

CHAPTER 3

INFORMATION TECHNOLOGY INFRASTRUCTURE

FLEXIBILITY (ITIF)

3.1 Introduction

Information technology (IT) projects need to cope with ongoing changes in IT. The previous chapter describes the fast pace of technology change, and these changes may be changing faster in the future. The construction industry needs to be ready in adopting new technologies for few reasons (1) rapid introduction of better technologies available in the market, (2) the current IT being used in the project needs to be replaced by a newer version of the technology, and/or (3) the current IT being used in the project turn out to be incapable of meeting project goals (Akintoye, Goulding, & Zawdie, 2012). As the level of service continues to improve across all industries, customer expectations in the construction industry could also rise. The industry now wants accurate, readily available and easily accessible information to support customer's expectations and competitive edge over other competitors.

The inspiration of proposing flexible IT infrastructure is mainly to address the issues mentioned in the literature review. IT infrastructure flexibility (ITIF) is consistently defined in literature as a set of shared IT resources that are a foundation for enabling communication across an organization an enabling present and future business applications (Byrd & Turner, 2001; Duncan, 1995; Niederman, Brancheau, & Wetherbe, 1991). ITIF includes technological and human components (Duncan, 1995; Byrd & Turner, 2001), as well as, management component (Fink, 2009; Mishra & Agarwal, 2010). This chapter introduces ITIF by exploring the components of three dimensions of technical, people, and management that are important to measure ITIF, where Byrd & Turner (2000) and Fink (2009) tested the reliability and validity for each dimensions as reflected by the high factor reliability score, which are higher than 0.85. – The discussion starts with various definitions of ITIF, literature review and proposing an ITIF Maturity Model. The significance of the proposed model will also be discussed.

3.2 Defining IT Infrastructure Flexibility

The concept of ‘IT Infrastructure Flexibility’ was first summarized a decade ago by Duncan (1995). Since then, many researchers have continued her work and over years. There were many different terms used in academia and in practice based on the focus of IT processes, strategies, methods, and/or tools to achieve ITIF, for examples IT Elasticity, Agile IT, and Utility-based Computing (Ness, 2005). In literature reviews, the common term used is ‘IT infrastructure flexibility’. Although not all researchers have referred directly to the term ITIF, all other related and relevant concepts were also considered.

The term *infrastructure* is referred the physical IT assets and to the software (Akintoye, et.al, 2012) that provide a technological foundation for organizations' present and future business applications (Adler, Scherer, & Black, 2011). Infrastructure is also defined as the networking and platform components of the technical architecture (Ness, 2005). Infrastructure allows data and applications sharing and accessible for organization used (Jorfi, Nor, & Najjar, 2011). Its meaning has been broadly applied to indicate the quality and quantity of IT technical and human resources within and across the organization (Cawford, Leonard, & Jones, 2011). Accordingly, *IT infrastructure* is defined from two perspectives: 1) an aggregation of technology components (Duncan, 1995), and 2) a combination of technology components and human factors, including resource planning and management factors that affect the capabilities of IT (Byrd & Turner, 2000). **In relation to these definitions, this research characterizes a construction organization establishes IT infrastructure when the IT system is set up, a group of IT personnel are assigned to monitor the development of their IT system, and IT investment is positioned in their annual budget to support their IT advancement.**

In applying the term *flexibility*, it reflect characteristics as the ability to control outside environment effectively (De Leeuw & Volberda, 1996) which it able to be used for a variety of tasks, responsiveness to change, or able to be easily transformed (Gross & Raymond, 1993). Nelson & Nelson (1997) define flexibility as an ability to adapt IT system to both incremental and revolutionary changes. Gross & Raymond (1993) stated that flexibility is emerging as a key characteristic of all types of resources that involve hard and soft matters; these include people and tools, and processes. Furthermore, few researchers also states that flexibility is also the ability to predict and sense environmental change (Whitworth & Zaic, 2003). With flexibility, businesses are able to effectively use IT in dynamic environments.

From the explanation above, Byrd and Turner (2000) have come out with ITIF definition, which is used widely in a myriad of research. This research will also adopt Byrd and Turner's definition of ITIF as follows:

“ITIF is 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”.

ITIF brings the elements of technical, people, and management issues together in developing or procuring a successful IT system that could last longer and able to adapt with new technology.

3.3 Benefit of IT Infrastructure Flexibility Implementation

Previous studies by Davenport & Linder (1994) and Tallon & Kraemer (2003) proved that ITIF is a key to success for IT during periods of intense change, particularly where flexibility in IT infrastructure acts as a foundation for overall IT flexibility. Flexible IT infrastructure is designed to enable a system to realize its performance goals in the face of change (Hwang, et al., 2011). In this situation, ITIF is believed to benefit construction organizations in aspect of cost and time saving, better communication, and competitive advantage.

i. Lower overall acquisition and management costs

Generally, ITIF research believe that a flexible IT infrastructure helps the organizations in handling IT changes with minimal increased cost, caused by a continuous change in the external and internal environment (Davenport & Linder, 1994; Lamb, 2011). IT investment is not solely on the product, but also needs longer-term investment for its maintenance, upgrading, and staff training and skills. As technology change very fast, construction organizations will need to allocate additional investment for this - this is the main reason for construction organizations to avoid new IT investments. To help overcome this problem, ITIF supports construction organizations by reusing the existing component of IT infrastructure every time new technology is introduced or changes to the IT system are needed. In addition, the staff needs additional training to gain new skills and knowledge at any time there is a change on the IT system, and the amount of cost depends on how widespread the system is at the users. Therefore, by implementing ITIF, the construction organizations have cost savings from providing training to their own staffs or clients by means of a consistent and unified IT system management is used (Afuah & Werner, 2007). This has been proven from best practice from other industries. The O’Keeffe & Company survey reported that 61% of 152 IT distributors in United States that have implemented ITIF has shown double-digit annual growth since year 2002 (Zaino, 2007), and in a case study conducted by NetApp (2011c) on the Tucson Electric Power Company, it was reported that by making 95% of their IT system flexible, (1) it has saved USD2 million over three to five years of implementation from roughly 15% of the company’s IT infrastructure budget, (2) the company also has saved USD400,000 per year in staffing costs, (3)

another USD100,000 annually is saved from maintenance costs, and (4) cost saving of USD400,000 from purchasing additional server hardware and data center equipment.

ii. Time saving – faster and more scalable IT services.

ITIF allows construction organizations to make the best decision towards business-IT infrastructure alignment so that they can quickly adapt to environmental changes and explore new ideas of processes (Leana & Barry, 2000). As re-development of new IT infrastructure takes too long to implement, ITIF enables IT systems to support changes and it can be improved without having to start all over again (Butler Group, 2006a). As a result, ITIF can shorten product time cycle, increase design alternatives and produce higher quality products (Omar, et al., 2010). In addition, ITIF provides capability of adjusting to wide variety of IT applications, and it has depth and scalability to apply to most construction organizations needs. ITIF implies building a system with capabilities to anticipate distinct requirements such as a broad range of products that offer suitability for each party involved as clients, contractors, and design team. A good example is demonstrated by the Tucson Electric Power Company, as reported by NetApp (2011c). The company has reduced time required to restore systems from an average of 4 to 48 hours, to an average 10 minutes, benefitting from the ITIF implementation. The company has also experienced 96% quicker in IT provisioning for test and development, than the time spent on the previous IT provisioning operation. Forrester (2011) also found that with an optimal level of IT flexibility, execution of changes to a system is 88% faster than the conventional IT system.

iii. Improved communication

ITIF offers expansion plans to other geographical locations. ITIF have the ability to improve connection between various parties in the project team, enabling the organization to grow globally. Organizations are able to obtain real time data and communicate with the project team anytime anywhere. Therefore, ITIF promotes better integration and better business process.

iv. Increase effectiveness and enhance competitive advantage

ITIF was consistently found in literature as a significant factor towards the effective delivery of IT services and solutions (Masrek & Jusoff, 2009; Rong & Grover, 2009). ITIF allows the construction organizations to exert greater control over IT operations within and beyond the organization to ever-changing technologies, legislation, policies, regulations and constituent expectations (SAP, 2009; Sweeny, 1995). Further, ITIF provides a powerful and viable approach in delivering an effective IT solution and services to the organization and project partners (Butler Group, 2006b; Chung, et al., 2005; Chung, et al., 2003; Masrek & Jusoff, 2009; Ness, 2005; Sääksjärvi, 2000; Sriprasert & Dawood, 2002). Additionally, by having both technical infrastructure and human infrastructure, it is proven in case studies that it can enhance competitive advantage to the organizations' flexibility (Byrd & Turner, 2001; Chung, et al., 2005; Fink & Neumann, 2007).

3.4 Dimensions of IT Infrastructure Flexibility

ITIF has been defined by Duncan (1995) as an aggregation of technology components; and as the research widens, Byrd and Turner (2000) proposed the dimensions of ITIF lie on a combination of technology components and human factors. Paschke, Molla & Martin (2008) and Fink (2009) 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. As technical, people, and management dimensions are significant determinants of strategic performance (Broadbent, et al., 1999; Fink, 2009), this research adopted these three dimensions in the maturity model measurement.

3.4.1 Components of IT Infrastructure Flexibility

The definition of flexible IT infrastructure qualities through the dimensions of technical, people, and management dimensions appear to be consistent among the literature reviewed (see Table 3.1 for a summary). This section extracts the components that fall under these three dimensions. The purpose of this extraction is to list out the ITIF dimensions and components for the questionnaire design. These components then were tested in the construction industry through the survey to validate the importance of the ITIF factors for each component from the construction industry perspective. This stage is essential, as this will differentiate the factors exclusively for the construction industry - led by two types of backgrounds. The first is IT professionals which include Chief Information Officer (CIO), Head of IT Department, IT Director, IT Manager, and IT professionals such as programmer and system analyst; and the second category is led by non-IT professionals with experience as a leaders in planning and decision-making of

IT in their organizations, for examples architects, engineers, project managers, and surveyors. This will be explained further in Chapter 5.

Table 3.1: ITIF components from research literature.

Year	Researcher(s)	Research Area	ITIF Components	Respondents
(1995)	Duncan	Study of resource characteristics and their measure. She develops three components of ITIF under technical dimension.	Network connectivity Platform compatibility Modularity	Chief Information Officers and high-level IT executives in twenty-one Fortune 500 firms: <ul style="list-style-type: none"> ▪ Petroleum ▪ Communications ▪ Consulting ▪ Retail ▪ Insurance
(1996)	Broadbent et al	Proposing ITIF constructs that combines technical and people dimension.	Communications management Standards management Application management Data management Human management	<ul style="list-style-type: none"> ▪ Finance ▪ Retail ▪ Manufacturing
(2000)	Byrd & Turner	Exploratory analysis of constructs. Researchers added IT personnel flexibility as an important dimension of ITIF and combined connectivity and compatibility into one dimension called integration.	Connectivity Compatibility Modularity Skilled IT personnel	IT managers in larger Fortune 1000 companies. The industries involved are: <ul style="list-style-type: none"> ▪ Manufacturing ▪ Insurance ▪ Health ▪ Services ▪ Retail ▪ Utilities ▪ Banks & financial ▪ Transportation
(2002)	Ozer	Role of ITIF in online business. The study investigates how online business can achieve flexibility through the different functional aspects of their business; technology, human resources, operations, marketing, finance, and management.	Technology Human resources Operation Marketing Finance Management	Internet consultants and managers.
(2003)	Chung et al	Relationships among ITIF and strategic alignment and application implementation. Only connectivity, modularity and IT personnel competency have positive impact on strategic alignment. Four components of ITIF (compatibility, connectivity, modularity, IT personnel competency) have positive impact on the extent of applications implementation.	Connectivity Compatibility Modularity Skilled IT personnel <i>Adopted from Byrd & Turner (2000) and Lee et al (1995).</i>	IT managers from IT companies.

Table 3.1, continued.

Year	Researcher(s)	Research Area	ITIF Components	Respondents
(2003)	Tallon & Kraemer	Develop a model on how ITIF and strategic flexibility interact with, and shape, strategic alignment. ITIF and strategic alignment complement each other. ITIF can have both direct and indirect effects on business value. ITIF is a determinant of strategic flexibility.	Connectivity Compatibility Modularity <i>Adopted from Byrd & Turner (2000).</i>	Most senior IT executives in IT companies.
(2004)	Byrd, Lewis & Turner	The importance of skilled IT personnel in ITIF.	Connectivity Compatibility Modularity Skilled IT personnel <i>Adopted from Byrd & Turner (2000).</i>	
(2005)	Chung et al	Relationships among ITIF, mass customization, and business performance.	Connectivity Compatibility Modularity Skilled IT personnel <i>Adopted from Byrd & Turner (2000).</i>	IT managers from Fortune 2000 companies: <ul style="list-style-type: none"> ▪ Banking ▪ Communications ▪ Financial ▪ Government ▪ Health ▪ Insurance ▪ Manufacturing ▪ Retail ▪ Real estate ▪ Transportation ▪ Wholesale
(2005)	Ness	Exploring relationships between strategic alignment and IT effectiveness. The relationships exist and ITIF have positive impact on strategic alignment and IT effectiveness.	Connectivity Compatibility Modularity <i>Adopted from Tallon & Kraemer (2003).</i>	Chief Executive Officers, Chief Information Officers, and senior IT managers from Fortune 1000 and Forbes 500 companies.
2005	Strohmaier & Lindstaedt	Introducing B-KIDE Framework to address the improvement of process flexibility.	Perception Decision making Action Impact	Not stated
(2005)	Patten, Whitworth, Fjermestad, & Mahinda	Proposes IT Flexible Framework (IFF) with three critical aspects that an organization should consider in managing flexible IT/IS.	Anticipation Agility Adaptability	Not stated
(2005)	Turner & Lankford	Discussing about the historical perspective of ITIF.	Slack Adaptability Intensity	Manufacturing industry
(2006)	Chanapos et al	Proposing ITIF framework.	Connectivity Compatibility Modularity Scalability Rapidly Facility Modernity Skilled IT personnel	IT personnel

Table 3.1, continued.

Year	Researcher(s)	Research Area	ITIF Components	Respondents
(2007)	Fink & Neumann	The mediating role of IT infrastructure capabilities on flexibility and IT personnel capabilities.	Connectivity Compatibility Modularity Skilled IT personnel	IT managers
(2008)	Paschke, Molla & Martin	Exploring IS as one of the dimensions of ITIF.	Connectivity Compatibility Modularity IT knowledge Business knowledge Market flexibility Integrity Business network flexibility	Chief Executive Officers and Chief Information Officers from IMPACT500 companies.
(2009)	Jie, Han, & Jennifer	Relationship between ITIF and IT responsiveness in small-medium enterprises. The impact of connectivity and compatibility on IT responsiveness is fully mediated by modularity and IT personnel competency, which in turn affect IT responsiveness directly.	Connectivity Compatibility Modularity Skilled IT personnel <i>Adopted from Tallon & Kraemer (2003) and Chung et al (2003).</i>	Owners and managers of Small-Medium Enterprises.
(2009)	Masrek & Jusoff	Exploring relationships between ITIF and intranet effectiveness. Compatibility, connectivity and IT personnel competency are significantly related to intranet effectiveness.	Connectivity Compatibility Modularity Skilled IT personnel <i>Adopted from Byrd & Turner (2000).</i>	Malaysian public organizations.
(2009)	Fink	Multi-dimensional analysis of constructs and groups all the factors.	Connectivity Compatibility Modularity Data transparency IT knowledge Business knowledge Management support – technical & business oriented <i>Adopted from Byrd & Turner (2000).</i>	IT managers in IT companies.
2011	Jorfi, Nor & Najjar	Emperically assessing the relationships among IT connectivity, IT capability, and strategic alignment. IT connectivity and IT capability has a positive effect on strategic alignment. IT connectivity has positive impact on IT capability.	Connectivity	IT managers of organizations in United Arab Emirates.

There are three components under the *technical dimension* that are commonly found in literature - connectivity, compatibility, modularity, and data transparency. Few researchers included integration, this is, however, is part of Duncan's (1995) original classification, which is included in the categories of compatibility and modularity. The element of technical infrastructure flexibility is the main dimension to be focused in the first instance of IT implementation. The 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; this could be a burden and a major barrier to construction organizations (Omar, et al., 2010).

Connectivity is defined as the ability of any technology component to communicate with any of the other components intra or inter organizational environment (Duncan, 1995; Masrek & Jusoff, 2009) which helps to facilitate the sharability of IT resources at the platform level (Tapscott & Caston, 1993). Compatibility is measured by the ability of IT infrastructure to share any type of information across any technology component throughout the organization (Duncan, 1995) and across organizations (Masrek & Jusoff, 2009). Modularity allows an IT infrastructure to be easily reconfigured any technology component with no major overall effect (Byrd & Turner, 2000; Duncan, 1995; Masrek & Jusoff, 2009; Schilling, 2000). Data transparency provides no restrictions to access the technology component (Fink, 2009).

People dimension consists of skilled and flexible IT personnel in achieving flexibility in IT infrastructure (Chanapos, et al., 2006; Chung, et al., 2003; Paschke, et al., 2008; Tallon & Kraemer, 2003). This refers to a person, or a professional team who has knowledge, skills and experiences required to manage IT resources within

organizations and the understanding of the organization's business. They must be knowledgeable and flexible in adapting any new technology, understand it quickly, and they should know and be updated with current technology released. At the same time, they have to be familiar with the nature of organization.

Recent studies in ITIF have discovered that business process in the organization need to be flexible in order to encourage flexibility in technical and human aspect; as reported by Fink (2009) that ITIF should lead to greater flexibility of IT infrastructure capabilities. Thus, he categorizes *process dimension* into two aspects - management-oriented and technical-oriented services. Both of the categories imply management's support for the long-term IT development. He also found that both technical and people dimensions (IT infrastructure resources) need to be in place for creating flexibility of IT infrastructure's process. Please refer to Figure 3.1 for more information.

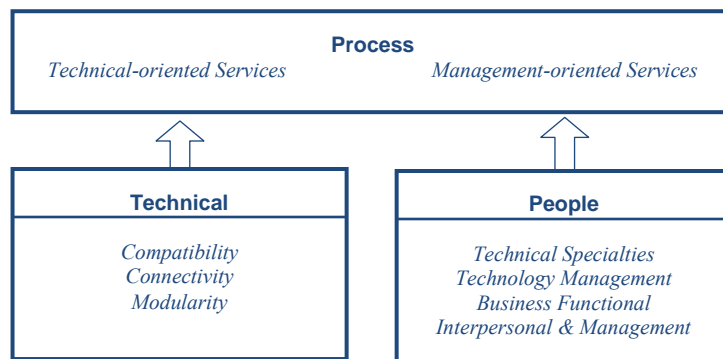


Figure 3.1: IT infrastructure flexibility proposed by Fink (2009).

3.5 IT Infrastructure Flexibility in Malaysian Context

IT infrastructure flexibility is still a new discipline for organizations in Malaysia but the interest is growing. The Malaysian Government has deployed flexible IT infrastructure and have started to gain benefits from it, especially in increasing the system's workflow effectiveness (Masrek & Jusoff, 2009). In construction industry, the Ministry of Works Malaysia has launched the Application System Directory 2011 (Ministry of Works Malaysia, 2011). In higher education, Malaysian universities have set to use flexible IT system in the national visionary planning (Ghavifekr, et al., 2012). In the private sector, NetApp Malaysia reported that USD500 million were spent on research and development that aimed at enabling IT to better respond to changing business requirements and maintain non-disruptive in Malaysian companies' operations (Goh, 2012). Cisco Malaysia gathered local and international technologists in Cisco Summit 2011 with the aim to increase companies' awareness and provide opportunities by showcasing the inner workings of the latest intelligent and IT flexibility that act as a foundation for a company's operations (Abraham, 2011). Dell Computers (2006) operated flexible IT infrastructure in their Malaysian supply chains operation before rolling it out globally, as a result, the Dell have successfully managed to streamline the monitoring and management of its databases, and their basic month-end batch jobs that used to take 8 hours, now take 2 to 3 hours by using flexible IT infrastructure.

3.6 Maturity Model

“Mature” is defined as having reached the state of full natural or maximum development (Andersen & Jessen, 2003). The concept of maturity was introduced to describe the level of development (Crowston & Qin, 2011). The ‘maturity model’ comes from the need to understand in which level of evolution a specific process is found in relation to arrangement, synergy between the parts involved, and its efficiency (Orti, Cavenaghi, & Albino, 2010). The Capability Maturity Model (CMM) describes stages through which software organizations evolve as the organization define, implement, measure, control, and improve their software processes (Aaen, 2002). A maturity model is a structure that characterizes the progress of the system from a less effective state to a more extremely effective state. The maturity model is used as a foundation for a process to assess the relative maturity of practices in many areas (Pöppelbuß & Röglinger, 2011). Tapia (2007) reported that a maturity model is descriptive and normative which focuses on ‘what’, where the maturity model describes the important characteristics or processes in which each organization will be distinguished at each specific maturity level (descriptive). The maturity model also provides a minimum set of factors that need to be adopted for improvement (normative).

The first maturity model was initially published in 1987 by the Software Engineering Institute in the United States (Bashir & Goel, 1999; Paulk, 2009). The model was formalized as the Software Capability Maturity Model (SCMM) that briefly described five maturity levels and contained a detailed description of recommended software engineering and management practices. The SCMM has inspired a variety of maturity models and other standards. In the last decade, Khandenwal and Ferguson

(1999) suggested the combination Critical Success Factors (CSF) method in a Maturity Model by gauging the maturity of an organization, industry, or region by the correspondence of the CSF.

3.6.1 Critical Success Factors (CSF) and Maturity Model

The concept of CSF is used as a necessary ingredient in a management of IT system to describe the major skills and resources to be successful in a given market (Grunert & Ellegaard, 1992). This represents a skill or resource that a business can invest in. The concept is close to a methodology for continuous business process improvement (Niazi, et al, 2003). By communicating CSF in maturity model, this ensures a project or a business is well focused and avoids wasting effort and resources on less important areas. CSF is best understood by example (Caralli, 2004). In determining CSF, two techniques that help are through rating the importance of the factors and estimate the strength of relationships between the factors (Grunert & Ellegaard, 1992; Fan, Rajib, & Alam, 2012).

3.6.2 Benefits of Maturity Model

Many researchers have researched into the benefits by using maturity models (Bittman, 2004; Gray, 2009; Tapia, 2007) – as a framework to manage the improvement efforts. It has been designed to assess the maturity (i.e, competency, capability, and level of sophistication) of a selected domain based on a more or less comprehensive set of criteria (Kirkwood, Alinaghian, & Srari, 2011). The model would provide a clear set of benchmark and help identify the organization's status today and where they want to be in the future. Maturity models help organizations to self-evaluate to understand their

current standing and to set where the company want to be in the short or long term with clear understanding of desired outcomes at each maturity level (Teng, Thekdi, & Lambert, 2012). Organizations will gain a deeper understanding of how they progress through maturity model and are useful in creating and implementing assessments. Whilst, maturity models can become readiness guidance in term of building a strategic plan and management targets, such as cash flow and budget where organizations' investment priorities can be set.

Software Engineering Institute's database (2012) reported remarkable benefits gained by companies who have used maturity model. The first is the use of maturity model *decreases costs*. The followings are the examples studied by the Software Engineering Institute:

- The Siemens Information Systems Limited reduced its cost of quality from over 45% to below 30% over a three-year period; and it also *shortened the delivery time*. Siemens also achieved a *Return on Investment* with 2 to 1 over 3 years and *it also increased customer satisfaction index* an average of 42%.
- General Motors India improved the percentage of IT project milestones met from 50% to 85%.
- Tufts Health Plans achieved 100% time delivery of major IT projects in a full year.
- IBM Australia experienced by its account productivity improved over 20%, with 95% of problems closed within the specified time frame through the maturity model.

3.7 IT Infrastructure Maturity Model

When the concept of maturity is applied in an IT infrastructure context, it refers to a state where the IT infrastructure is in a condition where it can be shared across customers, business units, and applications; dynamically driven by business policies and service-level requirements; and can automatically configure and optimize itself (Gartner, 2004).

Ness (2005) has strongly proposed a development of a maturity model by measuring the ITIF factors, in agreement with Masrek (2011). Ness believes that the construction industry critically needs an ITIF model to provide the organizations with the ability in obtaining and sustaining a competitive advantage. In order for the organization to make improvements, a goal must be set up and the requirements to achieve the goal made available – the progress toward achieving the goal must be measurable. Many researchers in ITIF have attempted to define factors in order to assess ITIF, however, there is a lack of systematic processes for the construction industry to achieve ITIF and measure its maturity. In response, this study will introduce an ITIF Maturity Model that is designed specifically to assess construction organization. By developing the ITIF Maturity Model, it is hoped it will become a very useful and powerful tool that can be used by the construction organizations coping the technological change, hence promoting the use of IT in the construction industry (Please refer Figure 3.2). This caters the implications occurred due to technological change, as discussed in previous chapter.

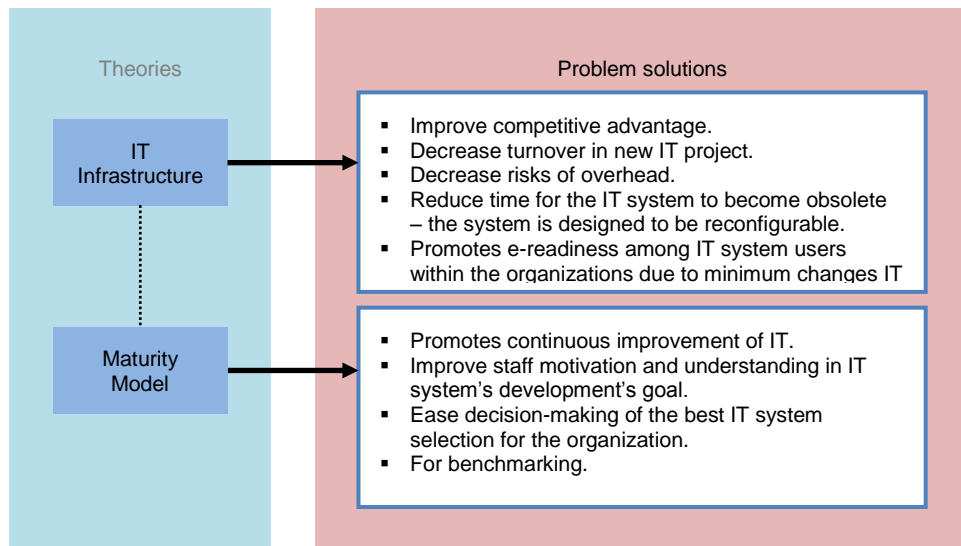


Figure 3.2: Potential benefits of proposed ITIF Maturity Model

3.7.1 Types of Infrastructure Maturity Model

Copeland (2003) described 34 prominent maturity models from various researchers in his research that related to technical, people, and cultural issue. In this research, only infrastructure maturity models were extracted from his list. There are sixteen infrastructure-related maturity models, including recent infrastructure maturity models that have been introduced. They can be categorized in four scopes of infrastructure maturity models as shown in Figure 3.3.

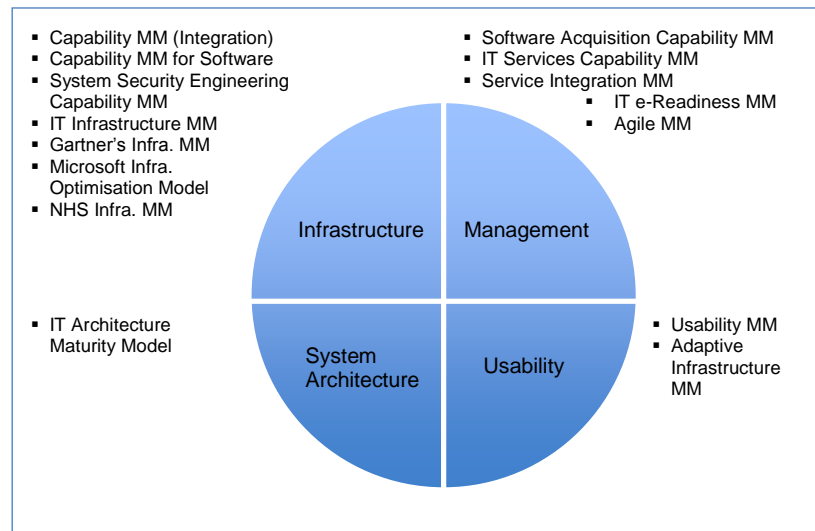


Figure 3.3: Scopes of prominent infrastructure maturity models.

Among all the published maturity models listed in Table 3.2, none of them brought up the element of ITIF. Most of the models measure process of IT system development. The levels of maturity vary in different maturity models. Majority of the maturity models developers adopted the levels of maturity from Capability Maturity Model Integration (CMMI) – the most prominent maturity model. The methodologies used for maturity models' development are consistently found in the literature, ranging from case studies, questionnaire survey, and focused-groups.

Table 3.2: Prominent IT infrastructure-related maturity models.

Maturity Model	Developers	Maturity Levels	Purpose	Elements Measured	Development Methodology
Software Capability Maturity Model	Software Engineering Institute (1991)	5 levels 5- Optimised 4- Managed 3- Defined 2- Repeatable 1- Initial	Measure the software process maturity because the developer believed that the quality of software is determined by the quality of its development and maintenance process.	Process	<ul style="list-style-type: none"> • Survey (Paulk, 2009) • Interview for case studies (Humphrey, 1987).
Capability Maturity Model for Software	Paulk et al (1993)	5 levels 5- Optimising 4- Managed 3- Defined 2- Repeatable 1- Initial	Software development.	Process	<ul style="list-style-type: none"> ▪ Case studies
System Security Engineering Capability Maturity Model	Hopkinson (1996)	6 levels 5- Continuously improving 4- Quantitatively controlled 3- Well defined 2- Planned and tracked 1- Performed informally 0- Not performed	Assessing capability of system engineering for the whole life cycle.	Process	<ul style="list-style-type: none"> ▪ Case study
Capability Maturity Model Integration	Software Engineering Institute (1997)	6 levels 5- Optimising 4- Quantitatively Managed 3- Defined 2- Managed 1- Performed 0- Incomplete	Integrate software engineering and product & process development in one model.	Product and process	<ul style="list-style-type: none"> • Case studies (Paulk, 2009)
Usability Maturity Model	Earthy (1998)	6 levels E- Institutionalised D- Integrated C- Implemented B- Considered A- Recognised X- Unrecognised	Assessing organization's progress towards human-centeredness in system development and operation.	People	<ul style="list-style-type: none"> ▪ Survey
Software Acquisition Capability Maturity Model	Cooper & Fisher (2002)	5 levels 5- Optimising 4- Quantitative 3- Defined 2- Repeatable 1- Initial	Describes developer and buyer's role in the software acquisition process.	Process	<ul style="list-style-type: none"> ▪ Focused-group
IT Services Capability Maturity Model	Niessink et al (2002)	5 levels 5- Optimising 4- Managed 3- Defined 2- Repeatable 1- Initial	Measuring capability of software applicable to organizations that provide IT services.	Service delivery process	<ul style="list-style-type: none"> ▪ Focused-group
IT Architecture Capability Maturity Model	US Department of Commerce (2003)	6 levels 5- Measured 4- Managed 3- Defined 2- Under development 1- Initial 0- None	IT architecture readiness.	Infrastructure and process	<ul style="list-style-type: none"> ▪ Scorecard

Table 3.2, continued.

Maturity Model	Developers	Maturity Levels	Purpose	Elements Measured	Development Methodology
Gartner Infrastructure & Operations Maturity Model	Gartner (2004)	6 levels 5- Business partnership 4- Service-aligned 3- Proactive 2- Committed 1- Awareness 0- Survival	Evaluate infrastructure maturity that considers management issues.	IT infrastructure	• Survey
Service Integration Maturity Model	Arsanjani & Holley (2005) - IBM	7 levels 7- Eco-system integration 6- Virtual infrastructure 5- Supply-chain integration 4- Process integration 3- Functional integration 2- Application integration 1- Data integration	Assessing the flexibility in architecting a service-oriented infrastructure.	Infra-structure	▪ Case studies
Microsoft IOM	Microsoft (2006)	4 levels 4- Dynamic 3- Rationalised 2- Standardised 1- Basic	Microsoft technical capabilities at each step with minimal link to business benefits.	IT infrastructure, application, business	• Micro level – specific questions used establishing yes/no then score calculated based upon answers
IT e-Readiness Maturity Model	Salleh (2007)	6 levels 6- Intra-organizational systems 5- Strategic system 4- Communication protocols 3- Work group system 2- Administration system 1- Stand alone system	Organization's readiness prior implementing IT. The scope of extracted maturity levels is in technological aspect that discusses about the type of system and communications used in the organizations.	Management issues on technical, people, process, and environment issues.	• Questionnaire and case studies.
Adaptive Infrastructure Maturity Model	Hawlett-Packard Company (2007)	5 levels 5- Adaptive, shared infrastructure 4- Service oriented 3- Optimised 2- Standardised 1- Compartmentalised	For developing flexible data centre.	Technology, process, people, and governance.	• Questionnaire and case studies
NHS Infrastructure Maturity Model	NHS (2008)	5 levels 5- Innovative 4- Optimised 3- Standardised 2- Controlled 1- Basic	Technology and business capabilities aligned to NSH needs.	IT infrastructure view across people, process, and technology	• Macro level of questionnaire.

Table 3.2, continued.

Maturity Model	Developers	Maturity Levels	Purpose	Elements Measured	Development Methodology
IT Infrastructure Maturity Model	Haris (2010)	5 levels 5- Innovative 4- Optimised 3- Standardised 2- Controlled 1- Basic	Combining few infrastructure maturity models becomes one model.	IT management	<ul style="list-style-type: none"> • Literature review and a case study
Agile Maturity Model	Ambler (2010)	5 levels 5- Measured 4- Respectable 3- Plausible 2- Certified 1- Rhetorical	For improving the marketing approach.	Management aspect from team level to corporate-wide level.	<ul style="list-style-type: none"> ▪ Not stated

3.8 Conclusion

The world has witnessed the development of many technological advances, and the construction industry is no exception. To keep up with the changes, the industry need a flexible IT infrastructure that will help the organizations save in technology investment costs, save time, increase effectiveness and competitive advantage. There is lack of research approaches in ITIF and severe limitations. This study helps to provide a clear definition and components of ITIF, and the need of proposing a maturity model.

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