AIS Contribution in Navigation Operation- Using AIS User Satisfaction Model

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ABSTRACT: AIS was introduced in 2002 and its phased implementation programme completed in 2004. Problems still exist in its reliable use for navigational operation. Our paper is part of a wider evaluation of AIS. This paper considers the users view of AIS and we have attempted to measure the extent of navigators' satisfaction with AIS in their navigation activities by using an AIS User Satisfaction Model.
This paper evaluates the validity of the AIS User Satisfaction Model using questionnaire data as a suitable structure for measuring the degree of navigators' satisfaction and usage of AIS, and probably applies for other similar technologies. This, in turn, could help to determine the measures that need to be adopted in order to improve quality and use of AIS as an effective navigation and anti-collision tool.

1 INTRODUCTION

Introduction of Automatic Identification System (AIS) in marine industry was aimed at promotion of efficiency and safety of marine navigation. Its mandatory phased implementation programme completed in December 2004, and consequently all SOLAS Convention vessels should have installed the equipment on the bridge by this date. Results of AIS data studies focused on the accuracy of the information transmitted by AIS, carried out at Liverpool John Moores University (Harati-Mokhtari et al, 2007), revealed that data provided by AIS are not reliable in many cases, especially the data entered into the equipment manually. Human failures were observed at different levels in AIS application for navigation, which are:

– Failures by frontline operator
– Installation Failures
– Design failures
– Training and management failures
– Regulatory failures

Therefore, the AIS could not wholly be trusted, and AIS usage and its data quality may even be deteriorated furthermore.

The reliable operation of AIS in early stages of introduction and correct implementation strategy are important concerns that could influence navigators' impressions, attitude, and behaviour toward their acceptance and future use of the system. The aim of this paper develops a suitable model for evaluation of AIS usage for navigation operation, particularly for anti-collision, by navigators on the ship's bridge. This study examines influence of some important factors in navigators' satisfaction with AIS technology that could affect its actual improved usage for the intended purposes in navigation.

2 TECHNOLOGY USAGE BEHAVIOUR AND IMPLEMENTATION ENVIRONMENT

Technology implementation may be based on voluntarily or mandatory adoption. Voluntarily adoption is a situation where adoption and use of technology is not obligatory and determined by the user's optional preference. The opposite is mandatory adoption is a situation where adoption and use of a system is directed from higher level than the user. In mandatory adoptions users are obliged to use the system to perform their job (Brown, et al, 2002). According to Adamson and Shine (2003), even in mandatory adoption and use of technology, some users may not comply with such mandate if they believe that the system is not satisfactorily supporting their work tasks, or they may use it as their only available choice but with a negative job satisfaction result.

3 AIS USER SATISFACTION MODEL (AISUSM)

Identifying appropriate functions and characteristics of new technology, such as AIS, will help in

delivering the accurate and useful system to its end users. Such identifications could be carried out by evaluation of the acceptability of the system by the user through understanding his responses and satisfaction level in system use. By identifying appropriate functions and characteristics demanded from AIS, required modifications could be made to the system and its implementation strategy.

According to Venkatesh (2000), a significant progress has been made recently in explaining and predicting users acceptance of technology at work, especially information technology. Most of commonly used theories and models of technology acceptance by end user have examined the acceptance of technology in voluntarily environment where adoption and use of technology are based on volitional choices, and only few of them have considered technology adoption and use in mandatory environment. However, End User Satisfaction Model (EUS) (Adamson and Shine, 2003) is considered to be suitable model for measuring system satisfaction in mandatory environment. It was argued (Venkatesh, 2003) that the role of social influence of subjective norm (according to Ajzen and Fishbein (1980), subjective norm is the end user's belief about how other people would view him/her if he performed the behaviour) is only important in initial stages of introduction of technology when user experience with technology is at low levels but it eroded over time and finally become insignificant with continued usage. Since the AIS has mandatory been used on all SOLAS Convention vessels from end of December 2004, the influence of subjective norm in this study is insignificant.

Therefore AIS User Satisfaction Model is adopted from EUS Model for assessment of navigators' satisfaction with AIS without consideration of subjective norm (figure 1).
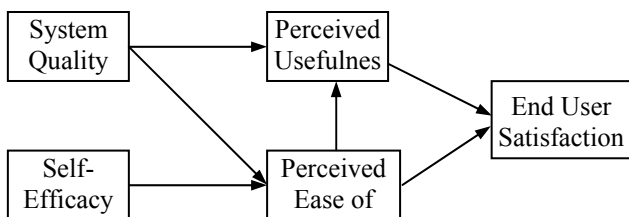

Fig. 1. AIS User Satisfaction Model (adapted from Adamson and Shine, 2003)

4 METHODOLOGY

A questionnaire that was already designed to assess the navigators' perception about different aspects of the AIS will be used to analyse validity of the AIS User Satisfaction Model for explaining and predicting navigators' acceptance of AIS at work. Apart fro demographic factors, there were 39 other items included in the questionnaire that are grouped to fit into the AISUS Model. The relevant groups are:

- System Quality (SQ)- The degree to which end user believes on ease of retrieving data, the system's response time, accuracy and reliability (Adamson and Shine, 2003).
- Self-Efficacy (S-E)- the level of individuals' beliefs on their ability to perform specific tasks successfully, with consideration of the degrees of efforts required in challenging situations (Adamson and Shine, 2003).
- Perceived Usefulness (PU)- the degree to which an individual believes that using a particular system will enhance his/her job performance and productivity (Davis, 1986).
- Perceived Ease of Use (PEOU)- the degree to which an individual believes that using a particular system will be free of effort (Davis, 1986).
- AIS User Satisfaction (AISUS)

The analysis will be carried out with the use of the computer software SPSS version 14. Cronbach's alpha coefficient (α), as one of the most commonly used indicators of the scale reliability (Pallant. 2004, and Field, 2005), will be used for analysing internal consistency of the measurement. Pallant (2004) and Field (2005) stated that Cronbach's alpha ranges in value from 0 to 1, and values of above 0.7 are acceptable values of alpha, but higher the score, the more reliable the generated scale is. The construct validity (relationship among variables) will be explored through statistical technique of multiple regression, which according to Tabachnick and Fidell (2000), Pallant (2004), and Field (2005) is used as a popular technique that can deal with variety of questions, especially in predicting a dependent variable (DV) from several continuous independent variables (IV), in many disciplines. The goal of regression in this research is to arrive at a set of regression coefficients (β values) for the IVs. Tabachnick and Fidell (2000) further pointed out *"regression analysis would only reveal the relationships among variables but do not indicate causality of the relationships"*. Therefore, since our data (one sample) are normally distributed multiple regression is considered to be the most suitable technique for our analysis.

4.1 Data manipulation

Scores for negatively worded items (high scores indicate low satisfaction) were reversed, and total scales scores were calculated for the model measurement constructs. The total scored named as TSQ, TSE, TPU, TPEOU, and TAISUS.

5 ANALYSIS

5.1 Data manipulation

Five of the items were found to have low reliability figures (Cronbach's alpha less than 0.7) and they were dropped from the final analysis. The remaining items were all reliable (with alpha value > 0.7). The total scale was reliable with alpha values of 0.8.4, further scales for TSQ, TSE, TPU, TPEOU, and TAISUS all were reliable with alpha values of 0.74, 0.71, 0.77, 0.74, and 0.70, respectively.

The distribution of the total scores for five variables examined by relevant histograms, and further crosschecked by calculating z-scores. The data were normally distributed.

5.2 Final analysis

Final data analysis is carried out for each of the five individual sub scales, and the results are given in following sub-sections.

5.2.1 Correlations

According to the value of Pearson correlation coefficient in correlation matrix, both of the TSQ and TSE scales correlate positively with TPU ($R = 0.504$, $p < 0.001$ and $R = 0.380$, $p < 0.001$, respectively). But TSQ has a larger positive correlation with TPU, than TSE. Thus it is likely that TSQ will best predict TPU. Apparently, there is not any correlation between TSQ and TSE (R= -0.049). One-tailed significance values show that both the positive correlations of TSQ with TPU and TSE with TPU are very significant as $p < 0.001$.

Pearson correlation coefficients also show that TSQ correlates substantially with TPEOU ($R = 0.360$, $p < 0.001$), but TSE has a smaller positive correlation with TPEOU ($R = 0.132$, $p < 0.001$) than TSQ. Although TSE had a lower positive correlation with TPEOU, it is still significant in predicting TPEOU. Bivariate Correlation between TSQ and TSE is -0.049. One-tailed significance values indicates that both the correlations between TSQ and TPEOU, and between TSE and TPEOU are positive and very significant, $p <0.001$.

Pearson correlation coefficient for both the scales of TPU and TPEOU are above 0.3, ($R = 0.543$, $p < 0.001$, and $R = 0.311$, $p < 0.001$, respectively) which show important correlations with TAISUS. But TPU has a larger positive correlation with TAISUS, than TPEOU. Bivariate correlation between TPU and TPEOU is 0.407 and bellow maximum limit of 0.9. One-tailed significance values indicate that positive correlations are very significant ($p < 0.001$) in both the cases.

5.2.2 Evaluation

Model summary for Total Perceived Usefulness of the AIS shows that 41.8% (R squared = 0.418) of the variance in TPU is explained by the model, which includes the TSQ (R squared = 0.254) and TSE (R square = .164). Adjusted R squared is 0.399 and the shrinkage is equal to $1.9\% = (0.418 - 0.399) \times 100$. Therefore, the percentage of the variance explained by the model for TPU is very close to that of the corrected estimate of the true population.

Result of the analysis of variance (ANOVA) shows that the improvements due to the regression models are much grater than inaccuracy within the models (the F-ratios are 22.099 and 22.939). This is unlikely to have happened by chance as both of the F-ratios are very significant with probabilities of < 0.001. Therefore the model is a significant fit of the data overall and it significantly improves our ability to predict the outcome variable because the F-ratio is significant (probability less than 0.05).

Model summary also indicates that 15.2% (R square = 0.152) of the variance in TPEOU is explained by the model, which includes the TSQ (R square = 0.129) and TSE (R square = 0.023). Adjusted R square is 0.125 and the shrinkage is equal to $2.7\% = (0.152 - 0.125) \times 100$, which shows that the percentage of the variance explained by the model is very close to that of the corrected estimate of the true population.

According to ANOVA both the F-ratio ($F = 9.667$, $p < 0.003$ and F = 5.729, $p < 0.005$) are significant and unlikely to have happened by chance. This indicates that the improvement due regression model is greater than inaccuracy within the model. Therefore, the ability to predict the outcome variable will be significantly improved by the model, and the model is a significant fit of the data overall due to the significant F-ratio (significance value is less than 0.05).

The result also shows that 30.4% (R square = 0.304) of the variance in TAISUS is explained by the model. This includes the TPU (R square = 0.294), and TPEOU (R square = 0.010). Adjusted R square is 0.292, which shows shrinkage of

$1.2\% = (.304 - .292) \times 100$. This means that the percentage of the variance explained by the model in not so much away from the corrected estimate of the true population. TPU causes R^2 to change from zero to 0.294, which this change in the amount of variance explained gives rise to a significant F-ratio of 46.751 with a probability of less than 0.001. Addition of TPEOU causes R^2 to increase by 0.010, and the change in the amount of variance that it can explain gives rise to an F-ratio of 1.5430, which is not significant with a probability less than 0.217.

According to ANOVA, both the F-ratio for model 1 ($F = 46.751$), and F-ratio for model 2 ($F = 24.261$) are very significant ($p < 0.001$ for both the cases), and therefore, it is unlikely to have happened by chance. These results show that both models 1 (with TPU as the independent variable) and model 2 (with addition of TPEOU as second independent variable) are significant fit of the data overall, and they significantly improves our ability to predict the outcome variable, because the F-ratios are significant (probability less than 0.05).

5.2.3 Model parameters

Summary of the regression model indicates that the TSQ, with standardised beta of 52.3%, makes a stronger unique contribution in explaining TPU, when the variance explained by the TSE is controlled for. The standardised beta value for TSE is showing a less contribution with 40.5%. Further, TSQ and TSE both with a significance value of 0.001 are making a unique, and statistically very significant, contribution to the prediction of the TPU scores. This also means no overlap between TSQ and TSE.

Confidence interval for TSQ is between 0.452 and 0.972, and for TSE is between 0.148 and 0.411, which both are relatively narrow, and do not cross Zero. This indicates that the parameters for these variables are significant and they have positive relationships.

Further, the zero-order correlations are 0.504 for TSQ and 0.380 for TSE. The part correlation coefficients are 0.523 for TSQ and 0.405 for TSE, indicating that TSQ uniquely explains 27% (0.523^2) and TSE uniquely explains 16% (0.405^2) of the variance in TPU scores.

In the case of TPEOU, TSQ with β value of 0.367 has 36.7% a unique contribution in explaining TPEOU, when the variance explained by the TSE is controlled for. The TSE with β value of 0.150 has less contribution with 15.0%. The results also indicate that TSQ with a significance value of 0.002 making a unique, and statistically very significant, contribution to the prediction of the TPEOU scores. However contribution of TSE with significance value of 0.198 is not significant that may be due to some degrees of overlap between TSQ and TSE.

Confidence interval for TSQ is between 0.219 and 0.955, which is relatively narrow and does not cross zero. Confidence interval for TSE is between -0.065 and 0.308, which is narrow but it does cross zero. This indicates that only the parameters for TSQ are significant, and it has a positive relationship, but the parameters for TSE are not significant and it has a negative relationship.

The zero-order correlation for TSQ is 0.360 and for TSE is 0.132. These values correspond to the same values of the Pearson correlation coefficients. TSQ (with part correlation coefficients of 0.367), and TSE (with part correlation coefficients of 0.150) each uniquely explain 13.5% (0.367^2), and 2.3% (0.150^2) of the variance in TPEOU scores, respectively, when the effects of the other predictors on the outcome are controlled for.

TPU with β value of 49.9% makes a stronger unique contribution in explaining TAISUS, when the variance explained by the TPEOU is controlled for. The standardised beta value for TPEOU is only showing a contribution of 10.8%. TPU with a significance value of 0.001 is making a unique and very significant contribution to predict TAISUS scores. But TPEOU with significance value of 0.217 does not make such a unique and statistically significant contribution to TAISUS scores prediction, which may be due to some overlap between TPU and TPEOU.

Confidence interval for TPU is between 0.449 and 0.921, which is relatively narrow and does not cross zero. The range of confidence interval for TPEOU is between -0.75 and 0.325, which despite being narrow, it crosses zero. These confidence intervals indicate that the parameters for TPU are significant, but the parameters for TPEOU are not significant and they do not have positive relationships.

The zero-order correlations (TPU = 0.543, and TPEOU = 0.311) again correspond to the Pearson correlation coefficients. The part correlation coefficients for TPU (0.456) and for TPEOU (0.098) indicate that TPU uniquely explains about 21% (0.456^2) and TPEOU could only uniquely explains less than 1% (0.098^2) of the variance in TAISUS scores, when the effect of the other predictor on the outcome are controlled.

5.2.4 Multicollinearity assessment

In the case of TPU, the lowest tolerance value is 0.998, which is not less than 0.10. The highest Variance Inflation Factor (VIF) value is 1.002, which is well below the critical value of 10. The tolerance and VIF values confirm that collinearity is not a problem for this model, and therefore, the

variability of TPU is properly explained by the TSQ and TSE.

The eigenvalues of the scales are between 2.95 and 0.006, which are fairly close, and condition index of the final dimension is 22.32, which is not very large compared to other dimensions. The variance proportions show that for TSQ highest percentage of its variance proportion (92% of the variance of the regression coefficient) is associated with eigenvalue number 3, and for TSE highest percentage of its variance proportion (89% of the variance of the regression coefficient) is associated with eigenvalue number 2. These data further indicate that multicollinearity is not a problem in this model.

In the case of TPEOU, the lowest tolerance value is 0.998, which is more than 0.10. The highest VIF value is 1.002, which is well below 10. These values of tolerance and VIF confirm that the problem of multicollinearity is not an issue for this model, and therefore, the variability of TPEOU is properly explained by the TSQ and TSE.

In addition, the collinearity diagnostics data shows that the eigenvalues of the scales are between 2.95 and 0.006, which are fairly close. Condition index of the final dimension is 22.32, which is not very large compared to other dimensions. The variance proportions show that for TSQ 92% of the variance of the regression coefficient is associated with eigenvalue number 3, and for TSE 89% of the variance of the regression coefficient is associated with eigenvalue number 2, which is a sign of no multicollinearity.

The lowest Tolerance value is 0.834 (more than 0.10), and the highest VIF value is 1.199 (well below 10). These show that multicollinearity is not a problem for this model in prediction TAISUS.

In addition, the eigenvalues of the scales are between 2.974 and 0.010, which are reasonably close. Condition index of the final dimension is 17.026, which in comparison to other dimensions is not very large. The variance proportions show that the highest percentage (80%) of TPU variance proportion is associated with eigenvalue number 3, and the highest percentage (100%) of TPEOU variance proportion is associated with eigenvalue number 2. These data indicate no multicollinearity.

5.2.5 Casewise diagnostics

Casewise diagnostics result for TPU shows that out of 116 cases only 3 cases (about 3%) are with standardised residuals outside the limits. Therefore, appears that there is not a big difference between outcome of the sample and the outcome of the model, and the model is reasonably accurate.

Casewise diagnostics result for TPEOU indicates that out of 116 cases only 2 cases (less than 2%) are with standardised residuals outside the limits of ± 2. Therefore, our sample appears to conform to the expectation of a reasonably accurate model.

Finally the result of casewise diagnostics for TAISUS indicates that out of 116 cases only 3 cases (less than 3%) are with standardised residuals outside the limits of (± 2). This means that about 97% of the cases are with standardised residuals within the limits, and therefore, our sample is reasonably accurate.

6 DISCUSSION AND CONCLUSION

6.1 Internal consistency

Preliminary data analysis showed that scores of the grouped questionnaire items, after dropping five items with low reliability from the analysis, were normally distributed. The remaining 34 items included in the questionnaire, for the final analysis according to AIS user satisfaction model, had a reliable total scale with an overall Cronbach's alpha of 0.804. Reliability figures for makeup items in model variables were 0.739 for system quality, 0.711 for system self-efficacy, 0.769 for perceived usefulness, 0.737 for perceived ease of use, and 0.704 for AIS user satisfaction, which are within acceptable limit.

6.1.1 Implications

Pearson correlation coefficients (R) are used to test relationship between the attitudinal forming variables of System Quality and Self-efficacy, and the sample's Perceived Usefulness and Ease of Use of AIS. The results are as follows:

SQ: PU (R = 0.504, $P < 0.001$, 1-tailed)
SE: PU (R = 0.380, $P < 0.001$, 1-tailed)
SQ: PEOU (R = 0.360, $P < 0.001$, 1-tailed)
SE: PEOU (R = 0.132, $P < 0.140$, 1-tailed)

Results show that both the System Quality and Self-efficacy have a statistically very significant and positive relationship with Perceived Usefulness. About Perceived Ease of Use, only System Quality has a significantly positive relationship with Perceived Ease of Use. But the positive relationship of Self-efficacy with Perceived Ease of Use is not statistically significant ($P > 0.05$). The strongest relationship is between SQ and PU with R = 0.504, and the weakest relationship is between SE and PEOU with R = 0.132. The relationships show that the System Quality is strongly related with AIS Perceived Usefulness and its Perceived Ease of Use. The results of Pearson correlation coefficients (R) for perceptual variables of Perceived Usefulness,

Perceived Ease of Use, and AIS User Satisfaction are as follows:

PEOU: PU (R = 0.407, $P < 0.001$, 1-tailed)
PU: AISUS (R = 0.543, $P < 0.001$, 1-tailed)
PEOU: AISUS (R = 0.311, $P < 0.001$, 1-tailed)

The above correlation coefficients show positive and statistically very significant relationships between the PU, PEOU and AISUS. It also can be seen that there is a relatively strong bivariate relationship between PU and PEOU. The relationship between PU and AISUS is stronger than the relationship between PEOU and AISUS. This means that if the AIS users perceive that the implemented AIS technology is useful and easy to use then they are likely to be satisfied with the system, and therefore, they more frequently use the AIS for navigational activities.

Path analysis of the model is drawn in figure 2 to show the importance of influence of different variables in predicting dependent variable in AIS User Satisfaction Model. The diagram includes standardised beta coefficients (β), which shows the strength of influence of each predictor variable on the criterion variable according to the measurement constructs of the model.
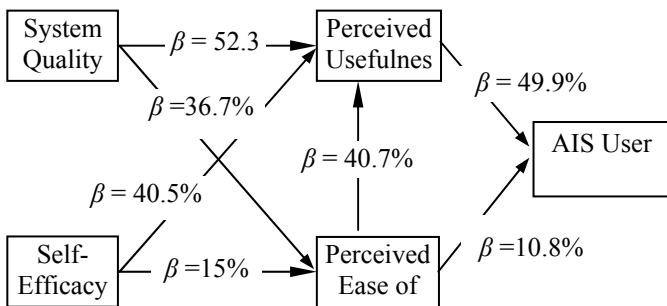

Fig. 2. Path Analysis of the AIS User Satisfaction Model

Path analysis of the AIS User Satisfaction Model, figure 2, demonstrates that:

Unique influence of each one of the independent variables on predicting Perceived Usefulness, when variance explained by other variable is controlled for, is 52.3% for AIS System Quality and 40.5% for navigators' Self-efficacy. These unique importances of variables in predicting AIS Perceived Usefulness are both very significant with a probability of 0.001 and without any overlap between them.

Unique influence of each one of the independent variables on predicting Perceived Ease of Use, when variance explained by other variable is controlled for, was 36.7% for AIS System Quality and 15.0% for navigators' Self-efficacy. The unique importance of the System Quality in predicting AIS Perceived Ease of Use is very significant with a probability of

0.002, but this unique importance is not significant for navigators' Self-efficacy ($P = 0.195$, which is more than 0.05). There is possibility of overlap between System Quality and Self-efficacy.

Unique influence of each one of the independent variables on predicting Perceived AIS User Satisfaction, when variance explained by other variable is controlled for, is 49.9% for AIS Perceived Usefulness and 10.8% for AIS Perceived Ease of Use. The unique importance of the Perceived Usefulness in predicting AIS User Satisfaction is very significant with a probability of 0.001, but the unique importance of Perceived Ease of Use is not significant ($P = 0.217$, which is more than 0.05). Some degrees of overlap might exist between Perceived Usefulness and Perceived Ease of Use.

Confidence intervals show that the parameters for AIS System Quality and navigators' Self-efficacy in predicting Perceived Usefulness are significant with positive relationships. According to part correlation values, AIS System Quality uniquely explains 27%, and navigators' Self-efficacy 16% of the variance in Perceived Usefulness of the AIS for navigation. A shrinkage of 1.9% shows that the difference in percentage of the variance in AIS Perceived Usefulness explained by the model and the corrected estimate of the true population is very low. The result shows that model was a good fit and it significantly improves prediction of Perceived Usefulness.

Parameters for AIS System Quality in predicting Perceived Ease of Use is very significant with positive relationships, but parameters for self-efficacy in predicting Perceived Ease of Use are not significant and with negative relationships. AIS System Quality uniquely explains 13.5%, and navigators' Self-efficacy 2.3% of the variance in Perceived Ease of Use of the AIS for navigation. The difference in percentage of the variance in AIS Perceived Ease of Use explained by the model and the corrected estimate of the true population is 2.7%. The result also shows that model is a significant fit of the data overall for Perceived Ease of Use.

Parameters for AIS Perceived Usefulness in predicting AIS User Satisfaction are significant with positive relationships. But parameters for Perceived ease of use in predicting AIS User Satisfaction are not significant and with negative relationships. AIS Perceived Usefulness uniquely explains 21%, and AIS Perceived Ease of Use uniquely explains less than 1% of the variance in Perceived AIS User Satisfaction for marine navigation. The difference in percentage of the variance in Perceived AIS User Satisfaction explained by the model and the corrected estimate of the true population is 1.2%. The result also shows that the model is a significant

fit of the data overall for Perceived Ease of Use. The model shows significant goodness-of-fit in predicting the Perceived AIS User Satisfaction.

It is also observed that the problem of multicollinearity due to perfect or strong correlation between independent variables does not exist in the model. Therefore, the regression coefficients are uniquely estimated in the model. Casewise diagnostics shows that the regression models are reasonably accurate as the maximum percentage of the cases with standardised residuals outside the limits is 3%. Therefore, there is not a big difference between outcome of the sample and outcome of the model.

The path analysis (figure 2) shows that the there is not a significant unique influence of the navigators' Self-efficacy on predicting Perceived Ease of Use. It is also revealed that the unique influence of Perceived Ease of Use is not significant on the AIS User Satisfaction. But a unique influence from navigators' Self-efficacy on the Perceived Usefulness was observed in the model, which is not included in the original model.

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