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A Study on Japanese and Chinese Manufacturing Employees' Willingness to Accept IoT Systems as a Service Based on UTAUT and ISO25010 Models

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ABSTRACT

The combination of data collected by devices using Internet of Things (IoT) and artificial intelligence technologies can help enterprise employees enhance work efficiency and managers make intelligent decisions to improve performance. However, the introduction of IoT faces numerous challenges. With the objective to empirically analyse employees' intentions toward IoT introduction, this study combines, software quality evaluation standard ISO25010 and the Unified Theory of Acceptance and Use of Technology (UTAUT) model to establish a new analysis framework, based on data collected through a questionnaire survey of IT technical employees of manufacturing companies in China and Japan. The structural equation model was used to quantify IoT perceptions of employees in these two countries for the first time, in terms of performance expectancy, effort expectancy, facilitating conditions, and pursuit of quality to identify factors influencing IoT technology adoption intention. The findings suggest that performance expectations, the pursuit of quality for IoT and external environmental factors have a positive effect on the adoption of IoT technologies by manufacturing employees.

Keywords: Structural Equation Modeling, Empirical Research, Adoption intention of IoT, unified theory of adoption and use of technology (UTAUT) model.

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1. INTRODUCTION

The smart factory proposes deploying sensors every step of the process and in every workshop, from product entry to production to output (Zhong, Xu et al. 2017). Through the networking of equipment and data collection capabilities, a real-time sensing network can be established to monitor each production process (Majid, Habib et al. 2022), provide early warnings of failures caused by manual and machine operation errors in such processes, and use a large amount of data collected by artificial intelligence to forecast the product life cycle and help management make strategic decisions. Given that multiple factors influence the intentions of enterprise employees toward the introduction of the Internet of Things (IoT), this study uses a well-established research framework called the Unified Theory of Acceptance and Use of Technology (UTAUT) to empirically analyse

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employees' intentions toward IoT introduction. The UTAUT model is a well-established model for measuring organizational and individual intentions to accept new technologies/systems (Kochhar, Swierc et al. 2018).This research used the UTAUT model to process the data by (1) analysing different sample cohorts, (2) distinguishing the attributes of respondents and conducting a multi-group comparative analysis, and (3) adding the software quality evaluation standard ISO 25010 to the UTAUT model to allow respondents to assess their intention to use IoT from the perspective of system quality.

This study intends to understand the core factors that influence the intention of IoT introduction in manufacturing industries in China and Japan in the context of Industry 4.0 and the early introduction of IoT devices in enterprises' digitalization. China and Japan, two prominent manufacturing nations globally, exhibit distinctive and representative profiles of manufacturing development and industrial structures. China, as the world's largest manufacturing powerhouse, boasts an extensive labour force, substantial market demand, and a progressively sophisticated manufacturing infrastructure. Both the government and enterprises are enthusiastic about implementing industrial upgrades and structural transformations. It's safe to say that China's manufacturing industry is currently experiencing profound technological changes. We are confident that our research on the theories and concepts involved will capture the interest of our respondents. On the other hand, Japan, being an advanced manufacturing nation, possesses abundant experience and a well-established technical system in manufacturing development. It leads the way in manufacturing across sectors like automobiles, precision instruments, and industrial machinery, surpassing many other nations. Japanese manufacturing companies excel in the application of information technology, and their technical systems and management methods exhibit a high degree of maturity. We believe that conducting individual research and a comparative analysis of two countries with highly concentrated manufacturing industries can serve as a valuable and well-referenced pilot study for future research on technology adoption within the manufacturing sector.

The remaining paper is organized as follows. Section 2 introduces the concept and application of IoT and the challenges faced in introducing IoT; Section 3 presents the research methodology and model innovations of this study; Section 4 presents the composition of the sample data and analysis results; and Section 5 presents the conclusions, limitations, and future research directions.

2. LITERATURE REVIEW

2.1 Definition of the Internet of Things (IoT)

IoT has been defined by experts and scholars variously. It is an open and comprehensive network of intelligent objects that can automatically organize and share information, data, and resources to react and act in the face of changing situations and environments (Sestino, Prete et al. 2020). It can also be thought of as a global network that allows communication between people, people, and things and between things, by providing a unique identity for each object, which is anything in the world(Tran, Sheng et al. 2017).

2.2 Development of IoT in China

Research on IoT sensor networks started in 1999, and IoT was positioned as a strategic emerging industry. In 2012, the Ministry of Industry and Information Technology of China explained the national 12th Five-Year Plan (2011–2015), including the development of IoT. By 2015, the basic technology, related applications, and

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standardization had achieved significant results (Qiu, Chi et al. 2020). in February 2013, to determine the development goals and ideas of the IoT. China established a joint meeting on IoT development in September 2013 and formed an expert advisory committee IoT. Ten special development action plans for IoT were issued by the joint meeting: 1) top-level design; 2) standards development; 3) technology development; 4) application promotion; 5) industry support; 6) business models; 7) security; 8) government support; 9) laws and regulations protection; and 10) talent training, As part of the action plan, the IoT Industrial Technology Innovation Strategic Alliance was established in October 2013 (Ashima, Haleem et al. 2021).

2.3 Development of IoT in Japan

The growth of the utility of IoT in many aspects of the Japanese economy makes it a suitable case study for examining its impact (Shenkoya and Dae-Woo 2019). In addition, there is a large amount of data on IoT usage in Japan to examine trends and their impact on people's daily lives. The development of technologies in telecommunications and electronics has contributed to the development of IoT in Japan. Kodama, Nakata et al. (2017) argue that the development and deployment of IoT and the digital economy are bringing about technological developments in the Japanese machine tool industry. Japanese construction companies have also adopted IoT to improve their proficiency. Japan is one of the few countries in the world that uses IoT to advance building information modeling (BIM) and RFID to build houses. BIM is a 3D smart building technology for building planning, design, and construction, whereas RFID is a wireless communication device.

In recent years, digital technologies have been used in various activities, from production to development and sales. For example, IoT is an IT system designed primarily for the production floor, but has significantly influenced the flow of design information within factories and throughout the supply chain. IoT has been positioned as one of the key enablers of Industry 4.0 and smart factories. This technology serves as an important supporting tool to facilitate the effective measurement, visualization, storage, and utilization of "genba" (field) data, and to improve operational performance (Fukuzawa, Sugie et al. 2022). In this context, superior decisions regarding IoT system investments have significantly influenced the manufacturing capabilities and competitive advantages of Japanese companies. However, the purpose of IoT investments, the actual status of the decision-making process of "IoT system investments" within plants, and the empirical analysis of these indicators and performance have not been fully investigated.

3. THEORETICAL BACKGROUND AND HYPOTHESES DEVELOPMENT

3.1 The challenges of IoT

IoT trends are unified, seamless, and ubiquitous. The development of the IoT is a gradual process; large-scale service deployments should be built into a set of standards. IoT challenges offer new opportunities for industry and end users in many applications. However, IoT currently lacks the theory, technical architecture, and standards for integrating the virtual and real physical worlds in a unified framework, presenting the following main challenges (Bader, Maleshkova et al. 2019).

Technical challenges: IoT technologies can be complex for several reasons (Yang and Gu 2021). Complexity and alternative technologies, unnecessary competition in the market, and barriers to deployment may pose problems, and systems and communication

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mechanisms with unnecessary dependencies may hinder the migration of IoT systems to the most cost-effective platforms. All of these factors may prevent the IoT from connecting as many "things" as possible.

Privacy and security challenges: The security and privacy issues of IoT are more prominent than those of traditional networks (Rizvi, Pfeffer et al. 2018). A significant amount of information contains users' privacy, and privacy protection is an important security issue in IoT. Owing to the combination of things, services, and networks, IoT security must cover more objects and layers of management than traditional network security does. Existing security architectures are designed from the perspective of human communication and may not be suitable for direct applications to IoT systems (Gehrmann and Gunnarsson 2020).

Standards challenge: Standards play an important role in shaping IoT. Standards are critical for allowing equal access and use by all participants (Centenaro, Costa et al. 2021). The development and coordination of standards and proposals will facilitate the efficient development of the IoT infrastructure, applications, services, and devices. In general, standards are developed collaboratively by multiple parties, which means the information models and protocols in the standards should be open.

Business challenges: For IoT, there are many possibilities and uncertainties in business models and application scenarios (Viriyasitavat, Anuphaptrirong et al. 2019). Consequently, it is inefficient in terms of business technology alignment, and one solution will not fit all possibilities. IoT is a challenging traditional business model. Although small-scale applications have been profitable in some industries, scaling to other industries is unsustainable. The business aspects need to be considered in the early stages of IoT development to reduce the risk of failure.

3.2 UTAUT

The constant quest to ensure user acceptance of technology is an ongoing management challenge and has attracted the attention of IS/IT researchers to the extent that technology adoption and diffusion research is now considered one of the more mature areas to explore (Venkatesh, Morris et al. 2003). The substantial activity here has witnessed the use of a wide range of exploratory techniques, examining many different systems and technologies in a myriad of contexts. Even the most cursory examination of the extant literature reveals a variety of stakeholder perspectives, technologies and contexts, units of analysis, theories, and research methods. This situation, in turn, leads to confusion among researchers as they are often forced to select features among competing models and theories. To counter this confusion and harmonize the literature related to the acceptance of new technologies, a unified model was developed that brings together different perspectives on user and innovation acceptance. UTAUT has four core constructs (performance expectations, effort expectations, social influence, and facilitating conditions) that are direct determinants of behavioral intentions and ultimate behavior, which in turn are moderated by gender, age, experience, and voluntariness of use (Venkatesh, Morris et al. 2003). By examining the presence of each of these constructs in a "real-world" setting, researchers and practitioners are expected to be able to assess an individual's intention to use a particular system, thus allowing for the identification of the key influences on acceptance.

The UTAUT theory was developed by reviewing and integrating eight major theories and models: Theory of Rational Behavior (TRA), Technology Acceptance Model (TAM), Motivation Model (MM), Theory of Planned Behavior (TPB), Combined Theory of

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Planned Behavior/Technology Acceptance Model (C-TPB-TAM), Model of PC Use (MPCU), diffusion of innovation theory (IDT), and Social Cognitive Theory (SCT). Each of these contributing theories and models has been widely and successfully applied by many prior technology or innovation adoption and diffusion studies.

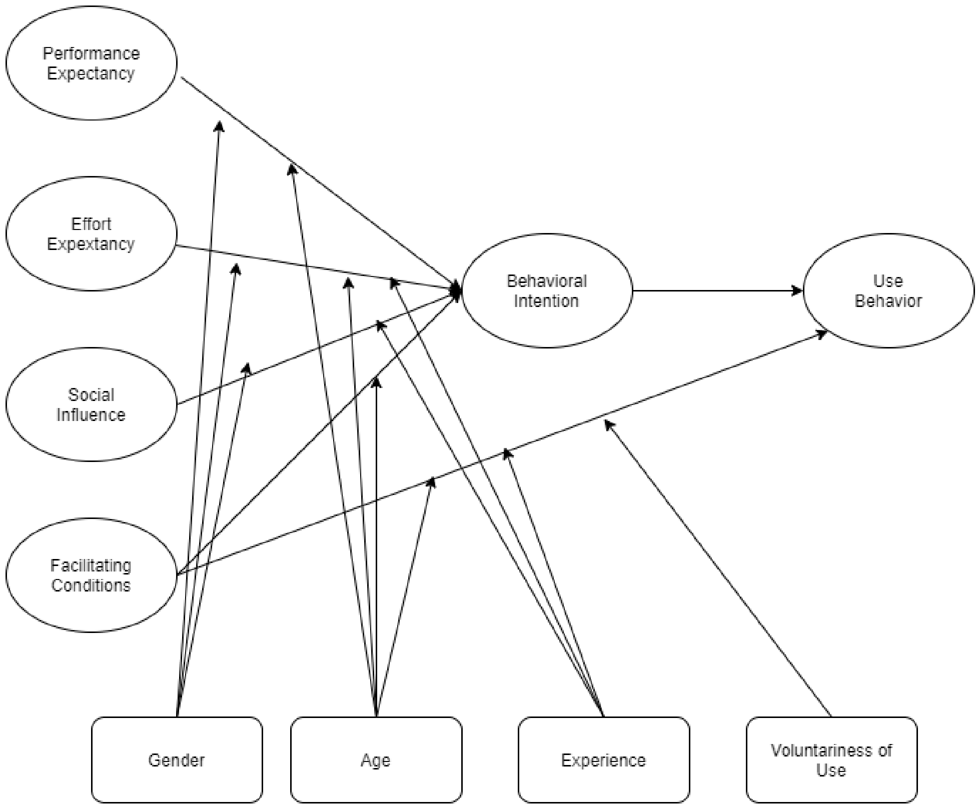

Figure 1 The UTAUT model structure diagram

3.3 The ISO 25010 Framework

ISO 25010 is an international standard for software and system quality assessment, is also known as the System and Software Quality Requirements and Evaluation (SQuaRE) model. The quality attributes in the model are presented from the top-level factors to the sub-factors. The top level consists of eight factors, described below, which are further broken down into 31 sub-factors at the lower level. ISO 25010 is a derivative of the ISO 9126 model and describes the 31 attributes that each quality software product must demonstrate. Several researchers (Peters, Aggrey et al. 2019) have used the ISO 25010 standard to propose new quality models in their studies.

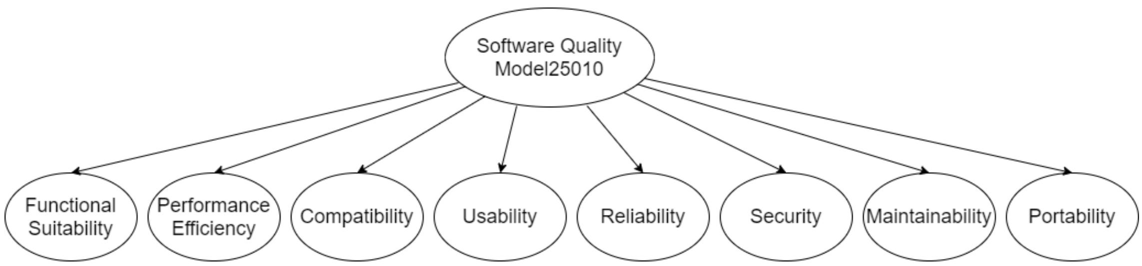

Figure 2. ISO25010 model structure diagram

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(1) Functional suitability: This characteristic represents the degree to which a product or system provides functions that meet the stated and implied needs when used under specified conditions.
(2) Reliability: This indicates the ability of a system or software product to maintain its performance level or functionality for a specified period under specified conditions.
(3) Usability: It describes the extent to which a software or system product can be used to achieve specific goals in terms of effectiveness, efficiency, and satisfaction in a given usage environment.
(4) Performance efficiency: This factor describes the ability of a software product or system to manage a given amount of resources to deliver and maximize performance, and is decomposed into time behavior, resource utilization, and capacity.
(5) Compatibility: This is the ability of a software product or system to interact with other software products or systems without failure to ensure that the system performs the required functions while sharing the same hardware or software environment with other systems.
(6) Security: This is related to how a software product or system protects its information and data (information resources) from unauthorized persons or other software products or systems.
(7) Maintainability: The ability of a software product or system to be modified, corrected, or adapted to changes in the current environment describes its maintainability.
(8) Portability: The ability of a software product or system to be transferred from one hardware, software, or other operating or usage environment to another operating platform defines its portability.

Different families of quality standards for software products are evolving, such as ISO/IEC 9126 and ISO/IEC 14598 from the ISO/IEC 25000 series, also known as Software Product Quality Requirements and Evaluation (SQuaRE) (Ali, Yap et al. 2022).

3.4 Hypotheses development

3.4.1 Performance Expectancy (PE)

Performance expectancy (PE) is defined as the degree to which the technology employed is effective for the user to perform certain operations. In this study, the extent to which the implementation of IoT improves or facilitates the user's daily work and management efficiency in their organization is examined. Therefore, the following hypothesis was formulated.

H1: Performance expectancy will have a positive impact on the acceptance intention of IoT.

3.4.2 Effort Expectancy (EE)

Effort expectancy (EE) refers to ‘the ease associated with using the system’(Venkatesh et al., 2003, p. 450). Especially when initially using technology, such as when accepting an innovation, the ease of using the technology strongly influences acceptance behavior. In this study, EE is defined as the degree of belief in how little effort is required to use IoT technology. As it has been consistently tested as a factor of intention to use in many studies, the following hypothesis was formulated.

H2: Effort expectancy has a positive impact on the acceptance intention of IoT.

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3.4.3 Social Influence (SI)

Social influence (SI) is defined as the degree to which individuals perceive the importance of their peers' opinions about whether they should use the new system (Venkatesh et al., 2003). In this study, it is defined as the degree of belief that one should or is expected to use IoT by the people around them (superiors, peers, and subordinates) in the company or organization. Therefore, the following hypothesis was formulated.

H3: Social influence has a positive impact on the acceptance intention of IoT.

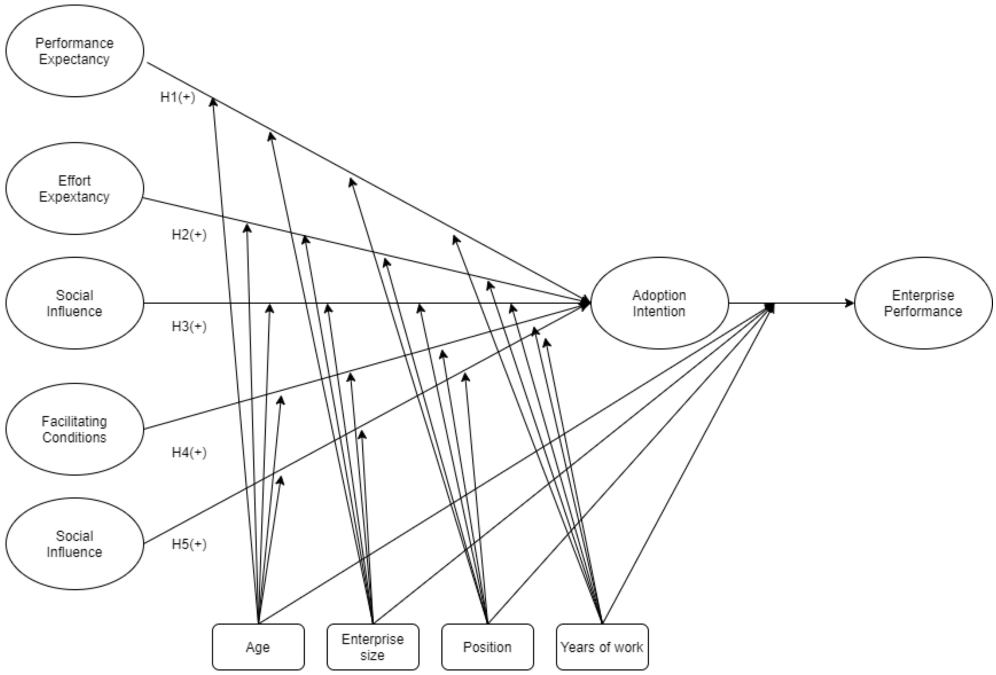

Figure 3. Proposal model structure diagram

3.4.4 Facilitating Conditions (FC)

Facilitating conditions (FC) refers to the availability of technological resources and infrastructure. Several studies have investigated the impact of facilitating conditions on consumers' perceived ease of use. In this study, it is defined as the degree of belief that a company/organization, strategy, or plan should or is expected to use IoT, yielding the following hypothesis.

H4: Facilitating conditions will have a positive impact on IoT acceptance intentions.

3.4.5 System/Software Functional Expectations (SFE)

This study aims to understand whether IoT software quality expectations influence usage intentions in terms of quality measurement for employees who use systems, software, and other IoT technologies as a medium for IoT. Therefore, the following hypothesis was formulated.

H5: System/software functional expectations have a positive impact on IoT acceptance intentions.

3.4.6 Operating Results Expectancy (ORE)

Operating results expectancy is an employee's evaluation of a company's performance and primarily reflects the company's expectations regarding performance. In this study, it

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is primarily used in place of the [usage behavior] indicator in the UTAUT model, since all respondents indicated they had adopted IoT. Thus, the following hypothesis was formulated:

H6: Adoption intention will have a positive impact on operating results expectancy.

4. METHODOLOGY

4.1 Data collection instrument

The study employed a quantitative research method and a web-based questionnaire. The target respondents were practitioners from manufacturing industries in Japan and China, and were concentrated in provinces with a high share of manufacturing industries, that is, they were relatively more developed. Participants were informed that their identities would not be revealed, and that their questionnaire responses would be used for research purposes only. They were also informed that their participation was voluntary and that they could withdraw at any time. The questionnaires were distributed in Japanese in Japan and in Chinese in China. They were distributed in Japan in late January 2022 as an Internet survey to employees in the IT departments of Japanese manufacturing firms. A total of 6971 samples were distributed, and 721 responses were collected, with a collection rate of 9.74%. The survey of Chinese manufacturing employees was conducted in mid-April 2022, and questionnaires were distributed as an Internet survey to employees in the IT departments of Chinese manufacturing companies. A total of 1300 samples were distributed and 396 responses were collected; the response rate was 30.46%.

4.2. Survey instrument

Based on the extended UTAUT model proposed in this study, the questionnaire was administered in three parts. The first part contained the demographic information of the respondents. The second part had questions on the factors affecting IoT adoption, including questions based on the UTAUT and ISO quality models. The third section comprised questions on business performance expectations. In the second and third sections, the responses were measured on a 7-point Likert scale, where 1 represents strongly disagree, 2 disagree, 3 fairly disagree, 4 neutral, 5 fairly agree, 6 agree, and 7 strongly agree.

5. RESULTS

5.1 Data Analysis

This study used the biased covariance-based SEM (CB-SEM) method to analyze the conceptual models using AMOS 27.0. A two-stage analysis approach was followed, first assessing the measurement model (i.e., validity and reliability) and then assessing the structural model (i.e., testing the formulated hypotheses). The first model determines how each construct is measured, while the second determines how the constructs are interrelated in the structural model.

5.2. Respondents' profile and characteristics

From the survey of Japanese manufacturing firms, the majority of respondents were company employees, 686 (95.1%), while the remaining respondents were contract workers, 16 (2.2%), temporary workers, 5 (0.7%), directors, 13 (1.8%), and company managers, 1 (0.1%).

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Based on company size, the majority of respondents worked in large companies with more than 1,000 employees. A total of 262 respondents (36.3%) worked for companies with fewer than 1,000 employees, and 459 (63.7%) worked for those with 1,000 or more employees. In terms of location, 189 (26.2%) respondents worked in Tokyo, 134 (18.6%) in Kanagawa Prefecture, 180 (25.0%) in Aichi Prefecture, 82 (11.4%) in Osaka Prefecture, 72 (9.8%) in Hyogo Prefecture, 41 (5.7%) in Saitama Prefecture, and 24 (3.3%) in Chiba Prefecture.

5.3 Measurement model assessment

The evaluation of measurement models included checking reliability (Cronbach's alpha and composite reliability) and validity (convergent and discriminant validity). For the internal consistency reliability test, the results in Table 2 show that the Cronbach's alpha values ranged between 0.794 and 0.901, both above the threshold value of 0.7, and the composite reliability (CR) values ranged between 0.823 and 0.959, both above the recommended value of 0.7. Therefore, the internal consistency reliability of the Cronbach's Alpha and CR was confirmed. Convergent validity measures whether multiple items are conceptually similar. Factor loadings and extracted average variance (AVE) were tested to check convergent validity. Table 2 shows that the values of the factor loadings are satisfied, as all of these are above the recommended value of 0.7, while the AVE values were between 0.628 and 0.768, both above the recommended value of 0.5. These results suggest that the measurement indicators used in this study are good measures of their respective constructs, and that the constructs are distinguishable from each other.

Table 1 shows the results of discriminant validity. To evaluate the discriminant validity of our measurement model, we used the Fornell and Larcker criteria. The results showed that the square root of the average variance extracted (AVE) for each construct (denoted in the diagonal cell in table 1) was greater than its correlations with other constructs in the model (denoted in the non-diagonal cell in table 1), which indicates that each construct has discriminant validity. Most of the correlations between constructs were smaller than the square roots of the AVEs, provide strong evidence for the discriminant validity of our measurement model.

Table 1 Results of discriminant validity

	Adop	Ore	PE	SFE	EE	EXE
IoT Adoption Intention（Adop）	0.836					
Operating results expectancy（Ore）	0.441***	0.793				
Performance Expectancy(PE)	0.801***	0.473***	0.876			
System/software function Expectancy(SFE)	0.756***	0.565***	0.783***	0.826		
Effort Expectancy(EE)	0.711***	0.542***	0.713***	0.719***	0.810	
External environment（EXE）	0.807***	0.527***	0.825***	0.855	0.761***	0.828

5.4 Structural model assessment

(1) Results of the Japan Survey

The fitness coefficients of the constructed model are shown in Table 2. All indexes meet the model fitness criteria, and the model fits the data well. The final modified model is shown in Figure 4. From the SEM results, the standardized coefficient of the influence of the external environment on willingness to accept is 0.245, and the standardized coefficient of the influence of system functional expectation on willingness to accept IoT

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is 0.201, with a coefficient of 0.749. The validation results do not indicate that effort expectations positively affect employees' willingness to accept. Rather, the external environment, system functional expectations, and performance expectations had a positive effect on willingness to accept. In addition, the study shows that willingness to accept has a positive effect on firm performance.

(2) Results of the China Survey

Table 2 Results of reliability analysis and CFA

	Factor loading	Reliability coefficient (alpha)	CR	AVE
Factor1.Operating results expectancy(Ore)		0.949	0.949	0.628
Your company has increased revenues	0.744			
Your company has increased profits	0.750			
Your company has reduced costs	0.690			
Your company is gaining market share	0.818			
Customer satisfaction is rising at your company.	0.860			
Your company has reduced customer complaint rates	0.839			
Your company has reduced the defect rate	0.839			
Your company has improved on-time delivery rates	0.818			
Your company has increased labor productivity	0.822			
Your company has reduced employee absenteeism	0.785			
Your company has reduced employee turnover	0.737			
Factor2.Adoption intention(Adop)		0.820	0.823	0.699
You are interested in learning and using IoT technologies	0.789			
Implement IoT in your company's sales and management systems in the future	0.881			
Factor3.External environment(EXE)		0.940	0.938	0.685
Your company is actively implementing IoT technology	0.862			
Your company already has plans to learn or use IoT technologies (corporate training, courses, etc.)	0.790			
Your company is expected to make business use of IoT technology	0.875			
Your company's top management is enthusiastic about implementing IoT	0.834			
In the opinion of your department, IoT should be implemented	0.828			
Your department's employees believe you should implement IoT	0.805			
IoT adoption is in response to the government's DX strategy	0.795			
Factor4.System/software function Expectancy(SFE)		0.938	0.937	0.682
Your company can implement IoT to enable employees to respond quickly to work	0.755			
Your company's implementation of IoT will not negatively impact existing systems or network environments	0.813			
Your company will focus on data recovery capabilities	0.827			
Your company will focus on data recovery capabilities	0.835			
Your company emphasizes the ability to prevent unauthorized access to or modification of data	0.852			
Your company emphasizes the ability to prove that a transaction has occurred or been completed	0.835			
Your company values functions that can be used in multiple systems (system versatility)	0.859			
Factor5.Effort Expectancy(EE)		0.881	0.85	0.66
You can learn how to use the IoT in the short to medium term	0.921			
You already have a good understanding and knowledge of IoT technologies	0.779			
You think IoT is not difficult to understand and use	0.717			
Factor6.Performance Expectancy (PE)		0.958	0.959	0.768

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IoT technology helps you in your daily work	0.876
By using IoT technology, you can accomplish important tasks.	0.895
Using IoT technology can improve the efficiency of your daily work	0.925
The introduction of IoT will improve your productivity	0.907
By adopting IoT, you can achieve business goals that are traditionally difficult to achieve.	0.869
By introducing IoT, you can shorten the processing time of your business.	0.873
Utilization of IoT helps your company reduce costs and promote paperless	0.783

The goodness-of-fit coefficients for the constructed model are shown in Table 5. Each indicator meets the necessary criteria for model goodness-of-fit, indicating that the model has a good fit for the data. The final model, a modification of the original model, is shown in Figure 5.The validated results show that system function and outcome expectations have a positive impact on employee acceptance intentions. Effort expectations negatively influence employees' acceptance intention. The external environment did not have a positive influence on acceptance intention. Acceptance intention positively influences firm performance. Effort expectation had an impact standardized coefficient of -0.211 on acceptance intention, system function expectation had an impact of 0.355 on acceptance intention, and outcome expectation had the largest impact on acceptance intention, with a standardized coefficient of 0.937. In line with these results, discriminant validity was established.

5.5 Analysis of group difference

To understand the IoT acceptance intentions across different groups of respondents, the study grouped them based on four variables: years of service, job title, age, and company size. Based on the divided sample, we reintroduced them into the model. The results are presented in the table 6. To examine whether the path relationships between the different groups are significant, a Z-test was conducted by splitting the four group variables and the results are as follows.

Table 3 Path analysis Japanese Part

Paths	Standardized coefficient	P	Hypotheses Supported?
EXE→Adop	0.245	***	Yes
SFE→Adop	0.201	**	Yes
EE→Adop	0.065	0.111	No
PE→Adop	0.749	***	Yes
Adop→Ore	0.604	***	Yes

Path significant at: **p<0.05; ***p<0.01,

Table 4 Goodness of fit index for Japan

CMIN/DF	RMSEA	GFI	CFI	AGFI	IFI	TLI
3.103	0.054	0.87	0.951	0.849	0.951	0.946

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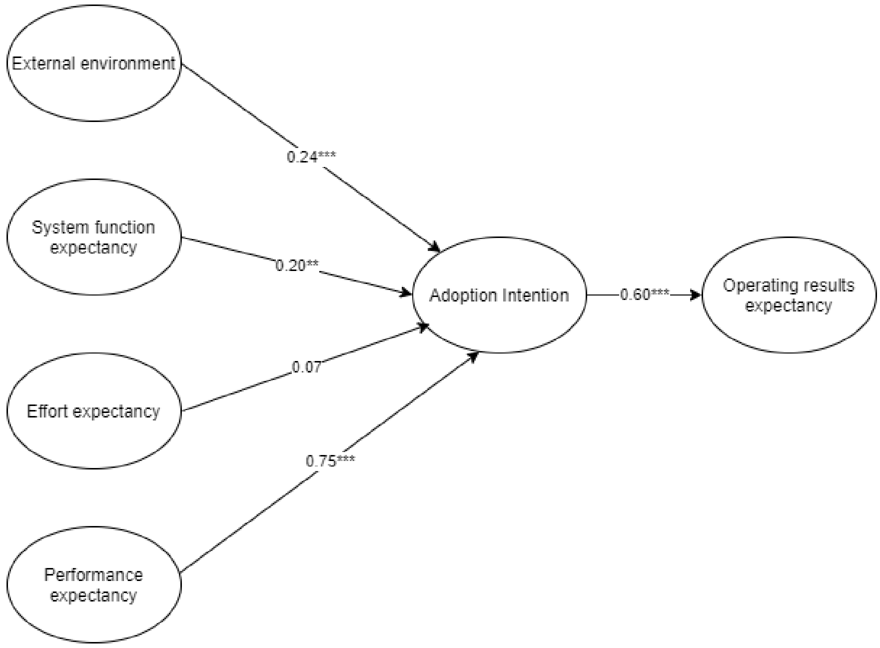

Figure 4 Model test results for Japan

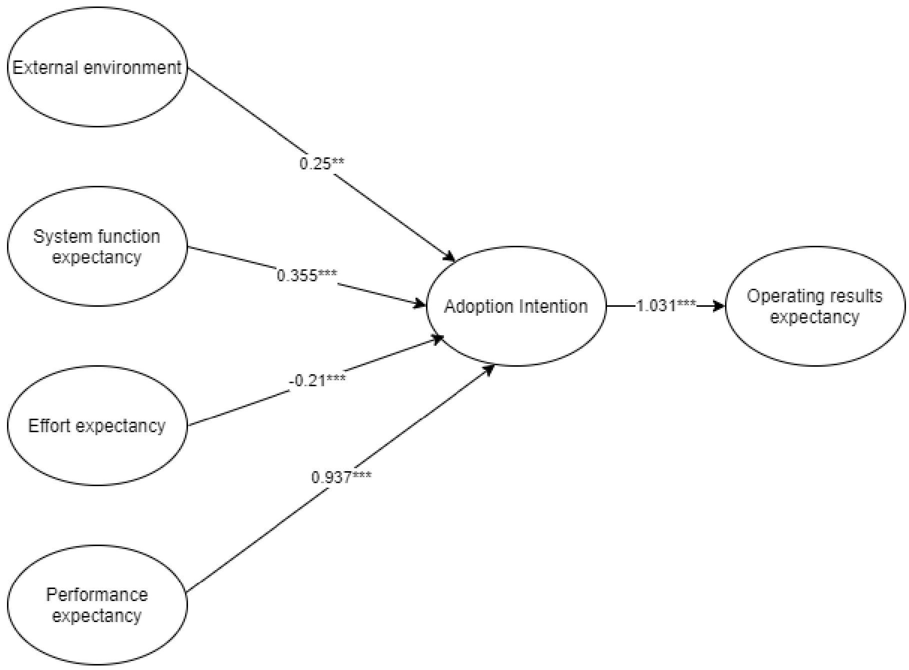

Figure 5 Model test results for China

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Table 5 Path analysis Chinese Part

Paths	Standardized coefficient	P	Hypotheses Supported?
EXE→Adop	0.256	**	Yes
SFE→Adop	0.355	***	Yes
EE→Adop	-0.211	***	Yes
PE→Adop	0.937	***	Yes
Adop→Ore	1.031	***	Yes

Path significant at: **p<0.05; ***p<0.01,

Table 6 Goodness of fit index for China

CMIN/DF	RMSEA	GFI	CFI	AGFI	IFI	TLI
3.474	0.079	0.87	0.838	0.776	0.839	0.825

In terms of firm size, the outcome expectations of SMEs and large firms differ markedly in their paths to acceptance. More than employees in large firms, those in SMEs believe that IoT helps them improve their performance. In the years-of-service category, there was a marked difference in the path from system function expectation and outcome expectation to acceptance intention between employees who worked for more than five years and those who worked for less. For the first group, the realization of system functional expectations is likely to increase acceptance intentions toward IoT compared to the second group. Both these groups, however, find IoT helpful in improving performance. Managers and regular employees have marked differences in the path from effort expectations to acceptance intention. Managers believe that IoT’s easy-to-understand, learn, and use characteristics increase their willingness to accept it, while general employees do not. Managers and regular employees have marked differences in the path from effort expectations to acceptance intention. Managers believe that IoT’s easy-to-understand, learn, and use characteristics increase their willingness to accept it, while general employees do not. For age groups, there is a marked difference in the path from effort and achievement expectations to acceptance intention between employees over and under 40 years of age. Those under 40 believe that after learning IoT, their acceptance intention for IoT has declined, but the older employees believe that the ease of understanding, learning, and using IoT increases their acceptance. While both employees over and under 40 believe that IoT will help them improve their daily work efficiency, the younger group believe that IoT can significantly improve it.

Table 7 Group analysis results

Influence path	P	Standardization coefficient	P	Standardization coefficient	z-score	Difference
Years of work	Five years and above		Under 5 years			
EXE → Adop	0.025	0.130	0.004	0.265	-1.233	Not significant
SFE → Adop	0.000	0.257	0.341	-0.095	3.044***	Significant
EE → Adop	0.054	0.071	0.491	0.035	0.569	Not significant
PE → Adop	0.000	0.429	0.000	0.795	-4.588***	Significant
Adop → Ore	0.000	0.743	0.000	0.688	0.400	Not significant
Position	Non-management		Management			
EXE → Adop	0.002	0.196	0.020	0.194	-0.016	Not significant
SFE → Adop	0.001	0.203	0.406	0.072	-1.225	Not significant
EE → Adop	0.172	-0.059	0.000	0.152	3.374***	Significant
PE → Adop	0.000	0.565	0.000	0.534	-0.418	Not significant

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Adop	→	Ore	0.000	0.809	0.000	0.612	-1.416	Not significant
Age			Under 40s		Over 40s			
EXE	→	Adop	0.002	0.294	0.009	0.158	-1.216	Not significant
SFE	→	Adop	0.263	0.109	0.003	0.182	0.63	Not significant
EE	→	Adop	0.000	-0.279	0.000	0.116	4.632***	Significant
PE	→	Adop	0.000	0.727	0.000	0.5	-2.217**	Significant
Adop	→	Ore	0.000	1.017	0.000	0.66	-1.867*	Significant
Company scale			Small and medium-sized enterprise		large company			
EXE	→	Adop	0.643	0.057	0.002	0.169	0.823	Not significant
SFE	→	Adop	0.911	0.013	0.001	0.189	1.362	Not significant
EE	→	Adop	0.235	0.107	0.102	0.051	-0.587	Not significant
PE	→	Adop	0.000	0.807	0.000	0.482	-3.146***	Significant
Adop	→	Ore	0.000	0.538	0.000	0.761	1.726*	Significant

6. CONCLUSION AND FUTURE DIRECTIONS

The study provides empirical evidence that makes noteworthy contributions to theory and practice. In terms of theoretical implications, this study has successfully extended and applied the UTAUT model to a new context and background, that is, a combination of the ISO25010 software quality evaluation model and an IoT investigation scenario. Taken together, the empirical findings suggest that the proposed conceptual model can more effectively explain behavioral intentions in general and provide research directions for the future introduction and management of IoT technologies. Regarding practical implications, this study investigates, for the first time, the understanding and perceptions of manufacturing employees in China and Japan regarding IoT. Comparing the differences in results between China and Japan can better support decision-makers in managing the introduction of IoT systems in different cultural environments. Moreover, by performing intergroup comparisons after differentiating multiple impact factors for the Japanese survey, one can better understand the perceptions of different types of employees about IoT in organizations, which can help bridge the differences in practitioner perceptions between organizations.

The study has two major limitations that point to provide fruitful avenues for further research. First, the International Standards Organization (ISO) has a variety of distinctions for IT software quality models. This study chose the more well-known ISO 25010 software quality model, but there may be more appropriate models and evaluation criteria for evaluating the quality of IoT software and systems. Second, software and network security are gaining attention from industry and academia. This study can continue to expand the criteria for IoT security in the future and introduce new quality models to improve the theory.

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