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Acceptance of Automation Manufacturing Technology in China: An Examination of Perceived Norm and Organisational Efficacy

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Abstract

With a shift to more automation technology, social acceptance of technology plays an important role in the manufacturing sector. To what extent this occurs, and affects the adoption of technology, has been little researched, but is important in deciding how such technology is introduced, and the nature of the shift from labour-intensive manufacturing to automation. This research applies the revised technology acceptance model (TAM) to examine the impact of social and individual antecedents on the acceptance of automation manufacturing technology. Survey data is collected from 258 Chinese manufacturers. Results suggest that perceived norms significantly affect organisational intention to use automation manufacturing technology both directly and via perceived usefulness; organisational efficacy explains the intention to use via mediating effect of perceived usefulness and perceived ease of use. This research is one of the first extending and applying TAM from individuals to organisations.

Keywords

Perceived norm; Organisational efficacy; Automation manufacturing; Technology acceptance; China.

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1. Introduction

Automation manufacturing technologies (AMTs) such as industrial robots and automated assembly systems have contributed towards the improvement of economic and environmental performance of businesses, in the forms like minimized environmental damage (Ribeiro *et al.*, 2016), greater cost-efficiency and flexibility (Zhang, Vonderembse, and Cao, 2006), improvement of reliability and productivity (Zhang et al., 2011). Moreover, advanced manufacturing technologies such as 3D printing (Gardan, 2016) and automation (Farooq et al., 2017; Wang, 2018) also form a strategy for facilitating industrial upgradation and sustainable development (Nahm and Steinfeld, 2014).

The application of advanced manufacturing technologies such as AMT and networking systems like big data (Zaki et al., 2019) and cloud manufacturing system (Helo and Hao, 2017) is gaining its momentum in global manufacturing for sustainability (Choudhary et al., 2019), operation efficiency, flexibility and global networking (Rashid and Tjahjono, 2016; El-Khalil and Darwish, 2019; Fatorachian and Kazemi, 2018; Feldmann and Olhager, 2019). According to the IFR (International Federation of Robotics) report, global sales of industrial robots reached the new record of 387,000 units in 2017, an increase of 31 per cent compared to the previous year. More than three million industrial robots will be in use in factories around the world by 2020 (IFR, 2018). As the world's largest manufacturer since 2011, China has experienced the fastest economic growth in the world and a substantial rise in labour costs over the past three decades. The rising costs together with the increasingly ageing population have fueled the need for more AMTs to improve efficiency and reduce the reliance on the labour-intensive workforce (Das and Nair, 2010; Wang et al., 2015).

However, the lack of general acceptance of AMTs is an outstanding issue in China. For instance, as per IFR, China's robot density in the manufacturing industry is about 35 robots per 10,000 employees in 2014, which implies the existence of immense growth potential in comparison with that of the global counterparts such as Germany (290), Japan (315), and even the global average (67). Therefore, there is an urgent need for a better understanding of the antecedents for the acceptance of AMTs in Chinese manufacturing and hence, the motivation for this study.

Based on the above contextual analysis, we propose the following primary research question: What are the key factors that would determine the acceptance of AMTs in Chinese manufacturing companies? Prior studies have approached the question from various organizational factors, suggesting that the decision to the use of AMTs depends on employees' educational background and skill level (Baptist and Teal, 2014), firm size (Jonsson, 2000; Diaz, Machuca, and Alvarez-Gil, 2003; Sohal *et al.*, 2006; Handley, 2012), staff training, and human resource management (Machuca, Díaz, and Gil, 2004). Das and Nair (2010) summarise four dimensions in determining the acceptance and use of advanced technology, namely, organisational, technological, contextual, and individual. However, the existing literature has explored the importance of the human side in AMT acceptance relatively less (Farooq et al., 2017).

The technology acceptance model (TAM) is a well-established social-cognitive model in the study of human behaviour in technology (Szajna, 1996; Venkatesh and Davis, 2000; King and He, 2006; Schepers and Wetzels, 2007; Venkatesh and Bala, 2008). The evidence and the issue under discussion provide a good case for the application of TAM to understanding the organisational behaviour in AMT acceptance. Proposed by Davis, Bagozzi, and Warshaw (1989), TAM explains and predicts how the information of technology is processed and affects individual users' internal beliefs, perceptions, and attitudes, which in turn leads to users'

intention to accept and use a particular technology or system. TAM has been widely applied to various behavioural studies in ICTs (information and communications technologies and systems), like green information and smart grid technology (Akman and Mishra, 2015; Toft, Schuitema, and Thogersen, 2014), health care systems (Holden and Karsh, 2010; Pai and Huang, 2011), enterprise resource planning systems (Amoako-Gyampah, 2007), mobile and internet banking technology (Joo and Sang, 2013; Marakarkandy, Yajnik, and Dasgupta, 2017), teleconferencing (Park *et al.*, 2014), and e-commerce (Ha and Stoel, 2009; Amirtha, and Sivakumar, 2018).

This study adds contributions to the knowledge of organisational behaviour in their technology acceptance. First, we extend the application of TAM from the study of individual behaviour to that of organisations through the lens of organisational decision-makers, the micro-foundations of organisations. Second, we introduce and investigate two new antecedents, namely, 'organisational efficacy' and 'perceived norm,' for the study of the organisational AMT behaviour. Different from self-efficacy, which is an individual's belief in his or her abilities to perform a certain act (Den Hartog and Belschak, 2012), organisational efficacy is the decision-maker's belief in the organisational capabilities. That is, the decision maker acts as the representative of the organisation rather than an individual. Similarly, different from an individual' perceived norm, where the norms come from personal ties such as friends, family, or relatives, the organisational decision maker's perceived norm comes from the key stakeholders such as the government, suppliers, and competitors.

Following this introduction, the rest of the paper is structured as follows. The next section reviews the literature to develop the research model and hypotheses. In section three, we introduce the research methods, including sample, data, and measurement. Section four reports empirical results. The last section concludes and discusses findings, highlighting implications for global providers and buyers of AMTs in the manufacturing industry.

2. Theoretical Ground and Hypotheses

2.1. Model Building

The theoretical underpinnings of this study draw on the social and cognitive behaviour literature in TAM (Ajzen and Fishbein, 1980). TAM stems from the Theory of Reasoned Action (TRA), originally proposed by Fishbein and Ajzen (1975, 15). According to TRA, a person's salient beliefs about an object are a fundamental information base determining his/her attitudes, which lead to the person's intention to the object, for example, favour for an action. Based on the theoretical underpinnings of TRA, Davis, Bagozzi, and Warshaw (1989, 985) proposed TAM, which specifically explains and predicts users' acceptance and behaviour towards computer technology (See Appendix A). The authors posit that Perceived Usefulness (PU) and Perceived Ease of Use (PEU) explain 'attitude' while at the same time PU mediates the relationships between PEU and the other two variables, Intention to Use (IU) and attitude. The two concepts, PU and PEU, were investigated and validated in a separate study in the same year (Davis, 1989). Ever since the two concepts have become two fundamental and distinct constructs commonly adopted in empirical research in explaining and predicting intention to use and or actual use (e.g., Szajna, 1996; Venkatesh and Davis, 2000; King and He, 2006; Schepers and Wetzels, 2007; Venkatesh and Bala, 2008). Further, Szajna (1996) revises and simplifies the original TAM model by removing the mediating variable 'attitude'; the empirical result suggests that the model consistently explains intention to use. Following Szajna (1996), we do not examine 'attitude' in this study.

We acknowledge that TAM has become so popular in technology-relevance behavioural research that perhaps some domain scholars deliberately avoid using it. Yet, this study continuously applies and further contributes to the TAM paradigm. The rationales follow. First, the popularity of TAM research is due to its simple but very powerful attribute in explaining human behaviour. The over-popularity has not undermined the theoretical power of TAM and

instead, its revised models have further developed the knowledge in understanding human behavior such as in digital technologies used in e-government (Jasimuddin et al., 2017;), e-commerce segment, internet banking adoption (Fawzy and Esawai, 2017), e-learning systems and smart systems. Second, TAM provides a basic tool to understand this research question.

We revise the original TAM (Davis *et al*., 1989) based on the research question and apply the revised model to the context in the Chinese manufacturing companies. In our revised model, organisational efficacy and perceived norm are two new concepts as the antecedents of PEU and PU. These details are presented in Figure 1.

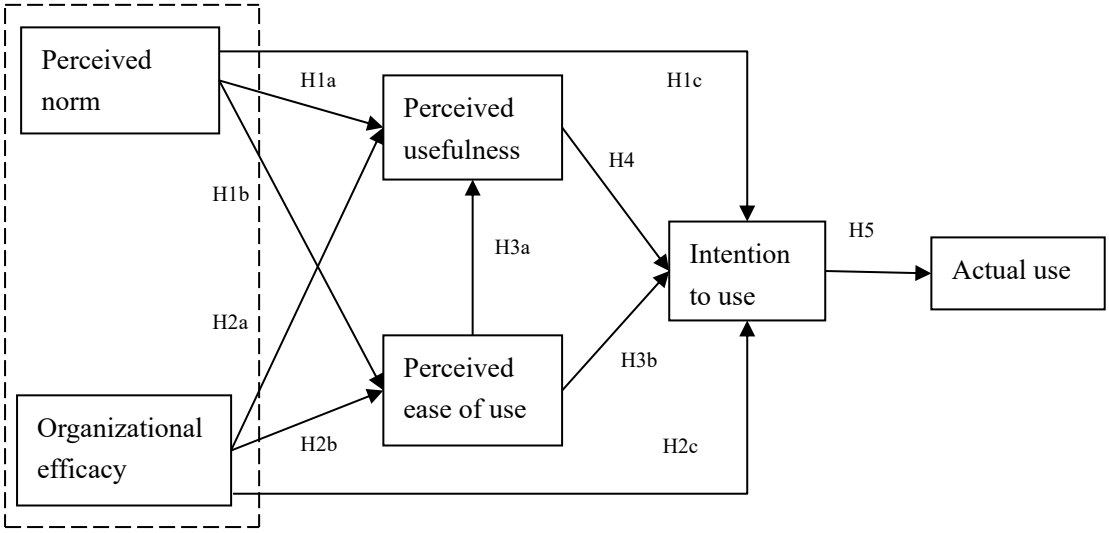

Figure 1. The research model.

Organisational efficacy stems from the concept of self-efficacy in the social cognitive theory (Hartog and Belschak, 2012). We define organisational efficacy as the decision maker's belief in organisational capabilities in using a target AMT to achieve the desired outcome, and the belief comes from the self-assessment by the organisational decision-maker. In the context of Chinese manufacturing companies, senior managers and executives are accountable for deciding their organisation to adopt AMT. We argue that their assessment of the organisational capabilities plays a critical role in the decision for or against the acceptance of the target AMT for their company. Normally, senior managers and top executives act as the representatives of

an organisation who make the direct decision for or again the acceptance of an AMT. The decision-makers have the position power to use relevant information required to judge the organisational capability. For instance, to what extent that the organisation can learn to use a newly introduced AMT; to what extent that the organisation is capable of using a newly introduced AMT; to what extent that the organisation can quickly master a newly introduced AMT with the assistance of the supplier.

In the original TRA, individual beliefs are on self-focused information processing mechanism without consideration of social influence on individual perceptions and behaviours. Perceived norm is originally proposed by Ajzen and Fishbein (1980), termed social norms in their improved TRA model. Venkatesh and Davis (2000) introduced perceived norm into a revised TAM as an external antecedent explaining both perceived usefulness and intention to use. Their empirical results suggest that the model better explains the variance of intention to use. Different from the study of individuals (Venkatesh and Davis, 2000), this research is in the organisational context. We argue that the perceived norm of the organisational decision-maker comes from key external stakeholders like the government and competitors of the organisation rather than from the individual personal referents like friends and relatives. Therefore, norms from the key stakeholders may affect the organisational decision maker's perceptions and the intention to accept an AMT for the organisation. The effects under discussion are more likely to happen in this research context as China is of a typical collectivist culture (Huang and Lu, 2017). Hence, we introduce perceived norm as a sociocultural construct to examine its impact on the organisational decision through the lens of the organisational decision-maker, who acts as a representative of the organisation.

2.2. Hypotheses Development

Perceived norm (PN)

The concept of perceived norm is defined as an individual's 'perception that most other people around him/her think he/she should or should not perform the behaviour in question (Fishbein and Ajzen, 1975, 302). The concept is a combinational result of the normative beliefs of a user and the motivation to comply with his/her individual or group referents (Vallerand et al., 1992).

In the studies of technology acceptance, favorable and unfavorable evaluation from the others about characteristics of a specific technology or system would directly affect the user's beliefs in terms of perceived usefulness and perceived ease of use of the technology or system (Venkatesh and Davis, 2000; Koufaris, 2002; Hsu and Lu, 2004; Venkatesh and Bala, 2008). Literature suggests that perceived norm also has a positive impact on intention to use (Venkatesh and Davis, 2000; Koufaris, 2002; Venkatesh *et al.*, 2003; Weerakkody et al., 2017).

Previous literature dominantly investigates individuals' decisions and behaviour in personal surroundings and hence, personal referents such as friends, relatives, and family (Venkatesh and Bala, 2008). However, this study investigates the organisational decision and behaviour in Chinese manufacturing enterprises. In the typical collectivism cultural background, individuals tend to follow group behaviour (Huang and Lu, 2017; Rhee et al., 2017). We argue that in this research context, the organisational decision maker's behaviour is more likely to be affected by social pressure, which may originate from the government, suppliers, and competitors. For instance, if the company (that is, represented by the decision-maker) believes that most of its competitors have an intention to use a certain AMT, the company will be more likely to follow suit.

Similarly, positive norms from the government, industrial experts, and suppliers about the usefulness and ease of use of an AMT will also positively affect the decision maker's perceptions towards the technology features of usefulness and ease of use. However, whether and how perceived norm, like the political orientation of the Chinese government and the strategic orientation towards the technological update, affects the decision maker's perceptions

and intention to use AMTs is unclear from the previous literature. Hence, we posit the following three hypotheses.

H1a Perceived norm is positively related to perceived usefulness

H1b Perceived norm is positively related to perceived ease of use

H1c Perceived norm is positively related to intention to use

Organisational efficacy (OE)

Organisational efficacy originates from the notion of self-efficacy, which is defined as users' judgment of their capabilities to fulfil a specific task (Compeau and Higgins, 1995). Self- efficacy mainly comes from past experiences, others' demonstrated effect, and social persuasion (Bandura *et al.*, 1999; Knight et al., 2014). For example, empirical study in the selling context has established that effort and sales knowledge explain the sales person's self-efficacy (Krishnan et al., 2002; Knight et al., 2014). It is a user's subjective evaluation about whether and how well they can engage in a technology that influences or determines the user's way to perceive difficulties and opportunities from the environment and hence, affects his/her behavioral intention, effort making and persistence against obstacles, and his/her performance (Bandura *et al., 199*9; Knight et al., 2014; Bolander et al., 2014). Some researchers argue that confidence about self-ability to effectively use a technology influences people's positive perceived usefulness and perceived ease of use (*Hsu, Wang, and Chiu*, 2009). However, other studies (Zainab et al., 2017) suggest that the effect of computer self-efficacy on perceived ease of use in e-training adoption is statistically insignificant. Research also suggests that self-efficacy directly determines behavioural intention to use new technology (Venkatesh and Bala, 2008; Hsu *et al.*, 2009).

However, previous literature dominantly investigates the individual-level behaviour and individuals' self-assessment of his/her capability to use a technology or information system.

Different from the individuals' self-efficacy, organizational efficacy reflects the organizational decision maker's confidence about the organizational capabilities of using a new or updated AMT to achieve the desired higher return (that is, perceived usefulness) from the use of the technology or to expect less effort needed to perform it (that is, perceived ease of use). It is unclear whether organisational efficacy affects the decision maker's perceptions and the intention to accept and use the AMT for manufacturing (Hartog and Belschak, 2012). Therefore, we posit the following three hypotheses.

H2a Organisational efficacy is positively related to perceived usefulness
H2b Organisational efficacy is positively related to perceived ease of use
H2c Organisational efficacy is positively related to intention to use

Perceived Ease of Use (PEU)

Perceived ease of use is defined as the extent to which users believe freedom from difficulty in using a particular technology and perception of the level of effort required for the users to skillfully operate the technology (Davis et al., 1989). People feel the technology will be useful for a specific task when they have perceived it as easy to use (Szajna, 1996; Hsu *et al.*, 2009; Joo and Sang, 2013). However, research also suggests that it does always happen. For instance, after learning how to use specific technology, people gain experience, and then the perceived ease of use does not affect the perceived usefulness of the technology (Ajzen, 1991). We expected that in the current Chinese manufacturing companies, the use of AMTs is at an early stage where the perceived ease of use affects people's perceived usefulness. Therefore, we posit the following hypothesis.

H3a Perceived ease of use is positively related to perceived usefulness

People intend to use technology when they feel it is easy to use (Hsu et al., 2009; Joo and Sang,

2013). This argument conforms with the congruency adjustment between existing employees' capability in technology and advances in acceptable technology (Jimenez *et al.*, 2011). In other words, it is not the most advanced technology that will be more like to be acceptable but rather an appropriate technology, with regard to easy to use, that fits the capability of the current workforce in using technology. However, a study conducted by Okafor, Nico, and Azman (2016) indicates that perceived ease of use doesn't have any influence on the adoption of online multimedia technologies for Malaysian SMEs. We expect that in the research context of Chinese manufacturing companies, perceived ease of use may be critical for those decision-makers, mostly CEO and senior managers, to accept an AMT because the ease-of-use technology enables companies to require less effort or cost in training people to operate it. Hence, this study proposes the following hypotheses.

H3b Perceived ease of use is positively related to intention to use

Perceived Usefulness (PU)

Perceived usefulness refers to the user's subjective perception of the extent to which the use of some technology can enhance performance (Davis, 1989). Like the perceived ease of use, perceived usefulness belongs to cognitive conditions for technology acceptance. Perceived usefulness plays a significant role in a user's intention to use, and previous empirical studies have supported this argument (e.g., Szajna, 1996; Hsu *et al.*, 2009; Joo and Sang, 2013). However, the previous research focused on the relationship between perceived usefulness and individuals' intention to use. Will whether or not a new AMT is perceived as useful(less costly or more productive) be related to a positive intention to accept and use the new AMT in the Chinese manufacturing companies? The answer is an unknown from the extant literature. The above discussion constitutes the following hypothesis:

H4 Perceived usefulness is positively related to intention to use

Intention to Use (IU) and Actual Use (AU)

Intention to use is defined as the extent to which users are willing to use technology and levels of efforts made for the willingness; actual use refers to the acceptance behaviour using the technology for a specific purpose in a particular scenario (Davis *et al.*, 1989; Venkatesh, 2003). The behavioural intention is the determinant leading to the actual behaviour of using the technology, and empirical tests have largely supported this relationship (e.g., Taylor and Todd, 1995; Venkatesh, 2000; Szajna, 1996; Jan and Contreras, 2011). Drawing on the TAM literature, this study designs to examine whether and how much an intention to use an AMT explains the actual use of the technology and the classical relationship for the individual-level behaviour holds in the organisational behaviour. Thereby, we propose the following hypothesis:

H5 Intention to use is positively related to actual use

3. Methods

3.1. Sample and Data

A convenient sampling method is applied to this study. A sample of manufacturing enterprises is used as the proxy of the Chinese manufacturing enterprises. The list and contacts of the sample manufacturing enterprises were accessed from Made-in-China.com.

Extant literature mainly relates to the general acceptance issue to the adopters, users, or operators, rather than the decision-makers of organisations. For instance, human operators' loss of supervisory control in operating automation manufacturing technologies (Le Goff *et al.*, 2018) and the end-users' problem in their intention to use the 3D printing systems in China (Wang et al., 2016), both study the individual-level behaviors despite the use of organizations as the context. We argue that at the organisational level, it is the organisational decision-maker rather than the end-user who finally determines whether to accept an AMT for the organisation.

The argument is in line with the study by Biresselioglu et al. (2018) suggesting that the key decision-makers in the development of smart and green energy technologies include formal social units such as policymakers and energy providers.

The sample consisted of chief executive officers (8%), manufacturing managers (28%), facilities and equipment operation managers (20%), production managers (21%), and engineering managers (23%). These respondents were the decision-makers, who directly and indirectly decide to purchase AMTs for their organisations.

The survey questionnaire was administered via face-to-face visits or emails. Of a total number of 288 responses, 267 completed the questionnaires and nine were considered invalid due to non-engagement responses to the survey questions such as using the same value '4' rating all scale variables — this resulted in a sample of 258 valid responses. . Among the sample, 28% is in textile, 52% in apparel and accessories, 12% in hardware, and 8% in bearing and machinery. These manufacturers include 28% small businesses with less than 100 employees, 47% medium-sized with 100-500 employees, and 25% large sized with more than 500 employees.

Structural Equation Modeling (SEM) and SmartPLS3 software were used for the empirical examination. In comparison with covariance-based SEM, the PLS-SEM technique allows this study to easily finds a solution for a complex model without the strict requirement for big sample size or normal distribution of the observations (Hair et al., 2014).

3.2. Measurement

Constructs scales were adapted from literature by adding contextual expressions relevant to automation manufacturing technology in the manufacturing industry (Table 1). Four-items of perceived norm were adapted from Hsu and Lu (2004). Organisational efficacy was measured by three items adapted from Compeau and Higgins (1995). Scales of perceived ease of use and perceived usefulness were adapted from Davis (1989) and Venkatesh and Bala (2008).

Intention to use was measured by four items adapted from Venkatesh and Bala (2008). Four items of actual use were adapted from Jan and Contreras (2011). A 5-point Likert scale was used ranking the measurement statements ranging from '1' (most disagreement) to '5' (most agreement). Report of the score means and standard deviations of the measured items are in Table 1.

Table 1. Questionnaire items, references and descriptive data.

Constructs	Questionnaire items	Mean± S.D.
Organisational efficacy (OE)	1.Our equipment suppliers think that we should use automation technology.	3.57±1.12
	2. Our competitors use automation technology, and we have to follow the trend.	3.47±1.20
	3. The government suggests that the application of automation technology contributes to sustainable development	3.69±1.10
Perceived norm (PN)	1.We can learn to use a newly-introduced automation technology with built-in instruction.	4.04±0.96
	2.We are capable of applying a newly-introduced automation technology.	4.24±0.85
	3.We can quickly master newly introduced automation technology with the assistance of the suppliers.	3.92±1.04
	4.We can quickly apply a newly introduced automation technology with technicians' assistance	4.08±0.83
Perceived usefulness (PU)	1.Automation technology can enhance the company's productivity.	4.13±0.88
	2. Automation technology can improve product quality.	3.93±0.97
	3.Automation technology is useful to maintain competitiveness.	3.96±0.98
	4. Automation technology can reduce costs.	4.15±1.03
Perceived ease of use (PEU)	1.Staff can easily operate a newly adopted automation technology.	4.10±0.91
	2.Staff can easily interact with a newly adopted automation technology	4.03±1.00
	3.Staff can easily become skilful in using a newly adopted automation technology.	3.42±1.15
	4.Staff can easily learn to operate a newly adopted	4.32±0.81

	automation technology.	
Intention to use (IU)	1. I am considering introducing automation technology for this company.	4.18±0.89
	2. I am willing to introduce automation technology for the company.	3.58±1.06
	3.I intend to introduce automation technology in the company.	4.07±0.88
	4.I expect that the company will apply automation technology.	3.70±1.10
Actual use (AU)	1.This company has used automation technology in manufacturing.	3.00±1.23
	2.This company has substantively used automation technology in manufacturing.	3.57±1.25
	3.This company has started to use robotics for production.	3.40±1.26
	4. This company has used advanced robotics for production.	3.55±1.22

4. Results

4.1. Construct Reliability and Validity

The statistical analysis takes two steps. We first test and validate constructs and then test the model and hypothesis. Construct Reliability (CR) was estimated, and the results are displayed in Table 2. CR values of all six constructs are greater than the guideline 0.7, ranging from 0.86 to 0.92; Cronbach's Alpha values range from 0.79 to 0.88, which are consistent with the CR values. Both results suggest very good construct reliability and internal validity (Anzengruber et al., 2017). Average Variance Extracted (AVE) values of all individual constructs are greater than the threshold 0.6, ranging from 0.61 to 0.80, suggesting good convergence validity (Hair et al., 2014).

Table 2. Construct reliability and convergence validity.

	Actual Use	Intention to Use	Perceived Norm	Perceived Ease of Use	Organisational Efficacy	Perceived Usefulness
AU1	0.745					
AU2	0.768					

AU3	0.823					
AU4	0.780					
IU1		0.811				
IU2		0.839				
IU3		0.815				
IU4		0.794				
PN1			0.831			
PN2			0.777			
PN3			0.77			
PN4			0.796			
PEU1				0.85		
PEU2				0.751		
PEU3				0.789		
PEU4				0.772		
OE1					0.90	
OE2					0.878	
OE3					0.900	
PU1						0.877
PU2						0.77
PU3						0.80
PU4						0.789
Cronbach's Alpha	0.79	0.83	0.81	0.80	0.88	0.84
CR	0.86	0.89	0.87	0.87	0.92	0.89
AVE	0.61	0.66	0.63	0.63	0.80	0.68

To check the discriminant validity, we referred to the criterion of Heterotrait-Monotrait Ratio (HTMT). All HTMT values are less than 0.90 (Table 3), suggesting no violation of construct discriminant validity. We further checked the loadings of all items, confirming the loadings of the items with their measured construct are the highest than their loadings with any other construct. The result ruled out the cross-loading issue and further confirmed the discriminant validity. After the measurement and constructs were validated, we proceeded to test the hypotheses and the regression model.

Table 3. Discriminant validity (Heterotrait-Monotrait Ratio, HTMT)

	1	2	3	4	5	6
1 Actual use						

2 Intention to use	0.667				
3 Organizational efficacy	0.610	0.656			
4 Perceived ease of use	0.645	0.817	0.686		
5 Perceived norm	0.587	0.93	0.588	0.712	
6 Perceived usefulness	0.662	0.892	0.673	0.815	0.783

4.2. Tests of Hypotheses and Model Fit

We tested the research model using the structural equation modelling technique and software SmartPLS3. Table 4 displays the results of hypotheses test. All but one hypothesis are statistically significant at 99.999% confidence level. Intention to use is a strong predictor of actual use (IU→AU: β = 0.54, t = 9.42). We expected that four constructs directly predict intention to use. Among the four, the expected effect of organisational efficacy on the intention to use is statistically insignificant (OE→IU: β = 0.09, t = 1.69) while the perceived norm is significantly related to the intention to use (PN→IU: β = 0.22, t = 3.9). The results also suggest that the effect of perceived ease of use on intention to use is significant (PEU→IU: β = 0.21, t = 3.51) but with less explanatory power than that of the perceived usefulness (PU→IU: β = 0.42, t = 6.07). However, perceived ease of use also indirectly affects intention to use via the mediating effect of perceived usefulness, that is, PEU→PU→IU (PEU→PU: β = 0.36, t = 5.56). Hence, the total effect of perceived ease of use on the intention to use (β = 36.12 = 0.36*0.42 + 0.21) is closer to that of perceived usefulness.

Table 4. Results of hypothesis and Model fit tests.

Research hypotheses	Standardised estimate	T-value	P-value
H1a: PN→PU	0.34	5.43	0.000
H1b: PN→PEU	0.40	4.81	0.000
H1c: PN→IU	0.22	3.89	0.000
H2a: OE→PU	0.21	3.58	0.000
H2b: OE→PEU	0.38	4.91	0.000
H2c: OE→IU	0.09	1.69	0.092
H3a: PEU→PU	0.36	5.56	0.000

H3b: PEU→IU	0.21	3.51	0.00
H4: PU→IU	0.42	6.07	0.000
H5: IU→AU	0.54	9.47	0.000
Model fit index: SRMR = 0.078; Chi-Square = 655.771; NFI = 0.801			

Note. $p < .05$ (two-tailed).

One of the two antecedents, perceived norm, significantly affect perceived usefulness (PN→PU: $\beta = 0.34$, $t = 5.43$); meanwhile, it also significantly influences on perceived ease of use (PN→PEU: $\beta = 0.40$, $t = 4.81$). The other antecedent, organisational efficacy, strongly and significantly affects perceived ease of use (OE→PEU: $\beta = 0.38$, $t = 4.91$); the expected impact of organisational efficacy on perceived usefulness is also statistically significant (OE→PU: $\beta = 0.21$, $t = 3.58$).

From the direct causal relationships under discussion, the two antecedents also indirectly affect intention to use via the mediating effect of perceptions. The perceived norm indirectly explains intention to use via perceived usefulness (PN→PU→IU: 0.34*0.42 = 0.14) and via perceived ease of use (PN→PEU→IU: 0.40*0.21 = 0.08). Similarly, the organisational efficacy indirectly explains intention to use via perceived usefulness (OE→PU→IU: 0.21*0.42 = 0.09) and via perceived ease of use (OE→PEU→IU: 0.38*0.21 = 0.08). The more complex paths for the antecedents indirectly affect intention to use involve both mediators, perceived usefulness and perceived ease of use: PN→PEU→PU→IU ($\beta = 0.06$), or OE→PEU→PU→IU ($\beta = 0.06$). All in all, the two antecedents, perceived norm and organisational efficacy, explain 65% of the variance of IU. All causal relationships are positive.

Table 4 also displays the model fit summary, like SRMR (0.078), Chi-Square (655.771), and NFI (0.801). The R square values displayed in Figure 2 indicate that the model explains around 65 per cent of the variance of the intention to use AMTs. The R square result of the intention to use in our model, 65 per cent, is much greater in comparison with the regression results, ranging from 39 per cent to 52 per cent of explaining intention to use in the longitudinal

field studies performed by Venkatesh and Davis (2000). Our result, 65 per cent, is also much greater than the empirical R square results (14 per cent in the post-implementation model and 52 per cent in the pre-implementation model) of the revised TAM by Szajna (1996). The comparisons further indicate the robustness of this model and the two antecedents in particular in explaining intention to use of AMT in Chinese enterprises. The result also suggests that the model explains only around 30 per cent of actual acceptance and use of AMTs . The reasons for the difference and paradox between the intention and actual behaviour need to be studied in a future search.

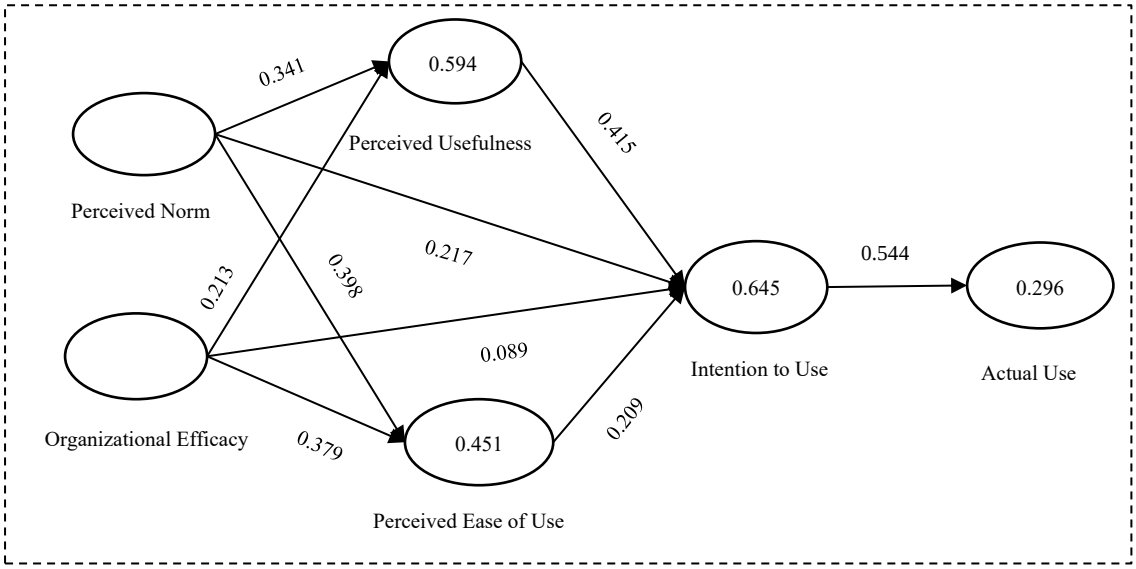

Figure 2. Results of Algorithm.

5. Discussion and Conclusion

5.1. Discussion of Results

The primary aim of this research seeks to extend the application of TAM to examine behavioural factors related to a general acceptance of automation manufacturing technology in Chinese manufacturing enterprises. We revised TAM and applied the revised TAM to examine effects of social and individual antecedents, namely, perceived norm and organisational

efficacy, on organisational perceptions and behaviour intention to accept and use AMTs in the Chinese manufacturing enterprises.

Results suggest that perceived norm affects intention to use AMTs in two ways. One way is of decision-makers' compliance that perceived norm directly influences intention to use (PN→IU), which is consistent with other empirical studies (Hsu and Lu, 2004; Tarhini, Hone, and Liu, 2014); the other way is via the path of internal cognition and identification, in which perceived norm indirectly affects intention to use through perceived usefulness (PN→PU→IU). This finding aligns with other findings by Schepers and Wetzels (2007), and Venkatesh and Davis (2000). In term of the effect size, it shows that the direct effect is much stronger than the indirect one, which indicates that the perceived norm from stakeholders plays a more important role in decision making. This result perhaps reflects the effect of normative beliefs and compliance with social pressures, that are from stakeholders of the company and in particular the Chinese government. The Chinese government has recently published the strategic vision, 'Made in China 2025'. The major policy aims to transform and upgrade the Chinese manufacturing industry. Under the vision, the use of AMTs has to increase from 55.1% in 2014 to 84.0% in 2025 by introducing numerical control automation in major processes and increasing R&D digitisation and design tools from 30.1% in 2014 to 64.0% in 2025. China will become a huge potential market for global technology suppliers. It estimates that by 2020, China will be the largest and fastest-growing robotics market in the world, accounting for more than 30 per cent of global spending (Perez, 2017).

Results of this study indicate that evidence supports the effect of organisational efficacy on the intention to use AMT indirectly through the mediating effect of perceived ease of use and perceived usefulness (OE→PU→IU + OE→PEU→PU→IU) while the direct effect of organisational efficacy on the intention to use is statistically insignificant. The overall effect of organisational efficacy is much weakened than that of perceived norm. When putting this

finding in the research context, the possible explanation might be that due to lack of experiences in AMTs in the Chinese manufacturing enterprises, the organizational decision-makers are more likely to consider viewpoints from stakeholders (i.e., perceived norm) more than out of their judgment of and beliefs (i.e., organizational efficacy).

Our empirical results with the evidence from the Chinese manufacturing industry confirmed those traditional TAM relationships suggested by Davis, Bagozzi, and Warshaw (1989) and Venkatesh and Davis (2000). For instance, in the organisational settings, perceived ease of use is significantly related to perceived usefulness (PEU→PU) and to intention to use (PEU→IU); perceived usefulness leads to intention to use (PU→IU); intention to use explains actual use (IU→AU). Our results are in line with other empirical studies (e.g., Svendsen et al., 2013; Taherdoost, 2018).

The insignificant result of OE→IU concurs with Hsu, Wang, and Chiu (2009). However, the insignificant relationship between OE and IU is inconsistent with some other TAM studies (e.g., Joo and Sang, 2013). Statistical significance for the PN→PEU relationship does not align with findings by Szajna (1996), and Schepers and Wetzels (2007). These discrepancies in empirical results of TAM studies are perhaps related to specific studies and research contexts. In this study, Chinese manufacturing enterprises were mostly starting to adopt AMTs. At this early stage, OE is building up while PN takes more critical role affecting the decision-makers. Further studies are needed to investigate the reasons for the discrepancy in the future.

5.2. Theoretical Contributions

Contributions of this research are in twofold. First, this study advances the TAM literature. We acknowledge that due to its powerful capacity of explanation and its simplicity, TAM has been extensively applied in the study of individual behaviours of acceptance and use of advanced technologies and information systems. However, to the best of our knowledge, this research is

the first to extend the application of TAM to the understanding of organisational behaviour, particularly in China, the world's largest manufacturer since 2011. We examined the organisational behaviour from its micro-foundations, specifically, the decision-makers of organisations (Liu *et al.*, 2017). Organisational decision-makers' belief in organisational efficacy, their perceptions, and attitudes, determine the acceptance and adoption of AMTs at the organisational level.

Second, we contribute to the knowledge of organisational decision-making. Due to the unique collectivism culture in the Chinese context, referents' attitudes and values, or perceived social influences, play a significant role in individuals' behaviour and behavioural intention (Rhee *et al.*, 2017; Weerakkody et al., 2017). However, for the organisational behaviour and behavioural intention, the referents of the organisational decision-makers are the organisational stakeholders such as AMT suppliers, competitors, and the government, rather than friends and family members of the individual-level behavioural decision-makers. Therefore, the measure of the perceived norm in our study is more appropriate for the study of organisational behaviour. Hence, perceived norm from stakeholders provides insights into the understanding the AMT acceptance in the Chinese manufacturing enterprises.

Third, organisational efficacy, originally developed for the study of organisational behaviour, bridges the social and psychological aspects of an organisation and its micro-foundations. By doing so, we approach the organisational behaviour of the acceptance of AMTs covering a broader sociocultural element. We view this as a significant extension to the TAM literature and adding knowledge to the understanding of organisational behaviour.

5.3. Practical Implications

Our results provide important insights and implications for global suppliers and buyers of automation manufacturing technologies. Perceived norm and organisational efficacy are two important factors explaining and predicting intention to use AMTs in China and perhaps some other emerging economies. Manufacturing companies' intention to accept AMT is currently influenced more by their external stakeholders (that is, perceived norm) rather than beliefs in their competences (that is, organisational efficacy). The empirical result is understandable and reasonable in the business situation like in the Chinese manufacturing industry when their experiences in adoption and use of automated manufacturing technology are at the early stage and remain at a low level. However, this situation may change in the future. For example, after more manufacturing companies used and gained experience in AMT, their acceptance of new and updated AMT may be affected more by organisational efficacy. For instance, shuttleless loom represents much advanced weaving machinery even at the international level in the textile industry, and the usage reached up to 90% or more in some of the Chinese textile clusters such as Xiaoshan, Shaoxing, and Ningbo in 2014 (China National Textile and Apparel Council, 2013). However, many of these companies copied their competitors and adopted similar technologies, which resulted in the overproduction of homogeneous products. When the companies accumulate more experience, the influence of perceived norm on their adoption of new and updated AMT will reduce accordingly, and instead, they make a judgment and behave more based on organisational efficacy rather than on the views of others (Venkatesh and Davis, 2000).

The above insights provide implications for the Chinese manufacturers to pursue the sustainable strategy of transforming and updating manufacturing competitiveness in the globe.

At this stage, the users are more concerned about the stability and ease of operation rather than progressiveness and diversity. Therefore, global suppliers should consider prior-sale

advertisements and promotion campaigns, and after-sale support and training services in addition to supplying stable and mature technology. With more accumulated experiences, the influences of external factors will gradually diminish, and the acceptance of AMTs will be affected more by organisational efficacy. This, in turn, promotes demand for diversity and consequently results in demand for up to date automation technologies in the future. This implication informs the global providers, who could strategically manage and supply to their global customers.

5.4. Limitations and Future Research

There are a few limitations in this study, which could foster further research directions. For focus, this research chooses perceived norm and organisational efficacy as two antecedents, leaving other dimensions as given. However, other factors such as organisational features, management support, and experiences surely affect actual use of automation technology (Venkatesh and Bala, 2008). Complementarities and trade-offs between the firm's other resources and to-be-adopted technologies are also relevant for technology adoption in manufacturing firms (Gomez and Vargas, 2012). Secondly, this research applies data from the Chinese manufacturing industry; care should be taken for the generalisation of the research findings since differences in contextual elements such as sociocultural and economic development may affect generalisation (Voss et al., 1995; Muk and Chung, 2015). Thirdly, this research has not controlled differences between manufacturing company size, section, or global integration level, which may affect decision-makers' behaviour. For instance, small manufacturing companies compete on speed, responsiveness and closeness to customers while big manufacturing companies compete on design and manufacturing processes (Voss et al., 1998). The existing paradox between the intention and actual behaviour requires for a future search, for example, the contextual or facilitating conditions perhaps explain to some extent, the collectivist (Khorasanizadeh *et al.*, 2016). However, studies suggest that different

manufacturers, ranging from start-ups to well-established, will take different strategies approaching technology (Kristianto *et al.*, 2012). These limitations constitute potential future research directions.

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Appendix A. Technology Acceptance Model (Davis et al. 1989: 985).