluates the readiness of construction companies regarding to the process of digital technology considering sustainable approaches. This paper contributes to the body of knowledge by developing an initial framework for measuring readiness index for predicting the possibilities of successful implementation process in a construction company.

The results show that the participants prefer to use a technology that links to the context of innovation and creativity in the company and create a competitive advantage for their company. The results also show that 'easy of learn' and 'ease of use' are two main factors influencing the companies' decision to use a new technology. In addition, the results show that the high cost of technology, lack of financial support, lack of executive specialist, resistance of traditional systems, the uncertainty of the return of investment, lack of encouragement of the government, unfamiliarity with equipment performance would prevent the use of the technology.

Respondents believe that by holding training courses,

promoting the corporate culture, informing about the advantages of sustainable construction technologies usage and legalizing it, adopting motivational tools and using penalties, the rate of green technology adoption can be increased. Furthermore, major environmental impacts of construction projects should be identified and the culture of sustainable development at all levels of the company should be created to increase using green technology. Future studies should apply the proposed model in different contexts to examine and identify how a new green technology can be utilized in a shorter time.

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7 Appendix I:

The following selected questions were asked from the participants.

Table 7 Selected questions

Identifier	Proposed Factors Influencing the Successful Implementation of Sustainable Construction Technology By a Company
OFC12	Organizational culture affects the decision to use the technology.
OFC12	Motivational mechanisms of the senior managers affect my decision in the use of technology.
EP5	Creating competitive advantage resulting from the use of technology affects my company decision in the use of technology.
EE3	Feasibility of applying this technology without prior experience affects my company decision in the use of technology.
EE5	Adoption of sustainable practices or procedures (e.g. waste management) affects the decision to use the technology.
EOU1	Ease of learning how to use technology affect my decision in the use of technology.
EE11	Creating the innovation in the process of company by using the technology, affects the decision to use the technology.
O5	Improving the quality of provided services by using the technology, affects the decision to use the technology.
UE1	Enhancing job performance using technology, affects the decision to use the technology.
UE3	Increasing individual motivation using technology, affects the decision to use the technology.
	Open Ended Questions
OP1	How is the decision-making process regarding the utilization of a new sustainable technology in your company?
OP2	What prevents the successful use of sustainable construction technology?
OP3	What are the challenges of sustainable construction technologies usage?
OP4	What are your solutions to facilitate and accelerate the use of sustainable construction technology?