Technology Usage Model (TUM): Validation Results

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Abstract

The TUM model was constructed to explain the use of information technology in two parts: the first is a sub-model of technology uptake, explaining usage in the first time period t_0 to t_1; the second is a sub-model of technology continuance, explaining usage in the second time period t_1 to t_2. A longitudinal field study was conducted to: (a) assess the TUM model's explanatory power; and (b) investigate factors affecting the uptake and continuance of information technology. The results suggested that the TUM model had moderate explanatory power of information technology uptake and continuance. User's expectations towards the information technology were a key factor affecting their usage in both time periods. Performance expectancy and effort expectancy affected the uptake. However, after users had an experience with the technology, only performance expectancy affected their continued use.

Keywords: information technology usage, uptake, continuance

1. Introduction

Usage is a first and vital condition for ensuring information technology (IT) pay-off: if technology is compatible with the tasks, the use of the technology could lead to an impact on individual user's performance that itself affects the organization's productivity and pay-off from IT investment [1]. The use of information technology by the end-users however is not guaranteed; they are sometime unwilling to use the technology, even if it affords them benefits; and those who do start to use it sometimes opted out later [2].

A model could help IT stakeholders to understand usage behavior by identifying the set of underlying factors and their quantitative relationships [3, 4]. Existing models (such as the Technology Acceptance Model and the Unified Theory of Acceptance and Use of Technology) view technology usage as an extension of acceptance behavior: if individual accepts technology, they will both take it up and continue using it. These models therefore encounter difficulty in explaining why those users who do start to use the technology opt out later (the 'acceptance discontinuance anomaly') [5]. Since deriving the benefits of technology depends not only on initial uptake but continuance, some researchers have developed technology continuance models. However, there are no existing models that bridge the gap between uptake and continuance to explain better the use of technology in the process.

The aim of this research was to construct the Technology Usage Model (TUM) which bridges the existing gap between findings on uptake and continuance of information technology in order to provide an improved understanding of the processes of information technology usage. The research was designed into two phases: model construction and model validation.

In the model construction phase, three research questions were asked and answered:

RQ1: What are the factors likely to affect the uptake of information technology?

RQ2: What are the factors likely to affect the continued use of information technology?

RQ3: What is an appropriate model of uptake and continued use of information technology?

Review of literature was used for answering the first two research questions (RQ1 and RQ2). The factors found from the review of literature were then integrated to construct the TUM model, as expressed in research question RQ3. Model validation was the second phase, in which four research questions were asked and answered:

RQ4a: How well does the TUM model explain the uptake of information technology?

RQ4b: What are the factors affect the uptake of information technology?

RQ5a: How well does the TUM model explain the continued use of information technology?

RQ5b: What are the factors affect the continued use of information technology?

2. Factors likely to affect the uptake of information technology (RQ1)

The Theory of Reasoned Action (TRA) asserted that individuals' behavior is driven by their motivation to perform that behavior, which is a comprising function of a person's expectations towards a target behavior [6]: see Figure 1.

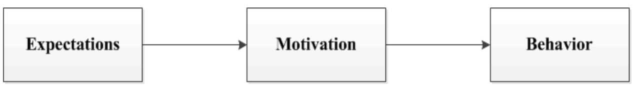


Figure 1. Theory of Reasoned Action

The figure infers that high level of expectation towards the information technology will motivate a new user to take up that technology. To find out what a user expects from the information technology, Technology Acceptance Model (TAM) was selected with three main reasons [7,8]. The TAM is tailored to the IT context. It is considered as a reliable model based on empirical evidence, with considerable support in explaining user uptake of various information technologies. Additionally, the practical utility of the model is also a reason for the section of the TAM model: system designer and developer have come degree of control over the two TAM factors. The TAM model was constructed by Davis in 1980 to explain the acceptance and uptake behavior of information technology [9]. The TAM posited that there are two particular expectations that impact on a new user's motivation towards information technology usage: perceived usefulness and perceived ease of use. Perceived usefulness, termed 'performance expectancy' (PE) in this study, refers to the degree to which an individual expects that the use of a new information technology enhances their job performance. Perceived ease of use termed 'effort expectancy' (EE) in this study, is defined as the degree to which an individual expects that the use of that technology does not require an increase in effort: see Figure 2.

Figure 2. Technology Acceptance Model

3. Factors likely to affect the continuance of information technology (RQ2)

A relationship of expectations and the continuance behavior was also found in research concerning information technology continuance [10,11,12]. Additionally, empirical evidence suggested that users' expectations changed over time as they experienced the technology after taking it up and this change in expectations might have a corresponding impact on users' continuance behavior: people opted out from the technology because their expectations changed from high before uptake, to low after using the technology [13,14, 15]. To better understand the continued use of information technology, the question is now 'how expectations do change or are modified over time?'

The Cognitive Dissonance Theory and Adaptation Level Theory were applied as grounded theories of the TUM model for providing the answer of temporal change in users' expectations

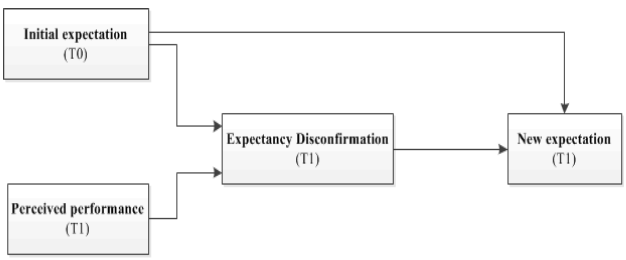
A. Cognitive dissonance theory

Under the assumption that individuals have a need to maintain some level of consistency (consonance) between their cognition and reality, the Cognitive Dissonance Theory (CDT) asserted that there will be a psychological state of dissonance when cognitive structures (expectation) and reality are inconsistent with each another [16]. In information technology usage, end-user may experience cognitive dissonance during the period of technology usage if their initial expectations (that earlier led to acceptance and uptake) are disconfirmed by the actual performance of the technology. Rational users may remedy this dissonance by distorting or modifying their expectations so they are more consistent with reality: see Figure 3.

Figure 3. Cognitive Dissonance Theory

B. Adaptation level theory

Adaptation level theory (ALT) suggested that individual users' initial expectations serve as their level of adaptation, by which they make a cognitive comparison between the adaptation level (initial expectation) and perceived actual performance to determine disconfirmation of technology usage [17,18] (see Figure 4).



Note: T0 = pre-technology usage variable; T1 = post-technology usage variable

Figure 4. Adaptation Level Theory

The disconfirmation then adjusts the initial expectation to the new expectation which is more consistency with reality. The new (modified) expectation suggests subsequent judgment of behavior and revises the adaptation level used in future continued use evaluation:

4. Technology usage model (RQ3)

By applied the three grounded theories mentioned earlier, the TUM model was constructed to explain the use of information technology in two parts: the first is a sub-model of information technology uptake, explaining technology usage in the first time period, t_0 to t_1; the second is a sub-model of information technology continuance, explaining technology usage in the second time period, t_1 to t_2. In Figure 5, the model is represented as a set of processes. The boxes with solid borders represent the psychological stages.

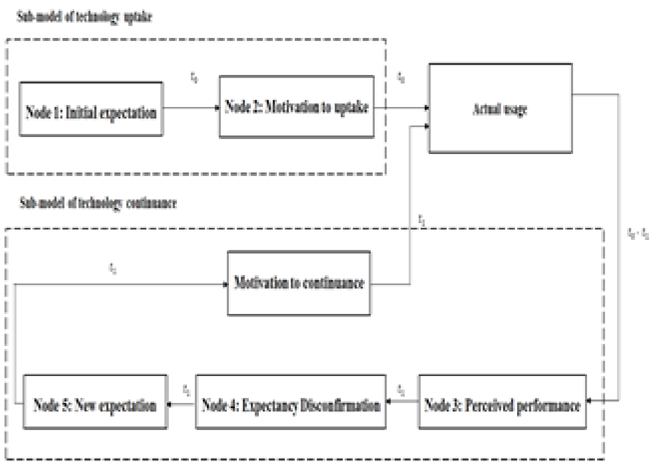


Figure 5. Technology Usage Model (TUM)

Node 1: Before a user takes up new information technology, an initial expectation is created. From the TAM model, a user has two initial expectations towards technology: performance expectancy and effort expectancy.

Node 2: User's motivation towards the uptake of technology is formed according to their level of two expectations towards the technology.

A User will then take up the technology if they have high motivation towards the uptake at time t_0 or high initial expectation that the use of technology will improve job performance (performance expectancy) and not require an increased effort (effort expectancy).

Node 3: During the usage time period, t_0 to t_1, perceptions of the actual technology performance will be formed. Adaptation level theory suggests that the initial expectation is formed for creating a reference level that a user then uses to make a comparison with perceived technology performance, in order to determine his/her level of confirmation. Thus, there are two aspects of percieved performance based on each expectation.

Node 4: A user then evaluate their perceived actual performances with their initial expectations to determine expectancy confirmations

Node 5: Dissonance (expectancy confirmation) produces discomfort and, correspondingly, users modify each of their expectations to be consistent with reality or the level of confirmation.

Similarly with the uptake behaviour, under the basis of the TRA, an experienced user will continue using the technology if they have high new expectations or high motivation towards continuance at time t_1.

5. The model validation methodology

To answer the research question RQ4a, RQ4b, RQ5a and RQ5b, a longitudinal field study was conducted over a period of two months with three points of measurement: t_0, t_1 and t_2. The data from the first usage time period (t_0 to t_1) was used for answering research question RQ4a and RQ4b, while the data from the second usage time period (t_1 to t_2) was used for answering research question RQ5a and RQ5b.

To control the potential effect of organizational variables (e.g. type of information technology and infrastructural constraints) on individual user use of technology [19, 20, 21], the participants in this experiment were users at a single organization. Students in Rajamangala University of Technology Thanyaburi were selected as a participant in the experiment and the study focused on their usage behavior of RMUTT Moodel technology.

A.Overview of research methodology for the model validation phase

The research methodology for each point in the longitudinal data collection is explained as follows:

- At time t_0

The aim of this phase was to measure each participant's initial expectations. The Thai questionnaire was used to measure the level of two initial expectations at time t_0: performance expectancy (PE_t0) and effort expectancy (EE_t0). Each item was measured on an 11-point Likert scale ranging from 0 ('Not at all') to 10 ('Very much'). As each variable was measured by multiple question items (3 items), a mean aggregated score was calculated to indicate the level of each initial expectation variable for individual participants.

- At time t_1

The second data collection was conducted one month after the first. At this point, only those participants who had used technology during t_ 0 and t_ 1 were: (a) measured level of technology usage and (b) new expectations at t_1. An objective measure (system tracking tool) was applied to measure the level of technology usage of two aspects; total number of times logging onto during t_0 and t_1 and total number of activities involving during t_0 and t_1.

- At time t_2

The aim of this phase was to measure the actual continued use of technology (level of use during t_1 and t_2).

B.Question item design and Pilot study

The two expectations (PE and EE) were measured by three items. The questionnaire was developed primarily by adapting previously validated items [7, 9, 22] to fit study's purpose. All sets of question items were translated into Thai by the researcher to make them easier for participants to answer.

A pilot study was conducted to evaluate and develop the Thai question items. In the pilot study, the questionnaires were distributed and collected directly for 30 users of RMUTT moodel. Cronbach's technique [23] was used to determine the internal consistency of the set of items (see Table 1).

Table 1. Items measuring expectations

	Items	Cronbach alpha
PE	▪ How much do you expect that RMUTT Moodel will be useful for your education? ▪ How much do you expect that RMUTT Moodel will allow you to learn more quickly? ▪ How much do you expect that RMUTT Moodel will improve your scores?	.92
EE	▪ How much do you expect that learning to operate RMUTT Moodel will be easy? ▪ How much do you expect that you will become skilful at using RMUTT Moodel? ▪ How much do you expect that RMUTT Moodel will be easy to use?	.88

All values were above 0.7, exceeding the threshold value recommended by Nunnally [24]. Therefore, the questionnaire for measuring expectations was considered a reliable measurement instrument.

C.Participants

In the model validation phase, the participants were user of RMUTT moodel. At time t_0, 138 participants had joined the experiment. At time t_1, there were 77 participants who had used technology and had joined experiments. At time t_2, data were collected gain only from those 77 participants who had joined experiment at time t_1.

D.Data analysis technique

Canonical correlation analysis was applied to investigate the explanatory power of the TUM model and the factors affecting usage in each time period.

In canonical correlation analysis, Wilks' λ value represents the percentage of variance in the combination of dependent variables that is not accounted for by the group of independent variables [25]. To represent the TUM model's explanatory power of information technology usage, R-square, Wilks' λ value was then subtracted from constant 1. To assess the explanatory power using Cohen's effect size [26], R-square was taken as the square root to represent R.

The scale was set as follows:

R = 0.1 represented *low* explanatory power

R= 0.3 represented *moderate* explanatory power

R = 0.5 represented *high* explanatory power

To investigate the factors affecting usage in each time preriod, as expressed in research question RQ4b and RQ5b, the structure coefficient (r) for each factor was applied: the factor was considered as contributing if structure coefficient (r) was higher than 0.5 [27].

Canonical correlation analysis requires a number of assumptions that were checked and not violated in this analysis.

6. The model validation results

This section reports the statistical results found from the model validation phase.

A. Canonical correlation analysis between the two initial expectations and the two measurements of technology actual uptake

To answer research questions RQ4a and RQ4b, canonical correlation analysis was conducted using the two initial expectations at time t_0 (PE_t0 and EE_t0) as independent variables, while the two measurements of technology actual usage during t_0 and t_1 (total number of times logging onto during t_0 and t_1 and total number of activities involving during t_0 and t_1) were used as dependent variables.

The relationship between the set of the two initial expectations at t_0 and the two measurements of actual information technology uptake at t_1 was statistically significant, Wilks' λ criterion = .78, F(4, 196) = 3.1, p = .016. Accordingly, there was at least one significant relationship between the two TUM initial expectations at t_0 and the two measurements of actual uptake at t_1. Because Wilks' λ represents the variance in the combination of dependent variables unexplained by the set of independent variables, 22 per cent (1- λ) of variance in actual IT uptake was accounted for by the TUM initial expectation variables.

The canonical correlation analysis yielded two functions with squared canonical correlations of .11 and .002, respectively, for each successive function (see Table 2).

Table 2. Canonical correlation analysis of the relationship between the two initial expectation variables and the two measurements of actual uptake

Function	Eigenvalue	Canonical correlation	Squared correlation
1	.13	.34	.11
2	.002	.04	.002

Dimension reduction analysis was used to determine which functions should be interpreted. Functions 1 to 2 was statistically significant, F(4, 196.0) = 3.1, p = .016 (see Table 3), however the cumulative effects of Function 2 in isolation was not statistically significant. Because of this, the first function was considered noteworthy in the context of this study.

Table 3. Dimension reduction analysis for canonical functions of the relationship between the two initial expectation variables and the two measurements of actual uptake

Roots	Wilks' λ	F	Hypothesis DF	Error DF	Significance of F
1 to 2	.88	3.11	4.0	196.0	.016
2 to 2	.99	.21	1.0	99.0	.644

The structure coefficient (r) for variables within the Function 1 are shown in Table 4.

Table 4. Canonical solution of the relationship between the two initial expectation variables and the two measurements of actual uptake

Variables	r	Summary
Number of times logging on during t_0 and t_1	.64	contributing
Total number of activity involving during t_0 and t_1	.97	contributing
performance expectancy at t_0	.99	contributing
effort expectancy at t_0	.55	contributing

There was a positive relationship between the dependent and the independent variates in the Function 1 since the canonical correlation between the dependent and the independent variates (.34) was positive. Performance expectancy at t_0 (r = .99) and effort expectancy at t_0 (r = .55) were a contributed independent variable, while number of times logging on during t_0 and t_1 (r = .64) and total number of activity involving during t_0 and t_1 (r .97) were a contributed dependent variable.

B. Canonical correlation analysis between the two new expectations and the two measurements of technology actual continuance

To answer research questions RQ5a and RQ5b, canonical correlation analysis was conducted using the two new expectations at time t_1 (PE_t1 and EE_t1) as independent variables, while the two measurements of technology actual usage during t_1 and t_2 (total number of times logging onto during t_1 and t_2 and total number of activities involving during t_1 and t_2) were used as dependent variables.

The relationship between the set of the two new expectations at t_1 and the two measurements of actual information technology continuance at t_2 was statistically significant, Wilks' λ criterion = .80, F(4, 146) = 4.3, p = .003. Accordingly, there was at least one significant relationship between the two TUM new expectations at t_1 and the two measurements of actual continuance at t_2. Because Wilks' λ represents the variance in the combination of dependent variables unexplained by the set of independent variables, 20 per cent (1- λ) of variance in actual Information technology continuance was accounted for by TUM new expectation variables. The canonical correlation analysis yielded two functions with squared canonical correlations of .19 and .01, respectively, for each successive function (see Table 5).

Table 5. Canonical correlation analysis of the relationship between the two new expectation variables and the two measurements of actual continuance

Function	Eigenvalue	Canonical correlation	Squared correlation
1	.24	.44	.19
2	.01	.11	.01

Dimension reduction analysis was used to determine which functions should be interpreted. Functions 1 to 2 was statistically significant, F(4, 146.0) = 4.28, p = .013 (see Table 6), however the cumulative effects of Function 2 in isolation was not statistically significant. Because of this, the first function was considered noteworthy in the context of this study.

Table 6. Dimension reduction analysis for canonical functions of the relationship between the two new expectation variables and the two measurements of actual continuance

Roots	Wilks' λ	F	Hypothesis DF	Error DF	Significance of F
1 to 2	.80	4.28	4.0	146.0	.003
2 to 2	.99	.76	1.0	74.0	.386

The canonical loading for each variable within the Function 1 are shown in Table 7. There was a positive relationship between the dependent and the independent variates in the Function 1 since the canonical correlation between the dependent and the independent variates (.44) was positive. Performance expectancy at t_1 (r = .94) was a contributed independent variable, while Number of times logging on during t_1 and t_2 (r = .87) and Total number of activity involving during t_1 and t_2 (r = .99) were a contributed dependent variable.

Table 7. Canonical solution of the relationship between the two new expectation variables and the two measurements of actual continuance

Variables	r	Summary
Number of times logging on during t_1 and t_2	.87	contributing
Total number of activity involving during t_1 and t_2	.99	contributing
performance expectancy at t_1	.94	contributing
effort expectancy at t_1	.36	No

7. Discussion

This section discusses the statistical results from the model validation phase.

A. The TUM model's explanatory power of information technology uptake (RQ4a)

The TUM initial expectation variables (performance expectancy at t_0 and effort expectancy at t_0) accounts 22 per cent of variance in actual IT uptake. According to the work of Cohen (1992), the TUM had moderate explanatory power of information uptake.

B. The factors affecting the uptake of information technology (RQ4b)

The result of the canonical correlation analysis of the relationship between initial expectations at t_0 and the actual uptake at t_1 revealed two expectation factors affecting the uptake.

Performance expectancy was a statistically significant contributing variable in the uptake of information technology. This meant that a new user who had a high level of expectation that usage of information technology could support him/her to work on task more quickly and achieve better work performance normally showed a higher level of uptake of that technology than a user with a low expectation. This was not a surprising finding since information technology is designed for facilitating user on targeted task: susers will spend more time on the technology if they expect that technology helped them to work better. This finding has important implications for system designers and developers in that the functionality of information technology should provide facilitate work effectively in order to encourage users to do job more quickly and achieve better work performance.

Effort expectancy was also a variable that contributed statistically significantly to the uptake of new technology among users in an organization. This indicated that a new users who had a high expectation that the use of technology would be easy normally demonstrated a higher level of uptake than a user with a low expectation. A possible explanation might be that, if a technology is too hard for users to use, the benefits of using it to work faster may be dropped because of the time and effort needed to use the system. Eventually, users may be reluctant to use the system. The finding has important implications for designers and developers in that technology should be designed to be easy to navigate and understand. When the technology is designed and developed in a more user-friendly form, it may be expected that user will tend to use it, and spend more time doing so. A further implication is for the heads of organization. They should provide structured training on the use of new technology in order to help users become familiar with the system. When the target users have some experience of the system, their personal belief that the use of system is hard may diminish, boosting the level of their uptake.

If the design and development of an information technology complies with these two prerequisite (performance expectancy and effort expectancy), it can be expected that users will tend to spend more time using it during the first time period.

C. The TUM model's explanatory power of information technology continuance (RQ5a)

New expectations proposed by the TUM model (performance expectancy at t_1 and effort expectancy at t_1) accounts 20 per cent of variance in actual IT continuance. According to this value, the work of Cohen (1992) suggested that the TUM had moderate explanatory power of information continuance.

D. The factors affecting the continaunce of information technology (RQ5b)

There was a surprising result; there was only performance expectancy at t_1 affecting continuance of information technology, while the influence of effort expectancy on the continuance did not lead to a statistically significance. Perhaps the explanation for the surprising finding is due to the user's experience with the system. The earlier studies indicated that effort expectancy directly affects uptake of new information system when a user has no prior experience with the system but that the effect was not significant among experienced users [28, 29, 30]. Prior experience with the system may have enabled this group of students to undertake the system easily. This might be why the effect of effort expectancy was not found in this study. This finding would suggest that future research should investigate the effect of effort expectancy on the usage of Information technology among both experienced and inexperienced users in the same study.

8. Conclusion

Information Technology (IT) cannot fully provide benefits to individual user and organization if the end users do not use the technology. However, the use of information technology is not guaranteed. To help IT stakeholders better understand the usage of information technology, the aim of this research is to construct the Technology Usage (TUM) Model.

The TUM model explains the use of information technology in two parts: the first is a sub-model of technology uptake, explaining usage in the first time period t_0 to t_1; the second is a sub-model of technology continuance, explaining usage in the second time period t_1 to t_2. A longitudinal field study was conducted over a period of two months with three points of measurement to: (a) assess the TUM model's explanatory power; and (b) investigate factors affecting the uptake and continuance of information technology. The results suggested that the TUM model had moderate explanatory power of technology uptake and continuance. User's expectations towards the information technology were a key factor affecting their usage in both time periods. Performance expectancy and effort expectancy affected the uptake. However, after users had used and had an experience with the technology, only performance expectancy affected their continued use.

The findings of this research have important implications for the various IT stakeholders in increasing usage of new information technology within organization: (a) technology designers and developers should provide functionalities in new technology that encourage users to do job more quickly and achieve better job performance – performance expectancy; (b) designers and developers should design technology to be easy to navigate and use, or organizations should provide structured training in the use of new technology – effort expectancy. By achieving these conditions, it may be expected that targeted users will have high initial expectations towards the technology and will tend to take up. During the usage period, an experienced user will tend to continue to use the technology if they perceived that the technology help them work better (performance expectancy at t_1).

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