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Investigating Users' Perspectives in Building Energy Management System with an extension of Technology Acceptance Model: A Case Study in Indonesian Manufacturing Companies

Jacky Chin, Shu-Chiang Lin *

Department of Industrial Management, National Taiwan University of Science and Technology, 43 Keelung Road, Section 4, Taipei 106, Taiwan, ROC

Abstract

This study investigates factors that may influence users' perspectives in utilizing energy management system. An extended model of the Technology Acceptance Model (TAM) with two external factors, compatibility (C) and technology complexity (TC), was developed to evaluate the implementation of the Building Energy Management System (BEMS) in Indonesia's manufacturing industries. 258 questionnaires were analyzed via the structural equation modeling and the result shows that both C and TC influence user's intention to use BEMS through the user's attitude, perceived usefulness and perceived ease of use. The findings can be served as guidelines for design improvements of similar energy management systems.

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Keywords: Building Energy Management System; Technology Acceptance Model; Structural Equation Modeling.

1. Introduction

The manufacturing industry sector has been considered as one of the most rapidly growing sector with respect to energy-consuming in southeast Asia. It was reported by the association of the Southeast Asian Nations (ASEAN) in 2011 that the consumed energy in industrial sector has reached 37% of total energy

* Corresponding author. Tel.: +886-2-2737-6330; fax: +886-2-2737-6344.
E-mail address: slin@mail.ntust.edu.tw.

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consumption, the highest among all sectors, and such consumption has been growing by the average of 4.2% per annum [1]. In southeast Asia, Indonesia was noted as the largest energy consumer, with 36% of the region's total primary consumption [2, 3]. As of 2013, the country's industrial sector was the sector with the greatest share of total energy consumption by the amount of 33%, followed by the residential sector for 27%, the transports sector for 27%, and the commercial sector as well as other sectors for 10% [2]. In summing up, the industrial sector has the highest share in the total energy consumption. Hence, improving energy efficiency in the industrial sector will surely provide greater benefits for energy allocation, energy distribution, energy security, as well as reducing environmental impacts. Energy efficiency is also critical for companies to run and maintain a sustainable process. With proper control of the energy usage, companies can reduce unnecessary energy consumption costs as well as the emissions of CO2 to their surroundings. To achieve these multi benefits, many ASEAN countries have adopted or announced the policies of implementing energy-efficiency programs, with many of which focus on energy management in industries and large buildings [1]. This study aims to investigate factors that may influence user's perspectives in energy management system that has been implemented in the industries.

To evaluate the effectiveness of energy consumption efficiency, a smart monitoring system is a necessity to be installed on-site. Several literatures showed that the implementation of the smart Building Energy Management System (BEMS) helps reduce energy consumption significantly when compared to using the conventional way without BEMS [4-9]. The few number of manufacturing companies that utilizing BEMS in Indonesia became a question in an industry sector. And with the advantages of BEMS, this system will greatly assist in a company's energy program. This Problem is closely related to the level of user acceptance of this system. Focuses directly on BEMS, this research investigates the potential factors that may influence user's acceptance of using such system. The technology acceptance model (TAM) is used in our study because TAM has been the most frequently applied and the proved model for explaining the behavioral intention. Similar studies that examined the users' behavior in smart BEMS or smart grid through TAM all focused on residential housing, commercial housing and general-purpose use of energy [10-12] instead of manufacturing industry. This research, on the contrary, aims for users of BEMS in manufacturing companies. The findings of this research serve as a design guideline for BEMS users such as the smart building grid meter company and BEMS providers such as the automation system (BAS) company to improve BEMS from users' perceptions and behaviors.

2. Literature study

2.1 Building Energy Management System

Energy management systems consist many control variables in its operation. The application of a traditional quantitative control method based on the preset constant values of physical parameters is not sufficient for users' response in the indoor environment [13]. Therefore, the BEMS is used to handle this situation, which is integrating users' responses in building controlling and monitoring. Traditionally, the technicians need to go to several panel locations in each building manually to check and to control the energy consumption in each hour. The checking items consist of monitoring of consumption in lighting, electricity supply to production machines, heating ventilation air conditioning and several others[5, 8].

The previous research studies related to BEMS usage described both evidences and benefits of BEMS in reduction of energy consumption, especially for companies [4-9, 14-17]. Those benefits, encourage this research to investigate the related factors that are useful to improve user's response in BEMS. The response improvement later will help the company who develop the BEMS to maximize the use of BEMS in terms of sustainable energy consumption savings.

2.2 Technology Acceptance Model

Technology acceptance model (TAM) was firstly described by Davis (1989) in his psychometric research. This model is able to investigate the factors of user's behavior towards using information technology or in adopting new technology. TAM model is considered as the most frequent refered model for analyzing user's behavior in accepting technology. An extension of the latest TAM, known as the TAM2, has also been used as a supplemental model in general [18],[19],[20].

There are many evidence studies reveal how TAM can explain software and IT product in behavior prespectives [21-23]. TAM is able to demonstrate that both Perceived Ease of Use (PEU) and Perceived Usefulness (PU) of technology applications can affect users' utilization efficacy of system [11, 19]. Furthermore, in BEMS behaviour research PEU and PU are considered as the important factors that influence user intention to use smart grid [10-12]. In our reseach, PU can be defined as a degree to which a person believes that using a particular system would enhance his or her job performance and PEU can be defined as a degree to which a person believes that using a particular system would be free of effort. According to Davis [20], Both PU and PEU have direct correlations to the factor Attitude (A) and have associations with the behavior intention to use. Attitude (A) can be described as the degree of which the user follows his or her positive or negative feeling to use new technology [11, 21, 22]. Attitude factor has a direct correlation to Behavior Intention (BI). BI is defined as a measure of the strength of individual's intention to perform a specific behavior [20]. In addition to BI, A, PU, and PEU, which are the four original internal factors in both the TAM and TAM2 models, other studies extend the investigation to various external factors. For example, Subjective Norm (SN) is considered in TAM2 [18]. This study considers Safety Concern (SC), Compatibility (C) and Technology Complexity (TC) as external latent factors. SN can be defined as perception that most people who are important to him think he should or should not perform the behavior in question [18]. SC is Believes regarding the processes, activities, or tasks that protect the confidentiality and accessibility of information [11]. Compatibility (C) can be explained as the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters [10]. Technology Complexity (TC) can be explained as individual perception of the difficulty understanding and using new technology [11, 23, 24]. Previous studies with extended TAM have confirmed that SN, SC, C, and TC influenced the acceptance of new technology. In detail, SN has a relationship to BI [18], SC has an indirect relationship with PU and PEU [11]. Empirical studies also indicate that C affect PU and PEU [10]. Meanwhile, although previous investigations of extended TAM on smart grid on residential housing and IT sector found that TC positively influenced PEU [11, 23, 24], it had not been studied in a manufacturing sector. In summary, nine hypotheses in Table 1 are constructed based on extended TAM in predicting acceptance of BEMS usage and this research also investigating the contributions level of external factors that influence the BEMS system.

Based on these nine hypotheses, a behavior analysis was performed to explain the users' acceptance model in BEMS and the result will be presented in the analysis and results section.

Table 1. Research hypotheses

Item	Hypothesis	Reference
H1:	Compatibility (C) is positively affecting Perceived Expected Usefulness (PU) to use BEMS.	[10]
H2:	Technology Complexity (TC) is positively affecting Perceived Expected Ease of Use (PEU) of users to use BEMS	[11, 24, 25]
H3:	Perceived Expected Usefulness (PU) is positively affecting Attitude (A) of users to use BEMS.	[19, 21, 24]
H4:	Perceived Expected Ease of Use (PEU) is positively affecting Attitude (A) of users to use BEMS.	[19, 21, 24]
H5:	Perceived Expected Ease of Use (PEU) is positively affecting Perceived Expected Usefulness (PU) of the user to use BEMS.	[19, 24]
H6:	Attitude (A) is positively affecting Behavioral Intention to Use (BI) of users to use BEMS.	[19, 20, 21]

H7:	Compatibility (C) is positively affecting Perceived Expected Ease of Use (PEU) of users to use BEMS.	[10]
H8:	Safety Concern (SC) is positively affecting Perceived Expected Usefulness (PU) of users to use BEMS.	[18]
H9:	Subjective norm (SN) is positively affecting Behavioral Intention to Use (BI) of users to use BEMS.	[18]

3. Method

The objective of this study is to investigate the effect of external factors concurrently to influence the technology acceptance in BEMS. In this research, an extended TAM was used as a methodology model for evaluating the implementation of BEMS in the manufacturing industries. In the model, behavior intention is posited as an indicator of success factor. The model also incorporates variables related to technical issues such as compatibility and technology complexity. A structural equation modeling (SEM) with confirmatory factor analysis is used to examine the relationship between factors and it is noted in each hypothesis.

The instrument development of methodology in our study is an online and offline questionnaire survey which contains two sections. The first section asked about 22 observed variables to measure the 8 factors in the proposed model, which are Subjective Norm (SN), Safety Concern (SC), Compatibility (C), Technology Complexity (TC), Perceived Ease of Use (PEU), Perceived Usefulness (PU), Attitude (A), and Behavior Intention (BI). The second section asked about the personal and academic data, which are age and current education level.

A total 258 respondents were participating in this research. The respondents were the workers from manufacturing companies in Indonesia, who using the BEMS for energy consumption monitoring. The overall age range was between 20 to 35 years old. All respondents completed the same observed questionnaire, the representation of the eight latent factors of technology acceptance in BEMS. All the observed questions of latent factors were measured in 5-point Likert scale, scale, ranging from 1 "I strongly disagree" to 5 "I strongly agree". An example of itemized questions asked to the respondent is shown in Table 2. Our questionnaire survey was distributed from December 2014 to February 2015. During that period, 258 questionnaires were collected and used throughout our analysis. Based on our 9 hypotheses, an analysis was performed to explain the user' behavior.

Table 2. Partial questions for research constructs.

Construct	Measurement items	
C	C_1	Using BEMS is compatible with all aspects of my work
	C_2	Using BEMS fits into my work style
	C_3	I believe my work style is in line with BEMS
TC	TC_1	I have no difficulty using BEMS menus to check the records
	TC_2	I have no difficulty in using and transferring data to other devices
	TC_3	I have no difficulty understanding the system architecture of BEMS

4. Analysis and Results

As previously mentioned, 258 questionnaires were properly filled out by respondents from manufacturing companies in Indonesia, who using the building energy management system for energy consumption monitoring. The percentage age of respondents was 81% for 18-24 years old, 18.6% for 25-

34, and 0.4% for greater than 34 years old. For working experiences at their current workplace was 81.4% for between 1 to 5 years and 18.6% for equal or more than 5 years.

The model based on TAM was measured using SPSS AMOS® 22, with the maximum likelihood method. Both our questionnaire reliability and convergent validity [26-29] have surpassed the minimum requirement, as shown in Table 3.

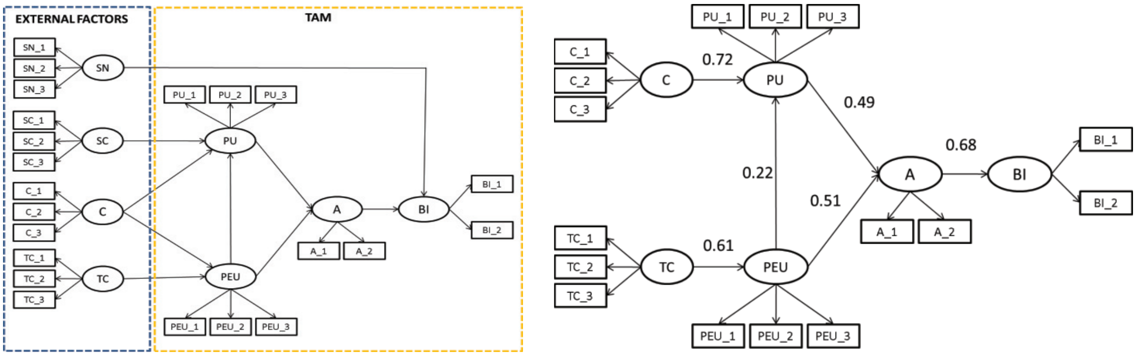
Table 3. Reliability and validity analysis result

Factor	Item	Factors Loading (≥0.7)[1]	Cronbach's α (≥0.7)[1]	Composite Reliability (CR) (≥0.6)[1]	AVE (≥0.5)[1]
Compatibility	C_1	0.771	0.78	0.824	0.61
	C_2	0.749			
	C_3	0.767			
Technology Complexity	TC_1	0.7	0.726	0.773	0.532
	TC_2	0.738			
	TC_3	0.806			
Safety Concern	SC_1	0.825	0.744	0.792	0.560
	SC_2	0.713			
	SC_3	0.701			
Subjective Norm	SN_1	0.781	0.763	0.802	0.574
	SN_2	0.738			
	SN_3	0.753			
Perceive of Usefulness	TC_2	0.738	0.788	0.804	0.578
	TC_3	0.806			
	PU_3	0.753			
Percieve Ease of Use	PEU_1	0.74	0.782	0.787	0.552
	PEU_2	0.757			
	PEU_3	0.792			
Attitude	A_1	0.734	0.753	0.713	0.554
	A_2	0.78			
Behaviour Intention	BI_1	0.738	0.76	0.694	0.532
	BI_2	0.706			

[1] indicates the required value [10-13]

Table 3 also shows that the value of our factor loadings passes the minimum threshold of 0.7 as recommended by some empirical research studies. This value indicates that our questionnaire is good enough to explain the dimensionality of C, TC, SC, SN, PEOU, PU, A and BI. The second measurement is Cronbach's α, where our analysis result reveals that the minimum values are obtained for every questionnaire question. The stable consistency for each question in describing the measured factor is proven by the indicator of α that exceeds 0.7. The next measurement, CR, indicates that the value has a good reliability with adding factor loadings in the formulation, and the results are more than 0.6. The last measurement, AVE, shows how the extracted variance has a good representation with the value of more than 0.5

The result of questionnaire measurement will lead to the next experiment by measuring the model and testing the proposed hypotheses. The results of the initial analysis for the proposed models show factors such as SC and SN have a weak relationship and did not pass the requirement ($p<0.05$), the significance value for SC was 0.526 and for SN was 0.09 (H6, H7, and H8 were not supported). Based on these results the authors reconstruct a model that became our final model. The result of our SEM experiment final model is shown in Figure 1.(b) The illustration shows the positive correlation for the six path correlations. Hence, the six hypotheses were proven to have positive path correlations.



(a) (b)

Figure 1. (a) Proposed BEMS Model, (b) BEMS Model Tested Result

For validating the structural model, a model fit analysis was performed to measure our model based on the several indicators and the result is shown in Table 4.

Table 4. Final Model Fit Parameters

Goodness of Fit Model Index	Minimum value [2]	Result
RMSEA	< 0.05	0.043
GFI	> 0.90	0.939
AGFI	> 0.90	0.915
TLI	> 0.90	0.964
CFI	> 0.90	0.971
NFI	> 0.90	0.917

[2] indicates the required value [25]

Table 5. Test results of final hypothesis

Hypothesis	Relationship	Estimate (β)	Significance (p)	Result
H1	PU ← C	0.726	0.005***	Supported
H2	PEU ← TC	0.612	0.02**	Supported
H3	A ← PU	0.499	0.01***	Supported
H4	A ← PEU	0.511	0.012**	Supported

H5	PU ← PEU	0.224	0.007***	Supported
H6	BI ← A	0.68	0.007***	Supported

** $p < 0.05$

*** $p < 0.01$

The hypothesis test result has shown support for relationships of TAM with BEMS external factors. As shown in Table 5, our results confirm both Compatibility and Technology Complexity factors influence users' intention through the Attitude, Perceived Usefulness and Perceived Ease of Use (i.e: the representation in hypotheses H1 and H2). Both compatibility and Technology Complexity are positively related to Perceived Usefulness and Perceived Ease of Use. The coefficient between Compatibility and Perceived Usefulness is significant with a value of 0.005 ($p < 0.01$). The coefficient between Technology Complexity and Perceived Ease of Use is also significant with a value of 0.02 ($p < 0.05$).

Moreover, the representation of basic TAM in H3, H4, and H5 are also supported. The coefficient between Perceived Usefulness and Attitude is significant with a value of 0.01 ($p \leq 0.01$). The coefficient between Perceived Ease of Use and Attitude is significant with a value of 0.012 ($p \leq 0.05$). The coefficient between Perceived Usefulness and Perceived Ease of Use is found to be significant with a value of 0.007 ($p \leq 0.01$). Similarly, coefficient between Behavior Intention and Attitude (H6) is also found to be significant with a value of 0.007 ($p \leq 0.01$).

5. Conclusion

The objective of this study is to investigate what external factors that concurrently influence the technology acceptance in Building Energy Management System. The latent variables of Compatibility (C) and the Technology Complexity (TC) were integrated as external factors into TAM. Both of those factors, Compatibility (C) and Technology Complexity (TC), influence user's intention through the attitude, perceived usefulness and perceived ease of use. The implication of the study, with the success of the final proposed model, makes a valuable contribution regarding the role of the TAM in explaining behavioral intentions in BEMS. The results of Chou et al (2014) research were consistent with the findings of the present study. Their study also indicated that TC had the strongest significant effect on PEU. The findings of this study were in line with Lowry's research (2002). The result of his study revealed that C had a weak relationship to PEU. The result of the theoretical model of TAM is very useful to provide an understanding of aspects of the user's acceptance of BEMS technology in manufacturing industry in Indonesia.

Based on the analytical results via SEM, all indicator results met the requirement for the recommendation of model fit as mentioned in the measurement model. Its show that our model is robust and can explain the real situation through the proposed factors. All the direct relationship hypotheses between C-PU, TC-PEU, PEU-PU, PU-A, PEU-A and A-BI were supported. Which are explained in the path relation model (i.e: the coefficient β of each path shows a positive value in Figure 1). It means that high compatibility is strongly associated with high user's perceived usefulness, and high-Technology complexity is also associated with high perceived ease of use. A significant contribution of this research is to demonstrate the relevance of Compatibility (C) and Technology Complexity (TC) as a consideration factors to the behavioral intention within the context of user acceptance BEMS. These variables have previously been suggested as potentially important in TAM's research studies, but had not been included in investigation in relation to BEMS acceptance in manufacturing industry in Indonesia.

The results from our study support that Compatibility (C) and Technology Complexity (TC) are noted as the important consideration in the study of technology acceptance of BEMS. Therefore, the system should be designed to distribute various tasks into proper computational units in order to reduce the complexity. Additionally, BEMS company must provide better data quality [6], such as improving the compatibility of database, which can be directly accessed through a common file used to create energy reports, in both graphs and charts of energy consumption. In light of these results, the BEMS (smart grid) company should consider a compatibility in their software and a technology complexity in their interface system to enhance the user in using the system. Specifically, to maximize consumer acceptance of BEMS, improve the display quality and simplifying the operation to be easily used by a wide range of working age and educational background. The BEMS provider must also provide direct or online training to minimize the complexity of the system.

Finally, this research has some limitations that need to be considered and discussed. Firstly, the respondents or subjects were workers from manufacturing companies in Indonesia, who familiar with BEMS for monitoring of energy consumption at least 1 year in their routine job activities. The results may be different from those who worked in managerial level, because managerial's job mostly related to evaluate data record analysis in the strategy program related to energy consumption efficiency. Secondly, future researchers should try to optimize the theoretical of TAM in BEMS by integrating other relevant variables for conducting further empirical investigations.

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