The Sting of Adoption: The Technology Acceptance Model (TAM) with Actual Usage in a Hazardous Environment

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Abstract

The Technology Acceptance Model (TAM) has been used for decades to explain adoption of business technology in a traditional office environment. It was later expanded to consumer side software. However, prior work still has some limitations. 1. These studies generally rely on self-reported intent to use measures rather than actual usage and 2. Prior research seldom looks at adoption in hazardous usage environments. This study extends prior research by looking at actual usage of new software in a hazardous environment, that of a bee yard. Results show that user perceptions of ease of use and usefulness are predictive of a user's intent to use the software and that the user's intent translates into actual usage of the software. Additionally, evidence is presented suggesting the need for an extension of the model to better reflect hazardous physical tasks and environmental conditions.

Keywords: TAM, Technology Acceptance Model, Beekeeping, Apiary Management

1. INTRODUCTION

The Technology Acceptance Model (TAM) has been used for decades to help guide and explain the adoption of information systems by various groups. However, some groups have been slower to adopt information technologies than others.

In this study we look at a profession crucial to both agriculture and the environment that has been particularly slow to adopt these technologies, the world's beekeepers. Given the importance of pollination to agriculture, being necessary for roughly ¾ of the world's food crops, the pollinators that beekeepers manage are critically important to our food supply.

With annual honeybee losses now approaching 50% in much of the world due to pests, pathogens and environmental factors, there is much cause for concern about the future of these pollinators.
Information technologies can be used to help beekeepers be more successful. Using the lens of TAM, we examine how we can understand and perhaps encourage the adoption of these technologies by beekeepers.

To validate TAM in the beekeeping domain, we partnered with a leading apiary management software provider known as Hive Tracks. Through this partnership, we were able to collect the data required, including an online survey and actual usage data from their software database. This provides the advantage of seeing how responding user's intentions to use software translates to their actual usage.

Hive Tracks has a focus on research and citizen science (Hive Tracks, 2018) providing a unique opportunity to utilize a large volume of quality data. With over 19,000 users, Hive Tracks is growing in popularity with the beekeeping community. Beekeepers use this system for many beekeeping activities, such as managing and monitoring hives, recording inspections, inventory management, calendar scheduling, data recording, and community collaboration.

The primary objective of this study is to validate TAM as a means of examining beekeeping software and, if validated, to utilize TAM to understand what changes are necessary to facilitate wider adoption of such software.

2. BACKGROUND

TAM has an extensive body of research that both supports and criticizes the theory it embodies (Chuttur, 2009; King & He, 2006; Lee, Kozar, & Larsen, 2003; Legris, Ingham, & Collerette, 2003; Li, Qi, & Shu, 2008; Qingxiong & Liping, 2004; Schepers & Wetzels, 2007; Sharp, 2007; Turner, Kitchenham, Brereton, Charters, & Budgen, 2010). In this section, we provide a very brief background of the model and its use in the associated field of agriculture. Further information regarding the TAM constructs can be found in the model development section that follows.

TAM Origins

TAM is a derivation of the Theory of Reasoned Action (Fishbein & Ajzen, 1975), outfitted for the prediction of IT acceptance and use (Davis, 1986). A revised version of TAM, known as parsimonious TAM (Davis & Venkatesh, 1996), hypothesizes that IT use can be predicted by its perceived usefulness (PU) and perceived ease of use (PEOU), mediated by a subject's behavioral intention (BI). All factors in the TAM equation, except actual IT use, are therefore measured as one's perceptions regarding one's beliefs and intentions.

TAM as a Tool for Understanding Adoption

In practice, TAM has proven to be both powerful and parsimonious as a useful tool for understanding technology adoption through perceived characteristics (Cazier, Wilson, & Medlin, 2009). Lee, Kozar, and Larsen (2003), also reported support for the central relationships of TAM. Among the studies which assessed each specific relationship, 88% find PU influences BI, 71% find PEOU influences BI, 84% find PEOU influences PU, and 87% find BI influences IT use.

Lee et al. (2003) describe 25 additional factors that have been studied as contributors to TAM, ranging from measures of voluntariness of use to users' prior experiences with the technology. However, due to concerns regarding survey length and confounding due to a new domain, these additional factors will be reserved for study at a future time. We will be focusing on the core factors consisting of perceived usefulness, perceived ease of use, behavioral intentions, and actual use.

TAM in Agriculture

In a world where sustainability challenges arise, it becomes imperative for the IS community to educate others to build innovative IS solutions for a modern world (Watson, Boudreau, & Chen, 2010). TAM has proven to be a useful tool to understand technology adoption in agriculture. Adrian, Norwood, & Mask, (2005) used TAM to investigate the perception and attitudinal characteristics of farmers who planned to adopt technologies. Rezaei-Moghaddam & Salehi (2010) also explored agricultural worker's intentions toward precision agriculture technologies. By following TAM, they were able to determine that observability, trialability, and attitude to use positively affect intentions for someone to adopt precision agriculture technologies.

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3. RESEARCH MODEL

As shown in Figure 1, the research model follows the parsimonious TAM. The model is formed from the three core constructs found in the majority of TAM studies and a reflective construct of actual usage. Relationships among the constructs follow those commonly found in the literature and include tests for mediation.

Construct Definitions

The following constructs and associated definition are utilized in the model.

Perceived Ease of Use is "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989).

Perceived Usefulness is "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989).

Behavioral Intent is "a measure of the strength of one's intention to perform a specified behavior" (Davis, Bagozzi, & Warshaw, 1989).

Actual Usage is defined in this study as the number of actions executed by a user on the system of interest.

Construct Relationships

Relationships among the constructs are codified in the following hypotheses:

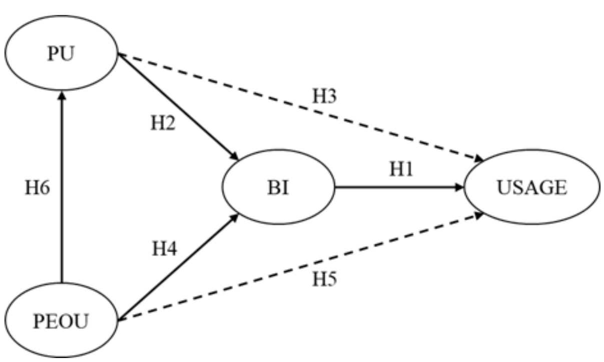

Figure 1. Research Model

H1: Increased intention to use apiary management software increases actual usage of apiary management software.

H2: Increased perceived usefulness of apiary management software increases the intention to use the apiary management software.

H3: An increase in perceived usefulness increases actual usage but is fully mediated by the user's behavioral intentions.

H4: Increased perceived ease of use of apiary management software increases the intention to use the apiary management software.

H5: An increase in perceived ease of use increases actual usage but is fully mediated by the user's behavioral intentions.

H6: Increased perceived ease of use of apiary management software increases the perceived usefulness of the apiary management software.

4. METHOD

The primary goal of the research is to validate that the TAM can be applied to the domain of beekeeping and, if so, to elicit improvements that can be made to the Hive Tracks software based on the model. To accomplish this task a survey is conducted of the Hive Tracks user base in conjunction with data extraction from the Hive Tracks database. Before undertaking the main study, a pilot study was conducted to find and resolve any issues with the survey instrument and extraction process.

Subjects

Subjects for the investigation are beekeepers registered as users of Hive Tracks software as of March 2018. Registered Hive Tracks users number over 19,000 individuals representing over 150 countries around the world (Hive Tracks, 2018). Users vary in both beekeeping experience level and number of hives managed. Additionally, experience level regarding use of the Hive Tracks software varies within the group.

Instrumentation

Two forms of instrumentation are utilized in the measurement model. A questionnaire is used to measure the antecedents of actual system use and collect demographic data. A measure of actual system usage is constructed from activity logs extracted from the Hive Tracks database.

Questionnaire

Items measuring the TAM constructs were chosen from previous research and adapted for the context of this investigation. For the constructs Perceived Ease of Use (PEOU), and Perceived Usefulness (PU) four items were selected to measure each construct. The construct of Behavioral Intent (BI) was measured with three items. Table 1 shows the adapted items, their origin, and the associated construct.

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Each item is measured using a seven-point Likert scale with endpoints labeled "Strongly Disagree" (Value = 1) to "Strongly Agree" (Value = 7). In addition, for each construct, a free-form question is included to allow participants to extrapolate on how to improve ratings on the construct. Additionally, participants are asked to provide basic demographic information including gender, year of birth, education level and number of hives managed.

The questionnaire is deployed utilizing the Qualtrics survey platform.

Actual Usage Measure

For the actual usage construct, four measures of user activity are extracted directly from the Hive Tracks database:

- The number of user logins.
- The number of user actions related to hive activities.
- The number of active hives associated with each user.
- The number of user actions related to non-hive activities such as reports and configuration.

The number of user actions related to hive activities is normalized by dividing it by the number of active hives found in the database to provide the average number of actions per registered hive. This measure in addition to the number of user logins and number of non-hive activities constitute the three operationalized measures of the actual use construct.

Data Collection

An invitation email was crafted containing a link for the online survey and sent to registered users by Hive Tracks management. The survey remained open for 30 days in which a user could elect to voluntarily respond. Following the close of the survey, actual usage data for responding users was extracted from the database for the following 30 days and for 11 months prior to the survey closing. Thus, allowing for examination of actual usage both before and after the survey.

Analysis

Confirmatory Factor Analysis and Structural Equation Modeling are accomplished utilizing SAS v9.4.

Measure	Questions
PEOU #1 (Premkumar & Bhattacherjee, 2008)	**Original:** Learning to use CBT is easy for me. **Adapted:** Learning to use Hive Tracks is easy for me.
PEOU #2 (Premkumar & Bhattacherjee, 2008)	**Original:** My interaction with CBT is clear and understandable. **Adapted:** My interaction with Hive Tracks is clear and understandable.
PEOU #3 (Lai & Li, 2005)	**Original:** It is easy to use Internet Banking to accomplish my banking tasks. **Adapted:** It is easy to use Hive Tracks to accomplish my beekeeping tasks.
PEOU #4 (Lai & Li, 2005)	**Original:** Overall, I believe Internet Banking is easy to use. **Adapted:** Overall, I believe Hive Tracks is easy to use.
PU #1 (Lai & Li, 2005)	**Original:** I can accomplish my banking tasks more quickly using Internet Banking. **Adapted:** I can accomplish my beekeeping tasks more quickly using Hive Tracks.
PU #2 (Lai & Li, 2005)	**Original:** Internet Banking enables me to make better decisions in utilizing banking services. **Adapted:** Hive Tracks enables me to make better decisions in beekeeping.
PU #3 (Lai & Li, 2005)	**Original:** Internet Banking enhances my efficiency in utilizing banking services. **Adapted:** Hive Tracks enhances my efficiency in beekeeping.
PU #4 (Lai & Li, 2005)	**Original:** Overall, I find Internet Banking useful. **Adapted:** Overall, I find Hive Tracks useful.
BI #1 (Lai & Li, 2005)	**Original:** I will use Internet banking on a regular basis in the future. **Adapted:** I will use Hive Tracks on a regular basis in the future.
BI #2 (Lai & Li, 2005)	**Original:** I will frequently use Internet banking in the future. **Adapted:** I will frequently use Hive Tracks in the future.
BI #3 (Lai & Li, 2005)	**Original:** I intend to continue using this software. **Adapted:** Overall, I will continue using Hive Tracks in the future.

Table 1. Original and adapted survey questions

5. RESULTS

Following the invitation to participate, 484 users responded by completing the survey. After preliminary examination of the responses, 49 cases were removed due to incomplete data or failure of bias/consistency check built into the instrument. Thus 435 usable responses are included in the analysis.

Item	Value	Percent
Gender	Female	26.46
	Male	71.43
	Prefer Not to Answer	2.1
Age (year)	< 31	3.04
	31-40	11.94
	41-50	18.50
	51-60	31.85
	61-70	22.95
	>71	4.68
	Missing	7.03
Education	Some Schooling	1.41
	High School Graduate, or the Equivalent	7.96
	Some college, no degree	17.56
	2-year degree	11.01
	Bachelor's Degree	28.10
	Graduate Degree	32.79
	Missing	1.17
Average Hives	Less Than 5	44.26
	5-10	29.51
	11-15	6.56
	16-20	4.22
	21-30	7.26
	31-40	2.34
	Over 40	5.85
Region	USA Midwest	19.44
	USA South	39.34
	USA West	14.99
	USA Northeast	12.65
	Other	13.59

Table 2. Participant Demographics

Participants
Although Hive Tracks has a good mix of users internationally, the majority of users are in the United States. Users are primarily hobbyist beekeepers with some sideline or part-time beekeepers. Respondents also have a variety of different experience levels in terms of beekeeping and using the software. Table 2 provides a demographic overview of the participants.

Measurement Model
To establish the unidimensionality of the scales a Confirmatory Factor Analysis utilizing the SAS 9.4 CALIS procedure was completed. To facilitate the analysis, a log transformation was applied to each of the actual use measurement items. No additional modifications were made to the measurement model.

Results indicated an acceptable measurement model (X2 = 224.75, df = 71, RMSEA = .07, CFI = .98). A Wald Test indicated all parameters are significant and thus none should be dropped. Table 2 shows the means, standard deviations, Cronbach's alpha, and intercorrelations for the outcome and antecedents variables. Additionally, the square root of the average variance extracted is included in bold on the diagonal to illustrate the discriminant validity of the scales.

Variable	Mean	SD	α	EOU	USF	BI	ACT
PEOU	5.25	1.33	.95	**.90**			
PU	5.01	1.39	.95	.79	**.91**		
BI	4.78	1.81	.98	.60	.69	**.97**	
USAGE	2.20	1.88	.96	.13	.11	.18	**.94**

Notes: Correlations are significant at the p<.05 level. Sqrt (Average Variance Extracted) indicated in bold.

Table 3. Scale Summarys and Correlations.

SEM Results
The estimated model indicated an acceptable fit with the data (X2 = 224.75, df = 71, RMSEA = .07, CFI = .98). Figure 2 shows the standardized effects for paths with p-values - dashed lines indicate insignificant paths.

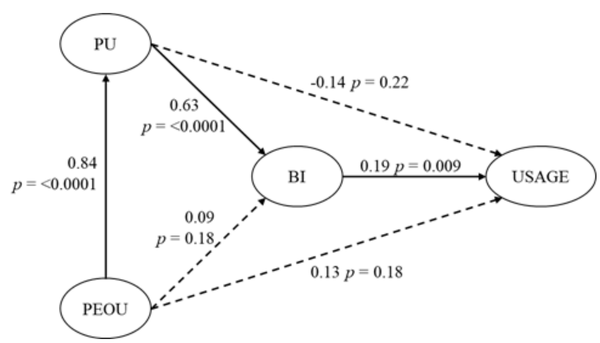

Figure 24. SEM Standardized Results

As indicated in Figure 2, support for hypothesis H1, H2, and H6 is demonstrated. An increase in PEOU increases PU (η = 0.84, $p < 0.0001$). An increase in PU increases BI (η = 0.63, $p < 0.0001$). Finally, an increase in BI increases USAGE (η = 0.19, $p = 0.009$).

No Support is found for the hypothesis H4 (PEOU => BI, $p = 0.18$). By association, no support is found for H5 as it relies, in part, on H4. A test for support of a direct effect of PEOU on USAGE is also unsupported ($p = 0.18$). Finally, further analysis demonstrates support for an indirect effect of PEOU on BI via PU ($\eta = 0.53$, $p < 0.0001$). Thus, an increase in PEOU increases BI and is fully mediated by PU.

Support for H3 is also demonstrated. With evidence for H2 and a direct effect of PU on USAGE not found ($p = 0.22$), further analysis demonstrates support for an indirect effect of PU on USAGE via BI ($\eta = 0.53$, $p < 0.0001$). Thus, an increase in PU increases USAGE and is fully mediated by BI.

From the estimated model it can be seen that perceived ease of use has a large effect on the perception of usefulness. Perceived usefulness, in turn, drives behavioral intent to use the software. The materialization of this intent can then be seen in actual usage as measured directly in the application.

Responses to the essay questions both confirm and supplement the model results. Suggestions to improve ease of use included: "allow me to edit fields like medication (not all of them on your list)"; "connect to QR reader on phone"; and "[add] voice commands." Thus, ease of use is a driving consideration for beekeepers. Likewise, suggestions to make the application more useful included feature requests such as "bulk import of supplies with a ccv would be nice" and "[add] ability to clone a yard."

Additional comments not directly related to the model are also noted. Many of these comments are related to pricing of the application. While germane to the question of how to improve user satisfaction, further research is needed to understand implications of cost on the model.

6. DISCUSSION

The results of this study are consistent with previous studies of TAM (King & He, 2006; Li et al., 2008; Schepers & Wetzels, 2007; Turner et al., 2010) and demonstrates support for the use of a parsimonious TAM in beekeeping. Cleary, how easy an application is to use and the useful features embodied in the application are a determinant of system usage.

However, the study also advances our understanding of what ease of use should mean. As one respondent noted: "My problem using the app is that I don't want to pull out my nice phone when I'm in the hives and my hands are covered with propolis." While another commented: "I need to be able to speak and have the notes automatically placed on the hive I'm talking to it about. I can't push buttons with my gloves on." This qualitative evidence suggests that explicitly accounting for the ease of integrating with physical tasks is needed in the model. Further research is needed to understand if this should be manifested as a facet of the ease of use construct or as an independent construct.

For providers of beekeeping software, this study clearly shows that while useful features are important, easy to use and useful features are even more important. Beekeeping involves several physical tasks, such as inspections, that are difficult to automate or reengineer. The physical nature of these tasks along with the environment in which they are performed must be considered in the design of software intended to support such tasks. With the recent advances in voice recognition and processing, the addition of such capabilities to beekeeping software would be a prudent design enhancement.

Limitations

The findings of this study should be interpreted with a degree of caution as only one beekeeping software application is examined. Additionally, the demographics of the participants may not be representative of the entire beekeeper population. The sample may be skewed as it is dominated by males, individuals of at least 51 years of age, and most of the participants hold at least a bachelor's degree. The actual distributions of these factors in the population is currently unavailable and such factors have proven valid in previous extensions of TAM.

The strong history of research surrounding TAM and its extensions is believed to mitigate such limitations as the core of the model has been supported by numerous studies in the past three decades. Additionally, the strength and significance of the relationships examined provide additional confidence in the findings.

Finally, since an online survey instrument is utilized, one must be vigilant of response bias. To mitigate this concern, establish scales and survey design found in existing TAM literature are employed. A pilot study was then conducted to ensure functionality of the instrument. Additionally, checks of the data for yea/nay-saying, acquiescence and extremity of answers were conducted.

7. CONCLUSIONS

This study demonstrates TAM as a viable lens for examining improvements is systems designed to support beekeepers and suggests an extension of the model for hazardous environments such as an apiary.

Beekeepers have been slow to adopt new technologies, especially information-based technologies, to help them better manage their colonies. Examining related industries, we can see several advantageous opportunities for impacting bee health including data collection, good data management, external data integration, and analysis of data. Maintaining healthy honeybee colonies requires intensive management by the beekeepers, so high-quality data collection will lead to effective understanding and optimization of the economic tradeoffs of Best Management Practices for the beekeepers.

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