International Journal of Technology 13(1) 26-37 (2022)
Received March 2021 / Revised June 2021 / Accepted September 2021

International Journal of Technology

http://ijtech.eng.ui.ac.id

The Role of a Leader and the Effect of a Customer's Smart Factory Investment on a Firm's Industry 4.0 Technology Adoption in Thailand

Kwanchanok Chumnumporn[1], Chawalit Jeenanunta[1*], Suchinthara Simpan[1], Kornkanok Srivat[1], Vararat Sanprasert[1]

[1]*School of Management Technology, Sirindhorn International Institute of Technology, Thammasat University, 99 Moo 18, Khlong Luang, Pathum Thani 12120, Thailand*

Abstract. Manufacturers are aware of Industry 4.0 trends due to the new technologies and the transformation of processes that require new competencies of employees and an integrated system in the supply chain network. The purpose of this paper is to examine the role of a leader through a transformational leadership style and the effect of a customer's smart factory investment on a firm's Industry 4.0 technology adoption in the Thai manufacturing industry. In total, 125 valid samples from different companies surveyed in the Thai manufacturing industry were used to analyze the mentioned relations. The multiple regression results show that a leader's transformational leadership and external pressure, such as a customer's smart factory investment, have positive impacts on a firm's operational technology (OT) and information technology (IT) adoptions. These results reveal that successful technology implementation requires both internal and external factors to push for organizational change.

Keywords: Effect of customer's smart factory investment; Industry 4.0; Technology adoption; Transformational leadership;

1. Introduction

Industry 4.0 or the smart factory is an industrial revolution that challenges manufacturing companies. Operational technology (OT) and information technology (IT) are converging by using the Internet of Things (IoT), cyber-physical systems (CPS), big data, and analytical, artificially intelligence, cloud computing, and autonomous robots (Schumacher et al., 2016; Fatorachian and Kazemi, 2018; Berawi, 2020). These advanced technologies are transforming products, processes, and business models to form new industrial patterns. The development results of the fourth industrial revolution are not only the new technologies but also a new entrepreneurial mindset (Sterev, 2017). For this reason, business leaders play an essential role in developing and motivating their individual followers by determining and setting clear missions and visions (Wang and Howell, 2012; Cinnioğlu, 2020). Top management strategies pose significant challenges to managing employees to change their behaviors and adopt new technologies (Ihua, 2009). Various research studies on the modern leadership theory have explored the distinct attributes of a leader who has a transformational leadership style as an agent of change (Yu et al., 2002;

*Corresponding author's email: chawalit@siit.tu.ac.th, Tel.: +66-2-986-9103 to 5, 7 to 9 ext 1105, Fax.: +66-2-986-9112 to 3
doi: 10.14716/ijtech.v13i1.4814

Hallinger, 2003; Bass and Riggio, 2006). Thus, it is essential to study how transformational leadership affects Industry 4.0 technology adoption.

While large-sized companies are very flexible in their investments to upgrade their technologies toward Industry 4.0, small- and medium-sized companies (SMEs) have limited budgets, knowledge, and expertise. These barriers faced by SMEs bring a low level of Industry 4.0 technology implementation in their enterprises. Nguyen's (2009) study about the impacts of internal and external forces on IT adoption shows that customer pressure positively affects the IT adoption of manufacturers, especially SMEs. Similarly, Intalar and Jeenanunta's (2019) research has confirmed the positive influence of a customer's information and communication technology (ICT) investment on a supplier's ICT adoption. Thus, this study includes the effect of a customer's smart factory investment as another empirical factor.

The key research question addressed in this study includes an analysis testing of the impact of transformational leadership and the effect of a customer's smart factory investment on a firm's OT/IT adoption. The rest of this paper is organized as follows: The theoretical background and the hypotheses are presented in Section 2. The hypothesis model is empirically tested in Section 3, and the results are discussed in Section 4. Finally, the conclusions are drawn in Section 5.

2. Literature Review

2.1. Industry 4.0 and OT/IT Convergence

The fourth industrial revolution is a phenomenon that affects the traditional approach to digitization. This leads to the creation of a digital twin or a virtual world. The digital counterpart can comprise the entire process of an organization, starting from the purchase of materials for production to the delivery of products and services. The digital twin aims to predict productivity, optimize the production volume, and solve complex technical industry problems (Golovina et al., 2020). The digital transformation merges OT and IT, which makes it possible to connect the physical factory floor and the cyber computational space for real-time data exchange and monitoring among all related perspectives (Lee et al., 2015). To develop automated interfaces between business and control systems, the ISA-95 standard, known as the automation pyramid, is widely adopted in the manufacturing industry. The automated stage is clearly defined by five layers of architecture, as follows: Level 0 – Physical production process, which comprises mechanical operations, field devices, sensors, actuators, and wiring; Level 1 – Process control network, which includes automation network and safety instrumented systems; Level 2 – Supervisory control applications, which include supervisory control and data acquisition (SCADA), human–machine interface (HMI), a distributed control system (DCS), a manufacturing execution system (MES), and industrial control systems; Level 3 – Operations management, which consists of scheduling, operations management, production, maintenance, optimizing process, and remote access; and Level 4 – Business planning, which combines enterprise resource planning (ERP) work management and enterprise data systems (Ikram and Thornhill, 2010; Koerber et al., 2018; Cirgref, 2019). The synchronization of OT and IT for industrial automation systems based on ISA-95 occurs between Levels 2 and 3 (The and Kuusk, 2021). OT is used for control and monitoring while utilizing the IT infrastructure; however, according to Haider (2012), OT and IT are considered separate and distinct. In the present study, Industry 4.0 technology adoption is investigated in terms of OT and IT. In this study, an organization's OT/IT adoption is determined based on the definitions of OT and IT taken from the Gartner IT glossary (cited in Cirgref, 2019). A firm's OT adoption is defined as the implementation of hardware and software to control or monitor processes, machines, and industrial equipment (Cirgref, 2019, p. 8). A firm's IT adoption is defined as the implementation of information processing technologies, which consist of hardware, software, communications technologies, and related services (Cirgref, 2019, p. 7).

2.2. Transformational Leadership and a Firm's Technological Adoption

The rapid changes in the world order due to digitalization have brought many innovations and new technologies to business processes. To transform organizations, Eisenbach et al. (1999) have noted leadership as an influence aimed to initiate changes in organizational processes and procedures for business improvement. A leadership style is a behavioral pattern that differs among leaders, based on their leadership capabilities, including knowledge and skills (Mumford et al., 2000). Leadership capabilities can be developed over time through education and experience (Northouse, 2016). In the workplace, leaders can apply their leadership style as a communication approach. Different leadership styles can encourage followers, with varying results (Van de Vliert, 2006). According to the modern leadership theory, transformational leadership is more effective than other leadership styles in enhancing innovation at the organizational level (Howell and Avolio, 1993; Lowe et al., 1996; Gardner and Avolio, 1998). For transformational leadership, this leadership style aims leaders to initiate emotional and physical efforts jointly with their followers and to motivate one another to attain higher levels of achievement. Such collaboration encourages sharing the organizational mission and infusing everyone with a sense of purpose, direction, and meaning (Bass, 1999). Previous studies (Schepers et al., 2005; Seyal, 2015; Waziri et al., 2015; Davutoğlu, 2018) have indicated that the transformational leadership style plays a critical role in the successful implementation of a technology. Transformational leaders have been determined as agents of change (Hallinger, 2003). Leaders who practice transformational leadership behaviors can motivate their followers to transcend their self-interest in order to achieve the organizational goals and objectives (Koçel, 2014, p. 668; Cinnioğlu, 2020). Additionally, transformational leaders who develop their followers' skills to increase self-efficacy can positively affect the latter's creativity (Bass, 1999). Employees with enhanced self-efficacy are more likely to be motivated to generate novel ideas and solutions (Gumusluoglu and Ilsev, 2009). In line with this, transformational leadership aims for organizations to solve their problems, such as an insufficient number of professionals, the lack of motivation and support, and inadequate staff training (Waziri et al., 2015). Hence, this leadership style is selected for this present study as the influencing factor for technology adoption.

Transformational leadership is defined as a process whereby a leader engages with his/her followers and makes a commitment to realize the organizational missions and goals by prompting some changes in the attitudes and behaviors of the organization's members (Yukl, 1999). According to the multifactor leadership questionnaire (MLQ-5X), transformational leadership behavior comprises five distinct components: (1) inspirational motivation, where the leaders motivate their followers through new ideas and goals by articulating a clear vision and viewing the future with a positive attitude; (2) idealized influence (attributed), where the followers attribute charisma to their leaders based on their trust, respect, admiration, and loyalty; (3) idealized influence (behavior), where the followers observe their leaders' behavior as having a sense of mission and value; (4) intellectual stimulation, where the leaders stimulate their followers to be creative and innovative by developing their abilities to confront and solve problems in a variety of ways; and (5) individualized consideration, where the leaders consider the individual needs of their followers and develop their individual strengths (Waziri et al., 2015; Northouse, 2016). This study expects a higher level of transformational leadership practices to lead to a higher OT/IT adoption level.

2.3. *The Effect of a Customer's Smart Factory Investment on a Supplier's Adoption of Industry 4.0 Technologies*

Smart factory systems enable information sharing between customers and suppliers in the supply chain network. In other words, Industry 4.0 makes customers and suppliers or partners work closely through real-time data sharing (Alam and Noor, 2009). By upgrading an ICT system, many customers request their suppliers to improve their business transactions and operation management (i.e., control, monitor, and exchange information) (Intalar and Jeenanunta, 2019). Customers encourage their suppliers to adopt compatible technologies in order to enhance the efficiency of information communication and increase their reliability (Youssef et al., 2012). Without customer pressure, many firms, especially SMEs, would be reluctant to invest in an ICT system due to their limited financial support, technological capability, resources, and IT knowledge (Nguyen, 2009; Consoli, 2012). A previous study on the Japanese automotive supply chain network (Sako, 2004) has explored the coordination between customers and the next-tier suppliers in procurement and joint research and development (R&D) activities. Customers may influence their suppliers to make a strategic planning decision on a particular technology investment related to their customer investment plan (Intalar and Jeenanunta, 2019). Therefore, it is crucial to investigate the role of customer pressure in the technology implementation by suppliers.

This study focuses on digitization and automation. Customers' smart factory investments refer to customer investments in Industry 4.0 technologies, both hardware and software, to improve business transactions, information processing capacity, production efficiency, automation in processes, and abilities to monitor/control the service and product value chain (Youssef et al., 2012; Intalar and Jeenanunta, 2019; Berawi, 2020). According to an important role of customer pressure in the supply chain, the effect of a customer's smart factory investment is defined as the pressure exerted by the customer in influencing his/her suppliers to invest in and adopt technologies related to Industry 4.0/a smart factory. Both internal and external factors have altered the level of a firm's technology adoption. Thus, the following hypotheses are formulated:

Hypothesis 1. Transformational leadership and the effect of customer's smart factory investment have a positive impact on a firm's OT adoption.
Hypothesis 2. Transformational leadership and the effect of customer's smart factory investment have a positive impact on a firm's IT adoption.

3. Methods

3.1. *Sample and Data Collection*

The data were collected from January to February 2020 through a survey by using mail (domestic services and e-mail). The target respondents were top-level management executives, such as the CEO, the factory director, and the plant manager, of Thai manufacturing firms. The survey questionnaires were distributed to 1,155 manufacturing firms. The list of firms was randomly selected from the Industrial Estate Authority of Thailand (IEAT) and the Thai Auto Parts Manufacturers Association (TAPMA) online databases. A total of 125 firms, comprising 10.82% of the target respondents, provided valuable and complete information for this research. A multiple regression test was performed to test the hypothesized relations between the independent variables (transformational leadership and the effect of a customer's smart factory investment) and the dependent variable (a firm's OT/IT adoption). According to Hair et al. (2019), a multiple regression requires at least 50 samples and preferably 100 observations for most research situations to maintain the power (probability) level of 0.8. Thus, this study had enough data for hypothesis testing by multiple regression analysis.

The respondents' characteristics are summarized in Table 1. In terms of business activities, approximately 15.20% of the responding firms belonged to the automobile industry; 10.40% were in the food, beverage, and tobacco industry; and 8.80% belonged to the plastic and rubber products industry. Based on the number of employees, the respondents represented large-sized firms (44%) and SMEs (28% each). In terms of gender, most firms had male CEOs (93.60%), and female CEOs comprised 6.40%. Regarding the nationalities of the CEOs, approximately 76.80% of the respondents were Thai, and 23.20% were expatriates.

Table 1 Demographic characteristics of the sample

Demographic	Classification	n	(%)
Main business activity	Automobile, auto parts	19	15.20
	Food, beverages, tobacco	13	10.40
	Plastic, rubber products	11	8.80
	More than one main product	9	7.20
	Chemicals, chemical products	6	4.80
	Iron, steel	6	4.80
	Other electronics and components	6	4.80
	Metal products	5	4.00
	Machinery, equipment, tools	5	4.00
	Non-ferrous metals	4	3.20
	Textiles	3	2.40
	Other non-metallic mineral products	2	1.60
	Other manufacturing	36	28.80
Company size	Large (≥ 200 employees)	55	44.00
	Medium (50–199 employees)	35	28.00
	Small (< 50 employees)	35	28.00
Gender of CEO	Male	117	93.60
	Female	8	6.40
Nationality of CEO	Thai	96	76.80
	Foreign	29	23.20

3.2. Measures

The multi-item scales of all the variables in the questionnaire were based on previously published scales, which were initially developed in English. The back-translation method was applied to translate all questions and their scales from English to Thai. Management researchers have frequently applied this translation technique (Matsumoto, 1994; Hwang et al., 1996). The translation of the survey was validated by three experts, including two academics and one top executive. The questions (particular words or sentences) were revised if they were ambiguous. The final survey was then conducted for the data collection. Transformational leadership was measured using the MLQ-5X questionnaire, which was adopted from Northouse's (2016) research. Five items were used to measure transformational leadership as the self-perception of leadership behaviors, with scale values from 1 to 5 (1 = Not at all, 2 = Once in a while, 3 = Sometimes, 4 = Fairly often, and 5 = Frequently). The effect of a customer's smart factory investment construct was measured using a 4-point Likert scale based on the one applied by Intalar and Jeenanunta (2019), ranging from 0 to 3 (0 = No, 1 = Little, 2 = Somewhat, and 4 = Much). Technology adoption was measured by 12 items for 2 dimensions: a firm's OT adoption and a firm's IT adoption. These constructs were developed from the ICT system adoption by Intalar and Jeenanunta (2019) and from Industry 4.0 technology-related studies (Ikram and Thornhill, 2010; Illa and Padhi, 2018; Frank et al., 2019). This study focuses on the following seven technologies applied in a firm's OT adoption: (1) automation controlled by programmable logic controller (PLC), computer numeric control (CNC), or robotic process automation (RPA); (2) design and manufacturing system (computer-aided design (CAD)/computer-aided manufacturing (CAM)/ computer-aided engineering (CAE)/ process simulation); (3) MES; (4) automation system for machines' synchronization (IoT/real-time control system (RCS)/HMI/machine-to-machine (M2M)); (5) SCADA; (6) material handling technology (conveyor/automated guided vehicles (AGVs)); and (7) tracking technology (barcode/radio frequency identification (RFID)/quick response (QR) code). For a firm's IT adoption, this study focuses on the following six technologies: (1) material resource planning (MRP); (2) cloud technology; (3) ERP; (4) customer relationship management (CRM); (5) business process management (BPM); and (6) supply chain management (SCM). All these items were measured on a scale with values from 0 to 4 (0 = No plan to adopt, 1 = Under evaluation or consideration, 2 = Trial adoption, 3 = Adopted, 4 = Adopted and integrated with another system). The descriptive statistics of the constructs are presented in Table 2.

Table 2 Reliability test and factor analysis

Variables	Mean	SD	Factor loading	KMO	α
Firm's OT adoption				0.867	0.901
Automation controlled by PLC/CNC/RPA	2.296	1.437	0.780		
Design and manufacturing system (CAD/CAM/CAE/process simulation)	2.072	1.514	0.740		
Manufacturing execution system (MES)	1.792	1.427	0.837		
Tracking technology (barcode/RFID/QR code)	1.688	1.394	0.815		
Automation system for machines' synchronization (IoT/RCS/HMI/M2M)	1.648	1.466	0.855		
Supervisory control and data acquisition (SCADA)	1.592	1.460	0.814		
Material handling technology (conveyor/AGVs)	1.360	1.461	0.712		
Firm's IT adoption				0.848	0.904
Material resource planning (MRP)	1.872	1.344	0.854		
Cloud technology	1.824	1.392	0.682		
Enterprise resource planning (ERP)	1.800	1.276	0.836		
Customer relationship management (CRM)	1.568	1.207	0.866		
Business process management (BPM)	1.432	1.207	0.884		
Supply chain management (SCM)	1.344	1.290	0.824		
Transformational leadership				0.872	0.876
Idealized influence (behavior)	3.296	0.852	0.818		
Inspirational motivation	3.216	0.955	0.827		
Individualized consideration	3.144	0.877	0.803		
Intellectual stimulation	3.016	0.898	0.810		
Idealized influence (attributed)	2.584	0.935	0.834		

4. Results and Discussion

This study used a multiple regression analysis implemented in the SPSS statistics software (version 23) to investigate the hypothesized relations. The data were analyzed using descriptive statistics, factor analysis, and correlations. The results are presented in two stages. At the first stage, the measurement instruments' construct validity and reliability are assessed. At the second stage, the model of the hypotheses is tested.

4.1. Validity and Reliability Test

A confirmatory factor analysis (CFA) was conducted on the measurement instruments for a firm's OT adoption, a firm's IT adoption, and transformational leadership. The construct reliability assessed the internal consistency of the components by using Cronbach's alpha (α). The seven items that measure a firm's OT adoption have a Cronbach's alpha value of 0.901. The six items that measure a firm's IT adoption have a Cronbach's alpha value of 0.904. The five items that measure transformational leadership have a Cronbach's alpha value of 0.876. According to Vanichbuncha (2012), the recommended Cronbach's alpha value is more than 0.70. Consequently, the measurement instruments of the constructs are reliable. Based on the CFA, the Kaiser-Meyer-Olkin (KMO) value should be more than 0.60 and the factor loading values should be more than 0.50 to ensure sampling adequacy (Vanichbuncha, 2012). The KMO values for transformational leadership, a firm's OT adoption, and a firm's IT adoption are 0.872, 0.867, and 0.848, respectively. All measurement instruments of the constructs have a factor loading value of more than 0.60. Therefore, the constructs are accepted, as shown in Table 2.

A Pearson product-moment correlation coefficient was applied to assess the impact of collinearity among the independent variables and to ensure the linear relations between the independent and the dependent variables. According to Hair et al. (2019), a collinearity problem occurs when the correlation coefficient is 0.70 or higher. The correlation coefficient values between the independent and the dependent variables are significant, as shown in Table 3. Moreover, the results show the non-significant correlation coefficient value between transformational leadership and the effect of a customer's smart factory investment on a firm's OT adoption (Hypothesis 1) and IT adoption (Hypothesis 2).

Table 3 Pearson's correlation coefficients between variables

Variables	1	2	3
Hypothesis 1			
1. Firm's OT adoption	1		
2. Transformational leadership	0.265**	1	
3. Effect of customer's smart factory investment	0.334**	0.115	1
Hypothesis 2			
1. Firm's IT adoption	1		
2. Transformational leadership	0.244**	1	
3. Effect of customer's smart factory investment	0.245**	0.115	1

Note: **The correlation is significant at the 0.01 level

4.2. Hypothesis Testing

The two multiple regression models were used to explain the two dependent variables. The equations of the hypothesized models for the multiple regression analysis are as follows:

Hypothesis 1. Firm's OT adoption = $\alpha + \beta_1 X_1 + \beta_2 X_2$,

Hypothesis 2. Firm's IT adoption = $\alpha + \beta_1 X_1 + \beta_2 X_2$,

where X_1 denotes transformational leadership, and X_2 represents the effect of a customer's smart factory investment.

The results shown in Table 4 demonstrate that both models are significant (Vanichbuncha, 2012). For Hypothesis 1, the results are accepted at the significance level of 0.01; the value of the F-test is 11.952 (sig. = 0.000), and the adjusted R^2 is 0.150. Both transformational leadership and the effect of a customer's smart factory investment are significant, with t-test values equal to 2.764 (b = 0.230, sig. = 0.007) and 3.697 (b = 0.308, sig. = 0.000), respectively. Consequently, transformational leadership and the effect of a customer's smart factory investment have a positive impact on a firm's OT adoption.

For Hypothesis 2, the result of the F-test is 7.336 (sig. = 0.001), and the adjusted R^2 is 0.107, which are accepted at the significance level of 0.01. Transformational leadership is significant, with a t-test value of 2.541 (b = 0.219, sig. = 0.012), and the effect of a customer's smart factory investment is also significant, with a t-test value of 2.563 (b = 0.221, sig. =

0.012); both independent variables are accepted at the significance level of 0.05. These results confirm that transformational leadership and the effect of a customer's smart factory investment have a positive impact on a firm's IT adoption. Therefore, transformational leadership and the effect of a customer's smart factory investment are important factors for both OT and IT adoption in the Industry 4.0 revolution.

Table 4 Results of multiple regression analysis on Hypotheses 1 and 2 (H1 and H2)

Independent variables	F-test	t-test	Beta	Adjusted R^2	Standard Error of the Estimate	Conclusion
H1. Firm's OT adoption	11.952**			0.150	0.922	
Transformational leadership		2.764**	0.230			Supported
Effect of customer's smart factory investment		3.697**	0.308			Supported
H2. Firm's IT adoption	7.336**			0.107	0.953	
Transformational leadership		2.541*	0.219			Supported
Effect of customer's smart factory investment		2.563*	0.221			Supported

Note: **The correlation is significant at the 0.01 level; *The correlation is significant at the 0.05 level

The results of the multiple regression analysis reinforce previous studies' findings about the impact of transformational leadership on technology adoption in organizations (Schepers et al., 2005; Seyal, 2015; Waziri et al., 2015). In their study about the Nigerian construction industry, Waziri et al. (2015) have found that construction managers who practice transformational leadership can quickly motivate their subordinates to implement a new technology. This implies the top management's aim toward the firm's successful implementation process by providing clear project goals and allocating resources well (Jafari et al., 2006). However, many top management executives have not arranged anything to prepare for technological changes or keep the concept of smart technologies. Bencsik's (2020) research about the challenges of management in the digital economy in three European countries (Germany, Hungary, and Slovakia) shows the German leaders' vision toward Industry 4.0 and digitalization beyond those of the two other nations. The German leaders are concerned about the future heading toward digitalization, AI, robotics, international relations and expansion, and investments. Consequently, German ownership holds the top rank in terms of investment and value-added production per country. Therefore, the top management should be concerned about the technology revolution and new leadership styles relevant to digitalization.

The outcomes of this study also highlight the importance of external pressure, such as the effect of a customer's smart factory investment on a firm's adoption of both OT and IT. The research results correlate with previous studies explaining how customers encourage their suppliers to invest in new technologies (Sako, 2004; Nguyen, 2009; Consoli, 2012; Intalar and Jeenanunta, 2019). Intalar and Jeenanunta (2019) have mentioned that customers can force their suppliers to apply the same technology that the customers have already implemented. Large enterprises have provided the supplier development program, which affects supplier investment decisions, especially among suppliers that are SMEs. This is a system of corporate governance that allocates resources to a compatible technology and new skill learning related to network technologies (Sako, 2004; Fabiani et al., 2005). SMEs should adopt investments in smart technology to acquire knowledge from their customers, especially technology-based firms. The aim is for SMEs to upgrade their level of automation, as well as increase their positive attitude toward adopting a new technology. Transformational leadership can inspire the assignment of higher values to technology implementation and promote the new technology in workplaces, with the intensive toward smart factory from the customer. Consequently, the customers' smart factory investments can help the firms successfully promote new technology practices in their organizations.

5. Conclusions

The main purpose of this paper is to investigate how transformational leadership (internal factor) and the effect of a customer's smart factory investment (external factor) affect a firm's OT and IT adoption. Successful technology adoption requires leaders to play an important role in designing the core technological values, purpose, and vision by creating policies, strategies, and structures that will guide their organizations toward successful technology integration and implementation. Additionally, there is strong evidence that when customers invest in new technologies related to Industry 4.0, this will affect their suppliers' Industry 4.0 technology adoption. The same level of technology aims to reduce coordination failures between manufacturers and their suppliers. Therefore, the top management executives (CEOs) should have a vision toward Industry 4.0 or a smart factory to lead their firms to achieve digital transformation. Moreover, the firms need to establish strong relationships and collaboration with their customers to learn how to improve their OT/IT systems and create automation in the production process. The higher level of automation in manufacturing processes aims to reduce the manufacturing lead time, increase productivity, and enhance product quality.

This study has not examined other internal and external dimensions. Further research could link other leadership theories (such as those involving leadership skills, leadership behavior, and agile leadership etc.) with a firm's technology adoption to analyze the former's influence on the latter. Researchers could also include other external factors, such as the government's Industry 4.0 policy, which supports manufacturers in collaborating with an external organization (e.g., a government labor training institution and a university) to upgrade a technology and upskill/reskill employees. It is also important to determine the appropriate strategic to enhance the success of Industry 4.0 technology in each business size in Thailand. Thus, further studies should test the initial hypothesis to investigate the effects of the leadership style and customer investment on a firm's technology adoption in the different contexts of the business size, the leader's gender, and the leader's nation. Furthermore, this study has conducted a narrow analysis. Future research should apply a non-linear regression method to investigate the effects of transformational leadership and a customer's smart factory investment on a firm's Industry 4.0 technology adoption.

Acknowledgements

This research was fully supported by the Center of Excellence in Logistics and Supply Chain Systems Engineering and Technology (COE LogEn), Sirindhorn International Institute of Technology, Thammasat University.

References

Alam, S.S., Noor, M.K.M., 2009. ICT Adoption in Small and Medium Enterprises: An Empirical Evidence of Service Sectors in Malaysia. *International Journal of Business and Management*, Volume 4(2), pp. 112–125

Bass, B.M., 1999. Two Decades of Research and Development in Transformational Leadership. *European Journal of Work and Organizational Psychology,* Volume 8(1), pp. 9–32

Bass, B., Riggio, R., 2006. *Transformational Leadership (2nd ed.)*. Lawrence Erlbaum Associates, Inc., Mahwah, New Jersey, USA

Bencsik, A., 2020. Challenges of Management in the Digital Economy. *International Journal of Technology*, Volume 11(6), pp. 1275–1285

Berawi, M.A., 2020. Managing Artificial Intelligence Technology for Added Value. *International Journal of Technology*, Volume 11(1), pp. 1–4

Cinnioğlu, H., 2020. *A Review of Modern Leadership Styles in Perspective of Industry 4.0.* In: Agile Business Leadership Methods for Industry 4.0, Emerald Publishing Ltd., pp. 1–23

Cirgref, 2019. *IT/OT Convergence: A Fruitful Integration of Information Systems and Operational Systems*. Available Online at https://www.cigref.fr/cigref-report-it-ot-convergence-a-fruitful-integration-of-information-systems-and-operational-systems, Accessed on January 6, 2021

Consoli, D., 2012. Literature Analysis on Determinant Factors and the Impact of ICT in SMEs. *Procedia - Social and Behavioral Sciences*, Volume 62, pp. 93–97

Davutoğlu, N.A., 2018. Sanayi 4.0'ın Liderlik Ve Insan Kaynakları Yönetimine Algısal Etkileri. *Journal of Social and Humanities Sciences Research (JSHSR)*, Volume 5(30), pp. 4041–4048

Eisenbach, R., Watson, K., Pillai, R., 1999. Transformational Leadership in the Context of Organizational Change. *Journal of Organizational Change Management*, Volume 12(2), pp. 80–88

Fabiani, S., Schivardi, F., Trento, S., 2005. ICT Adoption in Italian Manufacturing: Firm-Level Evidence. *Industrial and Corporate Change*, Volume 14(2), pp. 225–249

Fatorachian, H., Kazemi, H., 2018. A Critical Investigation of Industry 4.0 in Manufacturing: Theoretical Operationalisation Framework. *Production Planning & Control*, Volume 29(8), pp. 633–644

Frank, A.G., Dalenogare, L.S., Ayala, N.F., 2019. Industry 4.0 Technologies: Implementation Patterns in Manufacturing Companies. *International Journal of Production Economics*, Volume 210, pp. 15–26

Gardner, W.L., Avolio, B.J., 1998. The Charismatic Relationship: A Dramaturgical Perspective. *Academy of Management Review*, Volume 23(1), pp. 32–58

Golovina, T., Polyanin, A., Adamenko, A., Khegay, E., Schepinin, V., 2020. Digital Twins as a New Paradigm of an Industrial Enterprise. *International Journal of Technology*, Volume 11(6), pp. 1115–1124

Gumusluoglu, L., Ilsev, A., 2009. Transformational Leadership, Creativity, and Organizational Innovation. *Journal of Business Research*, Volume 62(4), pp. 461–473

Haider, A., 2012. Information and Operational Technologies Governance Framework for Engineering Asset Management. *In:* Mathew, J., Ma, L., Tan, A., Weijnen, M., Lee, J. (Eds.), Engineering Asset Management and Infrastructure Sustainability, Springer, London

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., 2019. *Multivariate Data Analysis (8th ed.)*. Cengage Learning, EMEA, Hampshire, UK

Hallinger, P., 2003. Leading Educational Change: Reflections on the Practice of Instructional and Transformational Leadership. *Cambridge Journal of Education*, Volume 33(3), pp. 329–351

Howell, J.M., Avolio, B.J., 1993. Transformational Leadership, Transactional Leadership, Locus of Control, and Support for Innovation: Key Predictors of Consolidated-Business-Unit Performance. *Journal of Applied Psychology*, Volume 78(6), pp. 891–902

Hwang, C., Yan, W., Scherer, R.F., 1996. Understanding Managerial Behaviour in Different Cultures: A Review of Instrument Translation Methodology. *International Journal of Management*, Volume 13(3), pp. 332–339

Ihua, U.B., 2009. SMEs Key Failure-Factors: A Comparison Between the United Kingdom and Nigeria. *Journal of Social Sciences*, Volume 18(3), pp. 199–207

Ikram, W., Thornhill, N.F., 2010. Wireless Communication in Process Automation: A Survey of Opportunities, Requirements, Concerns and Challenges. *In:* UKACC International Conference on Control 2010, pp. 1–6

Illa, P.K., Padhi, N., 2018. Practical Guide to Smart Factory Transition using IoT, Big Data and Edge Analytics. *IEEE Access*, Volume 6, pp. 55162–55170

Intalar, N., Jeenanunta, C., 2019. Effects of Customer's Investment in ICT on Partners' Decisions Through the Supply Chain: An Empirical Study of the Manufacturing Industry in Thailand. *Asian Journal of Technology Innovation*, Volume 27(2), pp. 239–256

Jafari, S.M., Osman, M.R., Yusuff, R.M., Tang, S.H., 2006. ERP Implementation in Malaysia: The Importance of Critical Success Factors. *International Journal of Engineering and Technology*, Volume 3(1), pp. 125–131

Koçel, T., 2014. İşletme Yöneticiliği *(Business Management).* İstanbul, Beta Basım

Koerber, B., Freund, H., Kasah, T., Bolz, L., 2018. Leveraging Industrial Software Stack Advancement for Digital Transformation. *Digital McKinsey*, (August), pp. 1–50

Lee, J., Bagheri, B., Kao, H.A., 2015. A Cyber-Physical Systems Architecture for Industry 4.0-Based Manufacturing Systems. *Manufacturing Letters*, Volume 3, pp. 18–23

Lowe, K.B., Kroeck, K.G., Sivasubramaniam, N., 1996. Effectiveness Correlates of Transactional and Transformational Leadership: A Meta-Analytic Review of the MLQ Literature. *Leadership Quarterly*, Volume 7(3), pp. 385–425

Matsumoto, D., 1994. *People: Psychology from A Cultural Perspective, Brooks/Cole Publishing Company.* Pacific Grove, CA

Mumford, M.D., Zaccaro, S.J., Harding, F.D., Jacobs, T.O., Fleishman, E.A. 2000. Leadership Skills for a Changing World: Solving Complex Social Problems. *Leadership Quarterly*, Volume 11(1), pp. 11–35

Nguyen, T.U.H., 2009. Information Technology Adoption in SMEs: An Integrated Framework. *International Journal of Entrepreneurial Behavior and Research*, Volume 15(2), pp. 162–186

Northouse, P.G., 2016. *Leadership: Theory and Practice (7th ed.)*. Sage Publications, Thousand Oaks, CA

Sako, M., 2004. Supplier Development at Honda, Nissan and Toyota: Comparative Case Studies of Organizational Capability Enhancement. *Industrial and Corporate Change*, Volume 13(2), pp. 281–308

Schepers, J., Wetzels, M., de Ruyter, K., 2005. Leadership Styles in Technology Acceptance: Do Followers Practice What Leaders Preach? *Managing Service Quality*, Volume 15(6), pp. 496–508

Schumacher, A., Erol, S., Sihn, W., 2016. A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises. *Procedia CIRP*, Volume 52(1), pp. 161–166

Seyal, A.H., 2015. Examining the Role of Transformational Leadership in Technology Adoption: Evidence from Bruneian Technical and Vocational Establishments (TVE). *Journal of Education and Practice*, Volume 6(8), pp. 32–43

Sterev, N., 2017. Marketing Leadership: The Industry 4.0 Need of Next Generation Marketing. *Trakia Journal of Science*, Volume 15(1), pp. 99–103

The, Y., Kuusk, A.G., 2021. Aligning IIoT and ISA-95 to Improve Asset Management in Process Industries. *In:* Crespo Márquez A., Komljenovic D., Amadi-Echendu J. (Eds) 14th WCEAM Proceedings, WCEAM 2019, Lecture Notes in Mechanical Engineering, Springer, Cham

Van de Vliert, E., 2006. Autocratic Leadership Around the Globe; Do Climate and Wealth Drive Leadership Culture? *Journal of Cross-Cultural Psychology*, Volume 37(1), pp. 42-59

Vanichbuncha, K., 2012. *Statistic for Research*. Chulalongkorn University Bookshop, Bangkok

Wang, X.H.F., Howell, J.M., 2012. A Multilevel Study of Transformational Leadership, Identification, and Follower Outcomes. *The Leadership Quarterly*, Volume 23(5), pp. 775–790

Waziri, A.Y., Ali, K.N., Aliagha, G.U., 2015. The Influence of Transformational Leadership Style on ICT Adoption in the Nigerian Construction Industry. *Asian Social Science*, Volume 11(18), pp. 123–133

Youssef, A.B., Merino, D.C., Hadhri, W., 2012. *Determinants of Intra-Firm Diffusion Process of ICT: Theoretical Sources and Empirical Evidence from Catalan Firms.* In: Allegrezza, S., Dubrocard, A. (Eds.), Internet Econometrics, Palgrave Macmillan, London, pp. 288–312

Yu, H., Leithwood, K., Jantzi, D., 2002. The Effects of Transformational Leadership on Teachers' Commitment to Change in Hong Kong. *Journal of Educational Administration*, Volume 40(4), pp. 368–389

Yukl, G., 1999. An Evaluation of Conceptual Weaknesses in Transformational and Charismatic Leadership Theories. *Leadership Quarterly*, Volume 10(2), pp. 285–305