

A SUCCESSFUL MODEL FOR TRANSFERRING DIGITAL TWIN TECHNOLOGY FOR MAINTENANCE OF INDUSTRIAL MACHINERY

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ABSTRACT

The research studied a successful model for transferring digital twin technology for maintenance of industrial machinery. will be widely beneficial, especially in developing countries like Thailand, which is the center of production and industry in many products. It will also serve as a guide for preparing the workforce to keep up with changes in technology and the country's context. This is demonstrated by a study on the success model of digital twin technology transfer for machine maintenance in Thailand's medium to large automotive parts manufacturing industry. Given the speed at which technology is developing in the modern world, the discoveries will be expanded upon to successfully transfer more sophisticated and complex technologies. This research aim to study the relationship between of variable technologies

Keywords: A successful model, transferring digital twin technology, industrial machinery

INTRODUCTION

Thailand serves as a manufacturing hub for automotive parts for numerous leading global brands. Automotive parts manufacturers in Thailand range from small enterprises producing items such as screws and bolts to large companies assembling components and exporting them as primary automotive parts. These companies must adhere to the standards set by the automakers of the respective brands that place orders or contract assembly work. As a result, they are required to implement strict quality control (QC) processes including the need of methodical maintenance of machinery to reduce downtime and to prevent additional errors that may come from production machinery, such deviations from acceptable values (Over/Under Tolerance) or quality degradation and defective work pieces, etc. This necessitates that these manufacturers import high-performance production technologies or machinery that meet the standards required by the contracting brand owners. Consequently, medium to large-scale automotive parts manufacturers in Thailand are well-positioned to adopt advanced technologies, such as digital twin technology, for production machinery maintenance ahead of other industries with similarly sized organizations. However, since these technologies are primarily imported, the implementation of digital twin technology requires thorough preparation to facilitate a structured and effective technology transfer process. Assessing the components of success factors for technology transfer is a top priority, enabling the development of operational guidelines and effective management of related factors. These components may include fostering a comprehensive understanding of the technology being transferred (Phakwat Boonho, 2016; Bacon, Williams, & Davies, 2020; Distanont, Khongmalai, & Kritpipat, 2018). There is acceptance of technology, the benefits are seen and the readiness to apply it. (Saowani Wichitkosum and Unruen Leknoy, 2017; Li & Zhu, 2021). There is the application of technology to solve

problems (Pathompong Chapphan and Nalinphat Bampenphian, 2023; Yu, Zhang, Zhang, & Fan, 2022). This also leads to tangible outcomes from the technology transfer, such as leveraging the technology to enhance business competitiveness and further utilizing it for innovation development (Singh & Dhir, 2023; Zhao, Jiang, Peng, & Hong, 202). This aligns with Bloom's taxonomy of learning levels, which provides a framework for categorizing educational objectives and cognitive skills. (Bloom's Taxonomy) consists of the following levels: knowledge derived from memory (Knowledge), understanding (Comprehension), application (Application), analysis (Analysis), synthesis (Synthesis), and evaluation (Evaluation) (Bloom, 1956). Each level of learning reflects different components of success in technology transfer, highlighting how various cognitive skills contribute uniquely to the overall effectiveness of the process.

In terms of factors affecting technology transfer, there are many concepts that can be classified, such as Cohen and Levinthal (1990) who classified factors affecting technology transfer into 3 parts: 1) technology recipients, 2) technology transferors, and 3) external organizational factors. There are many research studies (Awang et al., 2013; Dogra, Garg, & Jatav, 2013; Fang et al., 2010; Jabar, Soosay and Santa, 2011; Mohamed et al., 2012; Nguyen & Aoyama, 2014) that agree with the above concept. In addition, Choi (2009) mentioned additional factors in addition to the 3 factors above, which are inter-organizational communication factors. This is consistent with the research of Anita Dithanon, Orapan Kongmalai, and Pranee Krichapipat (2018) who presented the factors affecting technology transfer, which can be divided into 4 parts: 1) Knowledge absorption ability, 2) Characteristics of technology transferors, 3) Technology complexity, and 4) Inter-organizational relationships. The structural equation analysis also reflected the factors of inter-organizational relationships. The complexity of technology was also discussed, which is a result of rapid changes in technology and more complex in today's world.

In addition to the factors mentioned above, the relationship between organizations plays a crucial role in the absorption of knowledge by technology recipients and the characteristics of the technology providers. A review of relevant literature reveals that organizational communication factors are closely linked to the aforementioned relationships and are considered a key factor influencing the success of technology transfer. Effective communication between organizations can enhance knowledge sharing and foster a better understanding, ultimately contributing to the successful transfer of digital twin technology for machinery maintenance. (Battistella, Toni, & Pillon 2016; Choi, 2009; Singhai, Singh, Sardana, & Madhukar, 2021; Yu, Zhang, Zhang, & Fan, 2022) The COVID-19 pandemic has prompted numerous studies to highlight important case studies, particularly in the context of inter-organizational communication. These studies have emphasized the limitations in technology transfer when it comes to tacit knowledge—knowledge that is difficult to articulate or explain. It has been acknowledged that, despite the rise of digital communication tools, face-to-face communication remains essential for transferring tacit knowledge, as it fosters deeper understanding and allows for more effective exchange of complex, nuanced information that cannot be easily conveyed through virtual channels. (Singhai, Singh, Sardana, This is consistent with the strategy to technology dissemination for unknown recipients advocated by Saowanee Wijitkosum and Unruen Leknoi (2017), who underlined the necessity of familiarization and alignment with existing practices in ensuring successful and effective technology transfer. This idea is consistent with the element of integrating new and existing information, as mentioned in the study by Hafeez, Shamsuddin, Saeed, Mehmood, and Andleeb (2020). Both viewpoints emphasize the importance of linking new technologies with existing knowledge in order to achieve successful technology transfer. & Madhukar, 2021; Yu, Zhang, Zhang, & Fan, 2022) Indeed, the factors influencing the success of technology transfer can vary depending on the context of the technology being transferred and the research group involved. Therefore, identifying the factors that contribute to successful technology transfer requires consideration of other contextual elements, such as timeframes, budgets, and support from management or policy support from the government. These factors can significantly impact the effectiveness of technology transfer, as they shape the resources and conditions available for the successful implementation of the technology. (Pathompong Chapphan and Nalinphat

Bampenphian, 2023; Yu, Zhang, Zhang, & Fan, 2022) regarding the variable of intent to learn, which is an essential factor but cannot be distinctly categorized according to the objectives of the study, it may either be integrated with the technology recipient variable or categorized as a contextual factor. This is because the intent to learn is closely related to the support from management. The willingness and motivation of technology recipients to engage in learning directly influence how effectively they absorb and apply new technologies, making it a key factor in successful technology transfer (Alemtairy, 2020; Li, & Zhu, 2021; Singhai, Singh, Sardana, & Madhukar, 2021). Especially in modern technologies that are not yet widespread such as digital twins, it is necessary to discuss the importance of digital twin technology in machine maintenance before collecting research data so that the group of informants on the technology recipient side sees the benefits of technology together, which will help to improve the success of technology transfer (Saowani Wichitkosum and Unruen Lekloy, 2017; Ko, Kim, & Lee, 2021) and result in the research results being able to show the success model of digital twin technology transfer for industrial machinery maintenance most accurately and precisely.

This research examines a model for the success of digital twin technology transfer for machinery maintenance in medium to large-scale automotive parts manufacturing industries. The findings aim to revolutionize current maintenance practices, offering widespread benefits, particularly for developing countries like Thailand, which serves as a hub for manufacturing and various industries. Additionally, the study provides a framework for preparing the national workforce to adapt to technological changes and the country's evolving context. The insights gained will serve as a foundation for successfully transferring other advanced and complex technologies, addressing the rapid technological advancements in today's world.

OBJECTIVE

1. To examine the relationships among variables, including technology recipients, technology providers, technological complexity, communication methods, inter-organizational relationships, contextual factors, and the success of digital twin technology transfer for machinery maintenance in automotive parts manufacturing.
2. To study the influence of variables such as technology recipients, technology providers, technological complexity, communication methods, inter-organizational relationships, and contextual factors on the success of digital twin technology transfer for machinery maintenance in automotive parts manufacturing.
3. To develop a model for the success of digital twin technology transfer for machinery maintenance in automotive parts manufacturing.

METHODOLOGY

1. The Research methodology (sample, Methods of study, location, time period, data analysis)

1.1 The population and sample

This quantitative research, the population can be divided into 2 parts: technology recipients and technology transferors. The technology recipient population will be selected from workers in automotive parts manufacturing plants.

For the quantitative sample, the researcher estimated the sample size based on observation variables at a ratio of 1:20 (Jackson, 2003; Asparouhov, 2005). With 16 observation variables in this study, the sample size was determined to be 320 participants. These participants were randomly selected from employees working in automotive parts manufacturing plants, specifically those involved in machinery maintenance and personnel development roles, totaling 280 individuals. Additionally, 40 individuals, including officers and engineers responsible for digital twin technology training within the product-owning companies, were included in the sample.

For the qualitative data, in-depth interviews will be conducted with executives from medium to large automotive parts manufacturing plants in Thailand. A total of 10 factories with different product

types will be selected for the study. The sample includes 10 mid-level managers and 10 senior-level executives, totaling 20 individuals. These interviews aim to gather detailed insights into the technology transfer process, organizational practices, and success factors from a managerial perspective.

1.2 Study Methods

Scope of study

This research is divided into two parts: 1) The study of the variables influencing the success of digital twin technology transfer for machinery maintenance in medium to large-scale automotive parts manufacturing industries and 2. The qualitative study, which involves in-depth interviews with executives from medium to large manufacturing plants across different industries. This part aims to gather rich, detailed insights from industry leaders about their experiences with technology transfer and the factors that contribute to its success.

Scope of area

In Thailand

1.3 Research Tools

Quantitative Research Tools

Research instruments: In the quantitative research, questionnaires were used as a tool for data collection.

Qualitative Research Tools

In conducting qualitative research, the researcher will provide relevant information to demonstrate the importance of digital twin technology, its potential, and the business opportunities that arise when the technology is applied to key informants in advance, using an interview record and listening approach to obtain in-depth information according to the research objectives but with an open-ended answer. The main questions will consist of variables that affect the success of transferring digital twin technology for machine maintenance in the medium to large automotive parts manufacturing industry in Thailand, including technology recipients, technology transferors, technology complexity, communication methods, inter-organizational relationships, and contextual factors. In listening to key information, the researcher will review the comments received from the informants before proceeding to the next question to check understanding and confirm the accuracy of the information. Throughout the interview, the key informants will be asked for permission to record the conversation so that they can review and study it further in detail.

1.4 Collected quantitative data

Collected quantitative data

For data collection, the researcher used a questionnaire as the tool to gather information from the sample group, which consisted of 320 individuals involved with digital twin technology for machinery maintenance. The researcher coordinated with those engaged with the technology to collect online data, ensuring that all 320 completed questionnaires were gathered within the designated time frame. Afterward, the researcher verified the completeness of the questionnaires before proceeding with the data processing and analysis.

Collected qualitative data

In the qualitative data collection process, the researcher collected factors affecting policy success from related literature to synthesize into data collection issues and interview notes before conducting in-depth interviews with key informants who met the above-mentioned qualifications. The details and guidelines are as follows:

1. Before the interview

Before the interview, the researcher will explain the research objectives and the benefits to be gained from the research to the key informants, along with providing relevant information, such as basic knowledge about digital twin technology, its importance, potential, and business opportunities that arise when the technology is used, as well as requesting permission to record and audio conversations during the interview.

2. During the interview

The researcher will use the interview period of approximately 45-60 minutes, depending on the situation and cooperation of the informant. The interview will be conducted in a relaxed environment to allow key informants to express their views, understandings, and beliefs more freely. The researcher must strive to discover information on each topic to determine what variables influence the effectiveness of transferring digital twin technology beyond the analysis in the quantitative research step, including key information that addresses the research study's objectives. For each set of questions, the researcher will use previous feedback in the form of a question review to influence the next question. This is to ensure comprehension and confirm the correctness of the information obtained. The interview will continue until the data is saturated, the researcher does not find any additional questions, or no new information is discovered. (Douglas, 2003; Goulding, 2002; Saunders, et al., 2018)

In addition to audio recording, the researcher will take notes on key points during the interviews. This includes capturing observational data such as tone of voice, facial expressions, eye contact, and body language of the interviewees. The researcher will also document their own thoughts and feelings during the interview process to ensure a comprehensive understanding of the context and to aid in the interpretation of the qualitative data.

3. After the interview

Following the interview, the researcher will immediately record and transcribe the interview data on the same day. This approach ensures that all details from the interview are still fresh in the researcher's mind and allows for a thorough review of the data. The transcribed information will be used to refine the interview process for future sessions and ensure the quality and accuracy of the qualitative data collected.

1.5 Scope of time

This research will be conducted from February 2024 to April 2025.

1.6 Data analysis

Quantitative data analysis

The researcher used statistics for analysis as follows:

1. Descriptive statistics using mean and standard deviation to answer the research objective 1 to explain the level of variables affecting the success of transferring digital twin technology for machine maintenance in the medium to large automotive parts manufacturing industry in Thailand, namely technology recipients, technology transferors, technology complexity, communication methods, inter-organizational relationships, and contextual factors. In this regard, the researcher used a data collection tool as a scale to rate each variable, compared with the data interpretation criteria, and used the data interpretation criteria to interpret the meaning and mean according to the criteria of Boonchum Srisat (1996) because it is an interpretation criterion that rounds decimals to integers. The most appropriate mean is:

Mean 4.51 – 5.00 means the most

Mean 3.51 – 4.50 means a lot

Mean 2.51 – 3.50 means moderate

Mean 1.51 – 2.50 means little

Mean 1.00 – 1.50 means the least

2. The statistical analysis for this research employs a Structural Equation Model (SEM) to examine the variables influencing the success of digital twin technology transfer for machinery maintenance in medium to large-scale automotive parts manufacturing industries. This analysis aligns with the second objective of the study. To validate the fit between the developed structural equation model and empirical data, the researcher will utilize indices and criteria for evaluation based on guidelines proposed by various scholars. (Diamantopoulos, Siguaw, & Siguaw, 2000; Hooper, Coughlan, & Mullen, 2008; MacCallum, Browne, & Sugawara, 1996; Schumacker & Lomax, 2010)

Qualitative data analysis

In the data analysis process, the researcher will organize the data from the interviews with 20 key informants (Data Organization) and then display the results so that the data can be rearranged and reordered (Data Display) as well as summarize and interpret the data to be used with the success model for transferring digital twin technology for machine maintenance in the medium to large automotive parts manufacturing industry.

RESULTS

The results of this study on the success model for the transfer of digital twin technology for machine maintenance in the medium to large-scale automotive parts manufacturing industry can serve as a guide for managing the transfer of digital twin technology. It may also be extended to other advanced technologies. Training institutions can use the findings to improve processes and enhance the efficiency of transferring advanced technologies. This could lead to a revolution in maintenance practices, benefiting a wide range of industries, particularly in developing countries like Thailand, which serves as a hub for manufacturing and industry in various product sectors.

The findings will also guide the preparation of the country's workforce to keep up with technological changes and the country's evolving context. The insights gained will contribute to the success of transferring other complex advanced technologies, following the rapid technological developments in today's world.

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