A REVIEW ON THE FACTORS OF IT INFRASTRUCTURE FLEXIBILITY: A CONSTRUCTION INDUSTRY PERSPECTIVE

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ABSTRACT: Construction managers nowadays are facing with tremendous pressure to plan, implement, and adopt new technology solution due to the rapidity of technology changes. The future information technology (IT) trend will be looking at technology that can accommodate the technological changes. In this context, the concept of IT Infrastructure Flexibility (ITIF) helps the construction organization in handling the rapidity of technology changes without need to re-invest for a new technology. The aim of this paper is to provide a conceptual understanding on the ability of IT to respond to changes in business demand by exploring the factors that could be used to measure ITIF from a construction industry point of view, resulted from a lack of study that have been done to measure ITIF in this industry. The study is based on extensive reading of published works range from 1995, when the concept was first introduced, till 2010. The works were gathered from journals, books, and other information sources available on the Web. From the literature, the important dimensions of ITIF that could assess IT infrastructure in construction organizations fall under three aspects, namely; technical, people, and business process. This finding will provide potential information about each dimension in measuring ITIF where these dimensions indicate the factors that can be used for evaluating ITIF and recognize the elements for the development of ITIF strategies. By understanding these dimensions, construction managers will know the weakness and strength of their IT system and will ease the evaluation strategies and opportunities to increase ITIF and the resulting business value through increased IT effectiveness.

Keywords: IT infrastructure flexibility, IT infrastructure, IT revolution, technology adaptation, construction industry.

I. INTRODUCTION

Information technologies (IT) will continue to be predominant agents of change within the construction industry [1, 2]. Yet, IT environments today are dramatically different from the host-centric systems of 20 years ago. Today, IT systems span complex networks with multiple access points and servers, hundreds of software components and thousands of computing devices [3]. IT changes rapidly. Due to the e-commerce revolution, it may be changing faster than ever. Years ago, the use of PCs dominated the construction industry, but now the industry is no longer relying on PCs solely. The integration of computer based, 3D imagery in the design, planning and construction process becomes an essential part of a business that cannot be forgone. As the level of service in all industries continues to improve, customer expectations for certain level of service in the construction industry are set. For example, clients demand accurate information on project history, status, and financial performance, as well as customer history and projected business must be readily available and accessible to support these expectations and provide a competitive edge.

Up till now, Froese [4] claimed that the construction industry lags other industries in its rate of IT adoption. The industry has always become one of the lowest investor in IT [5-7]. The fragmented nature of the construction industry makes the industry hard to adapt IT [8]. Construction organizations have to face the fact that IT implementation can take many years to complete, and it is very expensive where it costs thousands or even million of dollars (Fig. 1). To spice things up, there is no guarantee of a successful outcome even with significant investments in time and resources. This characteristic becomes a contributing factor to why construction industry has ranked as one of the lowest investor in IT as construction industry consists majority of small-medium enterprises [9, 10]. Smaller organizations tend to be less IT intensive due to IT investment being risky and uncertain, which will be more difficult for these organizations to bear.
To understand how construction organizations handle the rapidity changes of technology, this paper explains how IT infrastructure flexibility helps construction organizations in managing this situation. This paper would further deepen our understanding on each factor that could be used in evaluating the flexibility of IT infrastructure by construction organizations. Understanding this issue is important for both practice and research because of its potential to provide information about how we can manage the technological changes in order to develop a strategy to face the future so that the construction industry could uptake new technologies steadily than before.

II. METHODOLOGY

The data and findings presented in this paper are mostly taken from secondary sources. The information was gathered from journals and literature books with a focus on the IT technology changes and trends research from which majority of them are from 2000 to 2010. The source materials of the data were obtained from the Scopus database, Google Scholar, and Google Web. In order to update the information for the findings, the Internet was used as an important source.

III. REASONS OF SLOWER TECHNOLOGY UPTAKE BY CONSTRUCTION INDUSTRIES

In comparing with other industries, there are constraints placed on innovation within construction because of the characteristics of the industry. Adversarial culture and fragmented nature are the main aspect that differs construction from other industries; owing to exclusivity and complexity of each construction project [12-14]. Further, construction projects involve many and distinctive parties in a construction project, where every parties have different value systems and methods of working in their own company [13, 14]. Thus, each organization has dissimilar level of readiness in adopting IT [14]. In addition, the construction industry consists majority of small-medium enterprises [9, 10]. In term of construction products, they are discontinuous and temporary where every project is unique and is carried out by one-of-a-kind team players and in one-of-a-kind processes. This project-based nature creates problems for rapid assimilation of new ideas within construction firms. Construction projects involve a very large investment, too.

On top of this, the other reasons lie on the features of IT implementation. IT development can take many years to complete, and the product is very expensive, yet none can guarantee of a successful outcome. The investment of IT is not solely on the product, but also it needs a longer-term investment for its maintenance, upgrading, and staff training and skills. As technology change very fast, construction organization needs to allocate some company’s investment for this. Because of these reasons, construction organizations tend not to take the risk of uptaking new IT thus makes the technology invention in construction industry slower compared to other industries.

IV. UNDERSTANDING IT INFRASTRUCTURE FLEXIBILITY

Facing the technology change is a big challenge for any organizations. Alsagoff [15] strongly proposed that organizations need a long-term framework that aims on changing business relationships from adversarial to an integrated mindset and creating value through flexibility and customization. Not just in management context, IT infrastructure itself needs to be flexible enough. As accord to the latest KPMG’s survey [16], it shows that 450 CIOs worldwide who had responded have agreed that IT infrastructure needs to have an ability to react to changes. Many gigantic companies have embarked in research concerning IT infrastructure flexibility such as IBM, Butlergroup, Oracle and Forrester Research. In academic journals as well, there has been an increasing interest in measuring the flexibility, as it is the particular characteristic in IT infrastructure that has a critical impact on the enterprise’s ability to use IT competitively [17-26]. By having a strategy in facing the technology change, it will help construction organizations to save cost and at the same time could get optimum benefits.

A. Definition of IT infrastructure flexibility (ITIF)

IT infrastructure flexibility (ITIF) has been a topic of discussion in academic, however many other terms have been used but have similar meaning to IT infrastructure flexibility (ITIF), for example IT Elasticity, On-Demand, Agile IT, Real-time Enterprise[15]e and Organic IT [27]. These terms vary based on their focus regarding the scope of IT processes, strategies, methods, and/or tools to achieve true ITIF [27]. In literature, however, a term commonly used is ‘IT infrastructure flexibility’.

Flexibility, in a broader scope, is emerging as a key characteristic of all types of resources that involve hard and soft matters. These include people and tools, and processes [28]. The term flexibility reflects such characteristics as the ability to control outside environment effectively [29] which is able to be used for a variety of tasks, responsiveness to change, or able to be easily transformed [28]. On the other hand, the term infrastructure, within the industry, is referred to the networking and platform components of the technical architecture [27]. Its meaning has been broadly applied within research to indicate the rapid deployment of technology through a firm’s existing technology and personnel-based resources [18, 30].

Hence, ITIF is defined as “…the ability to easily and readily diffuse or support a wide variety of hardware, software, communication technologies, data, core applications, skills and competencies, commitments, and values within the
technical physical base and the human component of the existing IT infrastructure”. This definition was proposed by Byrd and Turner [18] and it is widely been used in research papers.

B. The evolution of views about ITIF dimensions

Since it was first introduced, ITIF has been defined by Duncan [22] as an aggregation of technology components. When the time goes, Byrd and Turner [18] proposed the dimensions of ITIF lie on a combination of technology components and human factors. Paschke, Molla & Martin [31] then extended these views to include business process in the dimensions of ITIF, which comprising resource planning and management factors that affect the capabilities of IT. Please refer to Fig. 2.

![Figure 2: Views of ITIF dimensions](image)

V. FACTORS IN MEASURING ITIF

The factors of ITIF are widely discussed in the academic research. Consistency of the factors proposed can be seen, however there are some extensions of factors suggested by latest research. The followings are the summary of all the factors from literature review. Please refer to Fig. 3.

A. Technical dimension

In most studies of ITIF, they are three factors that have commonly discussed by many researchers, namely connectivity, compatibility and modularity [18-20, 24, 27, 30-34]. Few researchers included an extra variable for data transparency/integration/management, this is, however, is part of Duncan’s [22] original classification and plunges into the categories of compatibility and modularity. The followings are definitions of these three technical factors:

- **Connectivity** – the ability of any technology component to communicate with any of the other components intra or inter organizational environment [22, 24] which helps to facilitate the sharability of IT resources at the platform level [35].
- **Compatibility** – the ability to share any type of information across any technology component throughout the organization [22] and across organizations [24].
- **Modularity** – the ability to easily reconfigure any technology component with no major overall effect [18, 22, 24, 36].

B. People dimension

As accord to many researchers, skilled and flexible IT personnel contribute in achieving flexibility in IT infrastructure [18, 20, 30, 31, 34]. It refers to a person, or a professional team who has knowledge, skills and experiences required to manage IT resources within organizations and at the same time understand the organization’s business.

C. Business process

Business process needs to be flexible as well in order to adapt to organization’s environment changes. Parchke et al. [31] suggest three elements fall under this dimension, which are as market flexibility, integrity flexibility, and business network flexibility.

- **Market flexibility** – the ability to quickly respond to market demand.
- **Integrity flexibility** – the ability to quickly adapt and renew internal organizational processes and structures.
- **Business network flexibility** – the ability to quickly reconfigure and support new strategic networks.
VI. SUITABILITY OF FACTORS IN IT IMPLEMENTATION IN CONSTRUCTION ORGANIZATION

In literature, the abovementioned factors were not used in all experimentation. Many researchers tested limitedly to technical aspect [22-24, 27, 30, 31, 37, 38], and some of them assessed both of the technical and people dimensions [18-20, 32-34], and few researchers analyzed all three dimensions [24, 31]. However, in construction industry, as it brings unique features that differ it from other industries, the Authors suggest to measure all these three dimensions in IT implementation in construction context.

The element of technical infrastructure flexibility is the main dimension that needs to be focused in the first place of IT implementation. An IT infrastructure must be capable to adapt the rapidity of technology change, and without it, IT development could be very costly due to re-engineering or re-develop the infrastructure. Hence, this could be a burden and a major barrier to some construction organizations [39].

To support the flexible IT infrastructure, a team of skilled IT personnel must be positioned. They must be flexible enough in adapting any new technology, understand it quickly, and at the same time, they should know and be updated with current technology released. At the same time, they have to be familiar with the nature of organization business they are working on.

In fragmented nature of construction industry, there are many uncertainties that will occur due to the changing of legislation, requirements, technologies, and changing needs by every different party involve. To face this situation, construction organizations must have flexibility in business process as well, especially regarding company’s IT policy. An organization should have flexible IT strategies that allow the organization to quickly respond to market demand and avoid them from being resistance. At the same time, the organization must be able to adapt and renew internal organizational processes and structures so that new technologies are able to reconfigure and support new strategic networks. On top of this, by being flexible in business process will let technical and people aspects of IT infrastructure more adaptable to change.

VII. SIGNIFICANT ADVANTAGES OF ITIF

Previous studies agree that ITIF give positive advantages in managing the rapidity of IT change where ITIF is suggested to be viewed as an organizational core competency [21, 26]. The advantages of ITIF lie as following:

- The studies agree that ITIF is a key to success of co-operations during periods of intense change [21, 30].
- With a flexible IT infrastructure, it helps the organization in handling increased customer demands without increasing costs [21, 26].
- ITIF allows an organization to exert greater control over IT operations within and beyond the organization to changing technologies, legislation, policies, regulations and constituent expectations [40, 41].
- ITIF enhances organizations’ strategic options and as a result, it may reduce the time to market for new products [22, 42].
- ITIF is a significant factor towards the effective delivery of IT services and solutions [19, 20, 24, 27, 42-44].
VIII. CONCLUSIONS

The world is facing development of many technological advances in the construction industry in a rapid pace. To successfully take this challenge, flexible IT infrastructure allows organizations to respond to these situations while providing future integration. Previous studies confirm that ITIF is a fundamental requirement to deliver effective IT solutions. A conceptual understanding on the ITIF is presented here by exploring the factors of three dimensions of technical, people, and business process. These factors could become variables to measure IT infrastructure.

IX. RESEARCH CONTRIBUTION

Findings of this study will significantly contribute to the construction industry as currently, there has been lacking of research in this particular subject. It would also assist IT system implementers to devise plans and undertake necessary actions as that would further help to improve their IT implementation’s effectiveness in construction industry.

X. FUTURE RESEARCH

This paper is a part of PhD work. It discusses about factors of ITIF than potentially be used as variables to measure ITIF from construction industry point of view. The Authors’ goal for future research is to develop an ITIF maturity grid through a pilot study and case studies. The Authors believe that this model will benefit construction organization in evaluating their strategies and opportunities to increase ITIF and resulting business value through increased IT effectiveness.

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