Digital Twin: A Conceptualization of the Task-Technology Fit for Individual Users in the Building Maintenance Sector

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Abstract There have been numerous research studies on understanding buildings better and finding ways to improve water and energy consumption while making them more comfortable for occupants. With technologies such as Building Automation Systems, IoT devices, mobile applications and BIM software, more data can be generated and stored for intelligence and more effective facility management. The next big thing is the digital twin concept, where a virtual model is created from the physical building that brings together real-time information from all data capture devices, allows monitoring, historical analysis, predictive analytics, and simulation as well as interaction and intervention to be carried out. Many research studies have covered the characteristics, architecture, and benefits of digital twins and examined the potential implementation issues. However, the literature on evaluating return on investment (ROI) and acceptance of digital twins for the built environment at the individual user level is limited. This study aims to develop a conceptual model to examine the motivational intent and behavioural choice by individual users to utilise the digital twin technology to improve their performance. The objectives of this study are to examine technology acceptance theories and develop a conceptual model that measures the relationship between the tasks involved and the digital twin technology characteristics.

Keywords. Digital Twin, Task-Technology Fit, Smart Maintenance, Return on Investment, Information System

1. Introduction

Buildings account for a considerable percentage of total energy consumption. Many initiatives have been rolled out to find ways to monitor and reduce energy consumption, increase water efficiency and thermal comfort in buildings. There have been many research studies in technology for buildings and Smart Buildings. This Smart Building concept was introduced by the Energy Performance Building Directive. It aims to promote flexibility, renewal energy and interaction by the occupants [1]. To facilitate better understanding and maintenance of buildings, another major development has been the advancement of data capture devices and the Internet of Things (IoT). The IoT architecture concept is to equip all objects with identifying, sensing, and processing capabilities so that data could be captured from them and exchanged so that services can be later developed over the internet [2]. Applications of IoT in Smart Buildings include indoor comfort, energy management, facility management and security and safety of occupants [3]. Premise and cloud-based data lakes and business intelligence technologies have also emerged to cope with the increased data being generated and exchanged. [4]. The transformed and standardised data is then delivered to various users for their reporting and analytical purposes.

Another new key technology is the concept of digital twin originated in the manufacturing sector with the launch of the Industry 4.0 phenomenon. The digital twin model is a virtual real-time digital version of a physical object [5]. The digital twin concept leverages a combination of the latest data technologies, API connectors, software, big data, IoT sensors, artificial intelligence applications and 5G networks to produce this virtual representation. This in turn allows data connectivity and exchange for monitoring and simulation purposes in each of the product life cycle stages [6].

In 2019, there were more than 90,000 mentions on digital twin concept, applications and technology in google search and 2120 papers found in Google Scholar [7]. The content in these past studies can be classified as follows:

- Digital twin used in product life cycle phases.
- Concepts including definitions, characteristics and capabilities of the digital twin.
- Technology and details of the components to build a digital twin including an implementation framework and potential implementation issues.
- Differences between a digital twin and digital shadow.
- Data integration and data interaction.

The digital twin can be a complex production system that requires domain knowledge, technical skills and systems to integrate data to develop the virtual representation of the physical model [8]. This in turn raises the question of the return on investment (ROI). Return here refers to profitability, increased performance, and results. Performance is dependent on whether the technology in question is useful and being utilised by their individual users. Like ICT adoption, the decision to adopt digital technology can happen at mainly two levels: the organisational and the individual level [9]. At the organisational level, the outcome is profitability resulting from the investment of the new technology and how new technology can improve efficiency. Variables that contribute to the benefit from the technology include savings of capital and labour, overall productivity and efficiency gains, reduction in costs and better quality of product and service [10]. The decision to invest and adopt the new technology can also occur at the individual level. There are many factors that drive individual users to choose, adopt and utilise new technology. Their acceptance will result in greater utilisation and improved performance. Their acceptance to utilise the new technology is also important to ensure that its implementation will not be jeopardised but help to improve performance and a better ROI. There are limitations in the current research studies which have not developed a conceptual framework or evaluation model to examine the individual user's acceptance level or the motivation intent to utilise digital twin for the building maintenance sector and built environment.

This paper aims to develop a conceptual model for digital twin technology acceptance and fit for individual users. The objectives of this paper are to examine the tasks performed by individuals in the building maintenance sector, listing out the technology characteristics of digital twin, applying the relevant technology acceptance and fit theories to develop this conceptual model. The findings from this research may enable organisations to use to evaluate before investing money and time. This enables the organisations to understand how their individual users choose to use or not use certain technology characteristics. It can be used to complement the entire ROI calculation process at the organisational level. It also helps to identify any areas of uncertainty and risks. The proposed conceptual model can also be adapted to aspects outside maintenance and operations within the built environment.

2. Research Approach and Methodology

This paper aims to develop a conceptual model for evaluating the level of acceptance by and fit for individual users towards digital twin for the built environment. As part of this study, the objectives are as follows:

- Understanding the acceptance level by individual users towards new technology based on literature review.
- Examining the facilities management (FM) challenges.
- Defining the problem statements.
- Developing a conceptual model that provides the following:
- mapping the task characteristics of individual users to the digital twin technology characteristics; and
- designing a conceptual 5x5 matrix evaluation template that measures the relationship of the fit and the performance impact on individual users.

This study will be based on the Double Diamond in Design Thinking Process Model as an exploratory approach to identify the issues and then develop the conceptual model to solve the identified research problems [11]. It is made up of four stages: Discover, Define, Develop and Deliver (Figure 1).

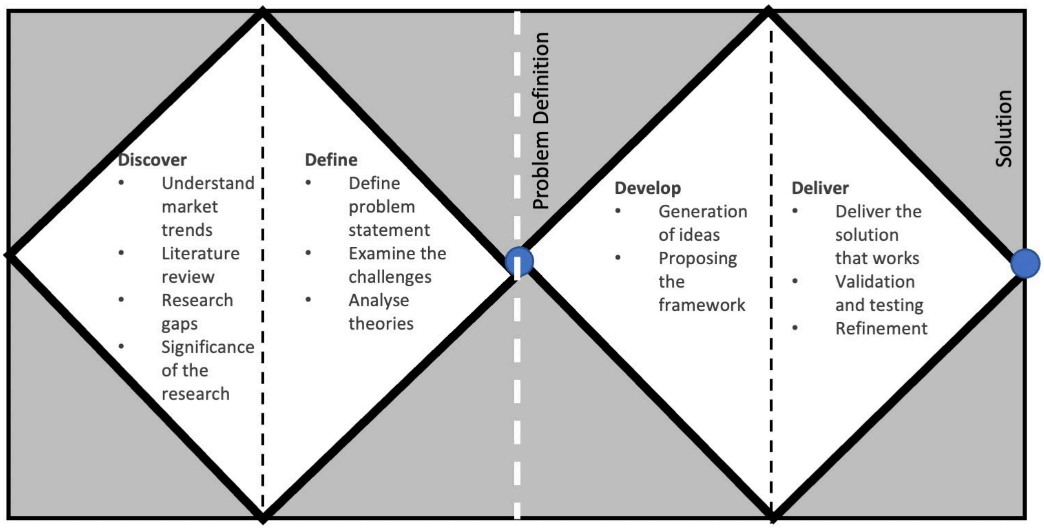

Figure 1: Double Diamond in Design Thinking Process (Tschimmel, 2012).

2.1. Discover – Understanding the Problem

2.1.1. Understanding the acceptance level of individuals towards new technology

Past studies on digital twin have covered the following [12]:

- the digital twin concept and summary of ideas and directions,
- the role of digital twin for Industry 4.0,
- analysis of the definitions and characteristics of digital twin, and
- challenges in the implementation of digital twin.

There are limitations in the literature relating to the evaluation of choice and acceptance by individuals who will use the new technology. Acceptance by users is an important factor to ensure that the new technology will be successfully implemented and utilised. There is a need to examine the factors that drive their utilisation.

There are two popular theories that explain the attitudes and motivation intent to accept and utilise new technology and systems. The first is the Technology Acceptance Model (TAM) proposed by Davis in 1986 which was adapted from the Theory of Reasoned Action by Ajzen & Fishbein [13]. This was used to explain and predict the level of acceptance by the individual towards the new technology and is mainly made up of two components: the perceived usefulness of the new technology and perceived ease of use. The perceived usefulness refers to the degree to which the user believes that using the new technology will improve the user's performance. Perceived ease of use refers to the amount of effort or how effortless the user perceives in using the new technology. Both factors will influence the user's attitude using the new technology. This attitude in turn will impact the behavioural intention to use the new technology and the utilisation rate [14]. TAM has been one of the most popular theories used widely to explain Information System usage such as e-learning [15], wireless internet [16], and health care [17].

However, TAM had some limitations. When it could not explain the behavioural intent and adoption, external variables would just be added. For example, when first launched, many Enterprise Resource Planning (ERP) systems were seen to be difficult to use and the ERP methodologies caused significant disruptions to their work but were still adopted and implemented as a result of influence from management and authorities and subjective norm in the industry [18]. TAM also assumes that the increase in utilisation of the new technology would result in an increase in performance. The perceived ease of use would also influence the perceived usefulness of the technology. The TAM model also needed other factors such as the organisational environment [19], social and implementation process [20]which can impact the adoption and performance of new technology.

The other popular theory is the Task-Technology Fit Theory (TTF) [21] which describes technologies as tools used by individuals in carrying out their tasks. It measures the relationship between the tasks carried out by individuals and the characteristics of the technology to be used. Technology can refer to systems, hardware, software, and services put together to assist users in their tasks. There have been many explanations of how technology can assist in the tasks [22], [23], [24], [25]. Goodhue and Thomson's explanation of technology affective tasks and performance can be carried out in three ways: new technology can improve the non-human portion of tasks. In the area of management information system (MIS), examples include providing information in less time or a more detailed and higher quality answer. The sequence of actions carried out by the task doer will remain the same. The second way is where the technology can alter the possible task execution sequences. An example of this is instead of transforming the data coming from separate data silos before combining the data, an alternative is to extract the data from the data silos first and then applying the transformation sequence before landing the data in a central data warehouse. Thirdly, technology can remove the need for that sequence or task. TTF relationship framework can illustrated in the model below (Figure 2) and consists of the following variables [26]:

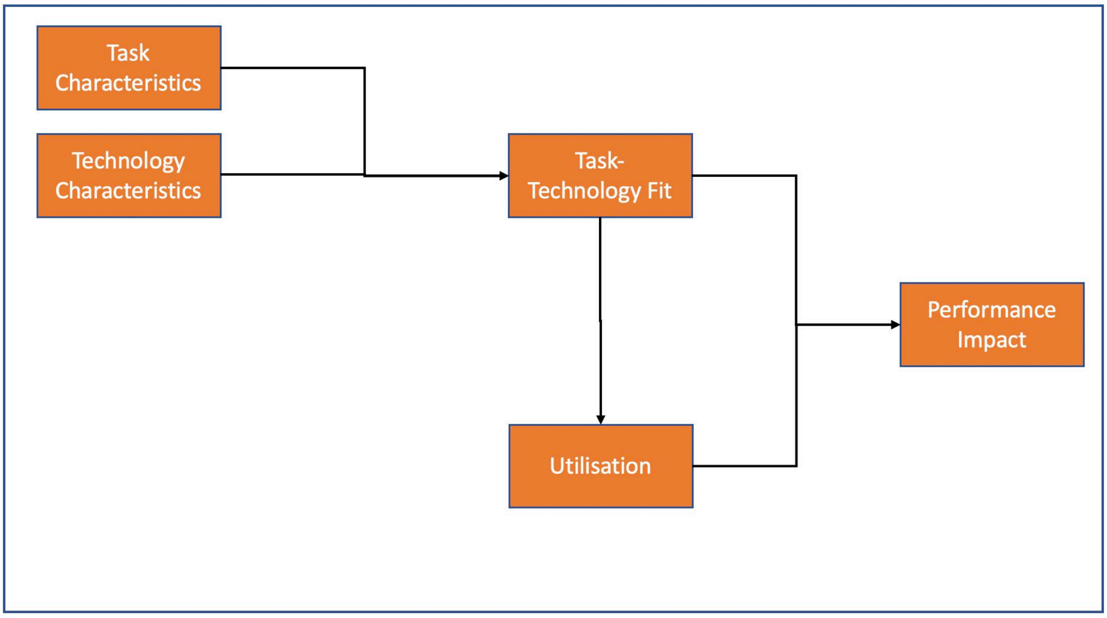

Figure 2: Task-Technology Fit (TTF) Model (Goodhue and Thomson, 1995)

Tasks characteristics refer to the actions and activities carried out. Technology characteristics are the tools and functions that help to execute the tasks. It can be in the form of a system, a set of systems or services. Utilisation refers to the use of technology to carry out the tasks. Individual performance refers to the impact on performance such as an increase in efficiency or quality of the output. This in turn indicates the success of the technology being utilised.

TTF measures the level of fit between the technology and tasks. If the fit increases, there will be a positive impact on the performance. The higher the TTF, the greater the positive consequences on the intention to utilize the system and results in greater utilization. A high TTF will also mean it will lead to better performance as it means that the technology will meet more closely to the tasks of the individual. While TAM focuses on the attitude of individual users and TTF measures the match between the tasks and the functions of the new system, both models have similarities but are different. Some studies have combined the models to deepen the exploratory research further [27].

2.1.2. Understanding the FM Challenges

Facilities Management (FM) teams are crucial in the operational phase of buildings The operational phase is relatively longer than the design and construction phase and constitutes about 60-85 percent of the building's total life cycle cost [28]. The operational phase covers mainly the operations and maintenance of buildings. Operations refer to services required to keep equipment and systems operating that meet the FM team goals while maintenance services help to restore equipment or systems to the designed conditions. The FM discipline has evolved through the years to include commercially and strategic functions and clearly defined objectives such as sustainability, energy and water efficiencies [29]. This has been accelerated by the needs at the organisation level to improve ROI, reduce costs and achieve better competitive advantage [30].

The above-mentioned has added to the number of challenges in building FM and maintenance. These challenges can be organisational in nature, technology, the user, or policy-related [31]. The organisation is very much focused on ROI and profitability. Various stakeholders' requirements may conflict with one another and impact the sustainability and FM goals. There is also a lack of understanding, engagement, and focus on the individual users involved in the FM. Their goals may not be aligned with that of the individual users. In the area of technology, the systems are becoming numerous, and more complex and exhibit little integration. Individual users also face numerous challenges. With an increased number of day-to-day operations, their functions go beyond operations and maintenance. They also need to cover service level agreements, service quality standards, cross charging, back-to-back agreements and audits [32]. There is also a lack of training to ensure they function effectively and efficiently.

2.2. Define - Examing the Problem

Based on the literature review, the problem statements of this study are formulated as follows:

- As individual users are important to the project, there is a need to validate if they will utilise the digital twin technology to improve their performance. This paper aims to develop a conceptual model to address this problem.
- Compare and match the tasks they carry out with the digital twin technology characteristics and determine the level of fit. If this fit is perceived to be high, the potential utilisation rate will increase.
- For the purpose of this paper, the tasks and digital twin technology characteristics will focus on building maintenance activities.

2.3. Develop - Proposing Idea and Concept

2.3.1. Developing the proposed TTF conceptual model for Digital Twin

The scope is to determine the relationship and measure the fit between the task characteristics and technology characteristics in order to achieve utilisation and increase performance without taking into account of attitude-related factors such as perceived usefulness and ease of use. The proposed TTF conceptual model for digital twin for individual users in the building maintenance sector is illustrated in Figure 3:

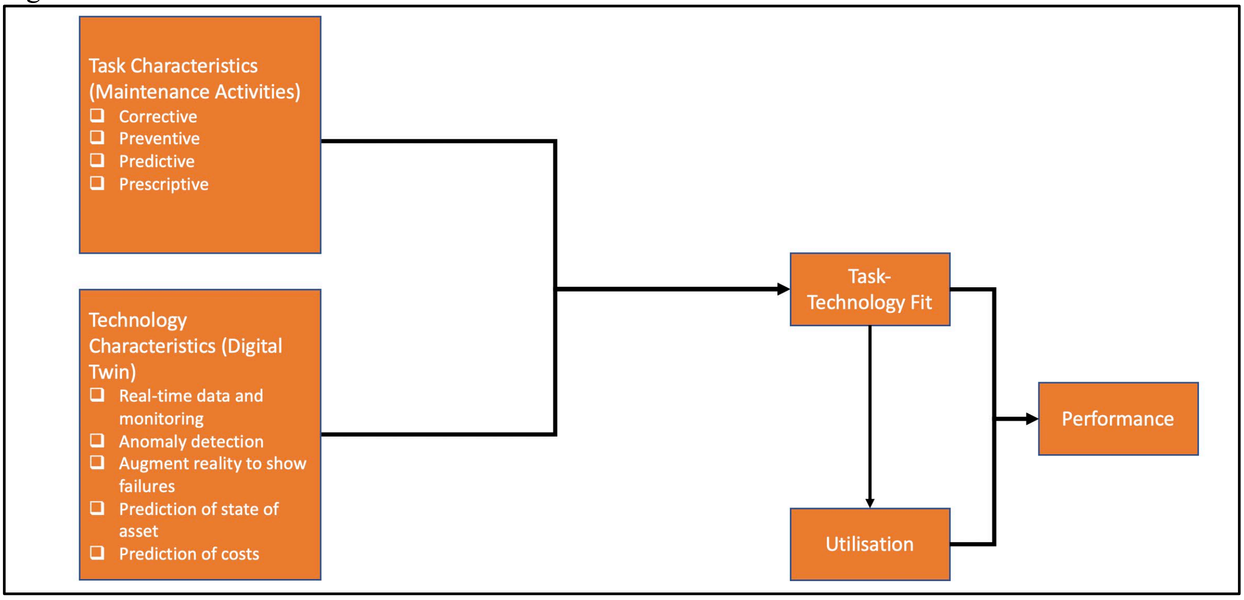

Figure 3: Proposed Conceptual Task- Technology Fit (TTF) Model for the Digital Twin for Individual Users in the Building Maintenance Sector

Task characteristics include corrective, preventive, condition-based, predictive, and prescriptive activities [33]. Technology characteristics consist of the digital twin functionalities [34].

2.4. Deliver - Developing the Proposed TTF Evaluation Tool for Digital Twin at Individual Level

The TTF- Digital Twin model is further developed into an evaluation template to be filled up by individual users. As shown in the table (Table 1) below, for each of the tasks, the individual user can select the relevant digital twin characteristics that will fit the maintenance activity.

TASK CHARACTERISTICS (MAINTENANCE ACTITVITIES)	TECHNOLOGY CHARACTERISTICS (DIGITAL TWIN)
❑ **Corrective (unplanned):** Activities that apply to elements that have failed or broken down.	❑ Real-time data and monitoring ❑ Overall anomaly detection ❑ Augmented reality to show failures ❑ Prediction of state of asset and costs ❑ Simulation of scenarios
❑ **Preventive (planned):** Scheduled and planned activities that check and detect anomalies. They can be performed when it is convenient.	❑ Real-time data and monitoring ❑ Overall anomaly detection ❑ Augmented reality to show failures ❑ Prediction of state of asset and costs ❑ Simulation of scenarios
❑ **Condition-based:** Maintenance is carried out to evaluate the condition or in response to a deterioration or damage as a result of change in the monitored paramter or measurement of performance.	❑ Real-time data and monitoring ❑ Overall anomaly detection ❑ Augmented reality to show failures ❑ Prediction of state of asset and costs ❑ Simulation of scenarios
❑ **Predictive (prognosis):** Predictive maintenance activity uses the data from all the systems to extract patterns and predict the remaining life of assets and costs and when a faillure will happen.	❑ Real-time data and monitoring ❑ Overall anomaly detection ❑ Augmented reality to show failures ❑ Prediction of state of asset and costs ❑ Simulation of scenarios
❑ **Prescriptive (knowledge-based):** Refers to optimising maintnenance activities based on predictions, leveraging on past and real-time data analysis. These activities also look at what-if sccenarios.	❑ Real-time data and monitoring ❑ Overall anomaly detection ❑ Augmented reality to show failures ❑ Prediction of state of asset and costs ❑ Simulation of scenarios

Table 1: Proposed Conceptual TTF Evaluation Template for Individual Users for Building Maintenance

Data collected from the proposed template can be applied to the proposed TTF-Performance Impact Matrix shown in Figure 4. It highlights the level of performance impact arising from the level of TTF for individual users. The higher the TTF, the better the utilisation and the greater the performance impact. This can be used to complement the overall ROI evaluation of the digital twin investment at the organisational level.

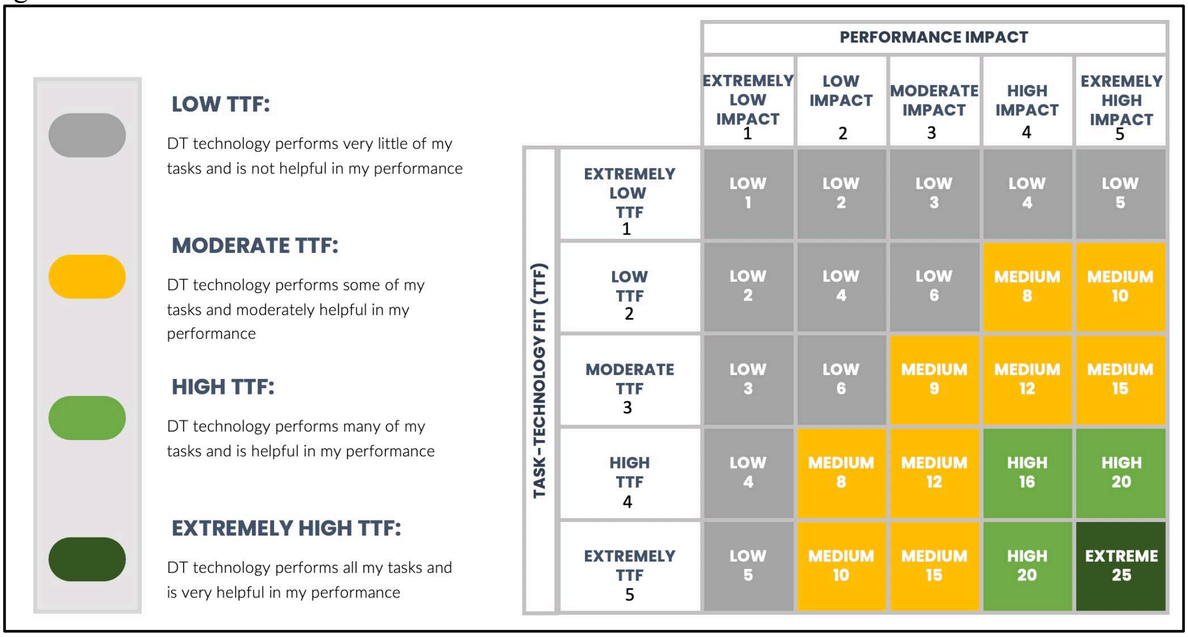

Figure 4: Proposed TTF- Performance Impact Matrix for Individual Users for Building Maintenance

3. Findings and Limitations

The objective of this paper is to evaluate the digital twin technology utilisation by individual users for building maintenance. It assumes the better the fit between their tasks and the technology characteristics, the probability of utilising the technology will be higher and the performance will increase because of the fit. The proposed conceptual digital twin TTF model aims to understand their choices and evaluation of new technology at an individual level. The output derived is the mapping of the individual's tasks to the technology characteristics for building maintenance. This can be expanded to include new functionalities and tasks subjected to the environment the individuals are in. This conceptual model can be translated into an evaluation matrix to understand their choices and identify any areas of gaps and action items needed before embarking on the journey of digital twin for the built environment.

The major limitation to this conceptual framework is that it is a simplistic one that excludes attitude related factors such as perceived usefulness and perceived ease of use found in the TAM models or social factors which may impact the influence and the perception of a digital twin as new technology or even organisational culture that may add additional processes and pressures that hinder efficiency and collaboration. A second limitation is that it does not cover other factors such as the business model, organisational structure and processes as explained in the Theory of Disruption [35].

An in-depth interview and questionnaire are needed to gather more insights and refine the conceptual model with additional relevant additional variables and inputs. This said limitation created by the early phase of this research project can be overcome easily at the later phase to include the above actions plan to build a more robust framework.

4. Conclusions and Further Research

Digital twin benefits include cost reduction and the ability to manage risks and uncertainties through better intelligence from data and predictive models, more effective decision making, conducting simulations without impact the physical building, and allowing better quality improvement opportunities [36]. Given its complexity and costs, there is a need to evaluate ROI and the user acceptance of this new technology. This paper, therefore, aims to evaluate the digital twin technology utilisation by individual users for buildings.

This paper is a part of a bigger study to develop a complete ROI/BRM evaluation tool for digital investment at both the individual and organisational levels. Future work will cover the Theory of Disruption and examine the integration of the TTF and TAM models to form a more complete technology fit acceptance tool. It will also incorporate additional external factors in order to increase the accuracy of prediction of the fit, test, and refined for organisations to adopt as a standard tool. The 5x5 matrix will be revisited and compared with other scorecard tools such as IT/IS balanced scorecard [37] for further refinement.

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