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# A two-staged SEM-neural network approach for understanding and predicting the determinants of m-commerce adoption

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ABSTRACT

The advancement in wireless and mobile technologies has presented tremendous business opportunity for mobile-commerce (m-commerce). This research aims to examine the factors that influence consumers' m-commerce adoption intention. Variables such as perceived usefulness, perceived ease of use, perceived enjoyment, trust, cost, network influence, and variety of services were used to examine the adoption intentions of consumers. Data was collected from 376 m-commerce users. A multi-analytic approach was proposed whereby the research model was tested using structural equation modeling (SEM), and the results from SEM were used as inputs for a neural network model to predict m-commerce adoption. The result showed that perceived usefulness, perceived enjoyment, trust, cost, network influence, and trust have significant influence on consumers' m-commerce adoption intentions. However, the neural network model developed in this research showed that the best predictors of m-commerce adoption are network influence, trust, perceived usefulness, variety of service, and perceived enjoyment. This research proposed an innovative new approach to understand m-commerce adoption, and the result for this study will be useful for telecommunication and m-commerce companies in formulating strategies to attract more consumers.



## 1. Introduction

Mobile commerce (m-commerce) refers to "any transaction, involving the transfer of ownership or rights to use goods and services, which is initiated and/or completed by using mobiles access to computer-mediated networks with the help of mobile devices" (Tiwari & Buse, 2007). m-commerce's impacts in businesses have been profound, and have changed business models in some industries (e.g. retail and entertainment). With the rapid growth of the mobile telephone population, combined with the development of wireless technologies, m-commerce is increasingly becoming an important part of businesses' strategies. According to researchers, m-commerce is now seen as the business model that has the potentials to have a greater impact on the business communities and industries than what e-commerce did in the late 1990s and early 2000s Chong, Chan, and Ooi (2011). Unlike e-commerce, m-commerce allows users to overcome the location barriers of accessing to the internet. Users are therefore able to use m-commerce anywhere, anytime. Today, the number of mobile phone subscribers is overtaking the number of Internet users in some countries, and realizing the potentials of m-commerce, many telecommunication companies have invested significantly in the development of m-commerce (Xie, Zhang, & Zeng, 2009).

Although the benefits offered by m-commerce have been discussed by various researchers such as Wei, Marthandan, Chong, Ooi, and Arumugam (2009) and Chong et al., (2011), consumers' actual m-commerce usage activities have remained low (Drossos & Giaglis, 2006). The current m-commerce applications offer users the opportunities for broadband internet access without geographic locations constraints, personalized services, and location based services (Chong, Chang, Ooi, & Lin, 2011). Despite these benefits, many m-commerce users are still using their mobile devices for only entertainment activities such as listening to music and content browsing. These activities although offer entertainments to the users, it does not make use of the other services that are offered by m-commerce, and thus hindering the growth of m-commerce. In order for m-commerce providers to survive and growth, it is important that users are able to use different types of applications, and this will create more incentives for other developers to continue to develop applications and contents for m-commerce.

A review of the recent literature on m-commerce also showed that the majority of the existing researches have mainly focused on the technological aspects of m-commerce (Ahluwalia & Varshney, 2007) and researches on the applications and strategies of m-commerce remain sparse. Among the studies that have examined m-commerce consumer adoption decisions, they have often developed their research model based on the technology

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acceptance model (TAM), and applied explanatory statistical analyses to examine the relationships between the adoption factors and behavioral intentions to adopt m-commerce (Chong, Chan, et al., 2011; Shmueli & Koppius, 2010; Wei et al., 2009). Prominent information systems (IS) researchers such as Venkatesh, Davis, and Morris (2007) and Barki (2007) have all claimed that TAM has its limitations. According to Barki (2007) it is almost a known fact to current IS researchers that both the perceived usefulness and perceived ease of use of an information systems will have a direct relationship with its behavioral intention to adopt. Given that the original TAM examines only the perceived ease of use and perceived usefulness, researchers and practitioners may find that studies based on the model is not sufficient to provide enough guidance to m-commerce providers in terms of the type of users who adopt/non-adopt m-commerce, and whether there are additional, specific issues which are relevant to m-commerce such the roles of network influence and securities. As such, there is a need to extend TAM when studying the adoption of m-commerce. Another limitation with existing studies is the explanatory statistical approaches employed. According to Shmueli and Koppius (2010), in order to advance current IS researches, there is a need to integrate predictive analytic methods in IS research to generate data predictions as well as methods for assessing predictive power. By employing predictive analytical techniques, researchers will not only create practically useful models, they can also help alongside explanatory modeling in theory building and theory testing.

This research therefore attempts to bridge the gap in the existing literature by firstly extending the TAM to understand users' intention to adopt m-commerce. Secondly, a two staged analytic methods was implemented. Structural equation modelling's (SEM) was employed in order to examine the factors that influence the adoption of m-commerce, while neural network was employed to predict the adoption of m-commerce. This research thus adopted the sequential multi-method research design recommended by Scott and Walczak (2009), whereby such approach is deemed to be able to provide a richer understanding of the topic studied. SEM is employed to verify the causal relationships validity by examining the goodness of fit of the model. The supported relationships in SEM and the significant variables from SEM analysis were then used as the inputs to the neural network structure to predict m-commerce adoption. The main advantage of combining these two approaches is that a new method for examining m-commerce adoption whereby the advantage of one technique will be used to offset the disadvantages of the other technique (Scott & Walczak, 2009).

## 2. Literature review and hypotheses development

### 2.1. m-commerce overview

Given that m-commerce is still growing and many new applications are constantly being developed, there are various definitions of m-commerce. Some researchers in the past have claimed that m-commerce is as an extension of e-commerce (Ngai & Gunasekaran, 2007; Varshney & Vetter, 2002; Wei et al., 2009). They stated the m-commerce is similar to e-commerce, except the transactions in m-commerce is conducted wirelessly using a mobile device. On the other hand, Feng, Hoegler, and Stucky (2006) argued that m-commerce is much more than merely being an extension of e-commerce. They believed that m-commerce has different interactions with users, usage patterns, and value chain, thus offering business models that are not available to e-commerce (e.g. location based marketing). Tiwari and Buse (2007) provided a clear distinction between m-commerce and e-commerce by viewing m-commerce as m-business. This allowed them to expand the scope of m-commerce to be beyond monetary transactions. They believed that by emphasizing on "transaction of monetary value. Researchers have ignored the commercial nature of marketing measures and after-sales services in m-commerce (Tiwari & Buse, 2007; Wei et al., 2009). Siau, Lim, and Shen (2001) similarly differentiated both e-commerce and m-commerce. They believed that m-commerce is different with e-commerce conducted over wired internet based on the unique characteristics of mobile devices. m-commerce has characteristics such as ubiquity, personalization, flexibility, and dissemination. Ubiquity means m-commerce providers are able to reach their customers anywhere, anytime (Siau et al., 2001). Users of m-commerce on the other hand, can obtain information whenever, and wherever they want. Personalization allows m-commerce applications to be personalized in order to represent information or provide services which are appropriate to specific group of users. Unlike e-commerce on computers, mobile devices such as mobile phones are usually owned by a single user. With smart phones, individual users are using their phones for various activities such as social networking, scheduling events, emailing, searching for maps and directions. Information which are unique to the individuals are useful for m-commerce providers to provide personalized services. m-commerce's flexibility allows users to conduct internet based activities such as transactions and surfing while they are travelling. Lastly, m-commerce allows the dissemination of information by providing simultaneous delivery of data to mobile users who are located in a specific geographical region (Siau et al., 2001).

Based on the above discussions, this research differentiates m-commerce and e-commerce, and adopts the definition from Tiwari and Buse (2007) which states that m-commerce is "any transaction, involving the transfer of ownership or rights to use goods and services, which is initiated and/or completed by using mobiles access to computer-mediated networks with the help of mobile devices".

### 2.2. Technology acceptance model

Existing information system technology adoption literatures have mostly built their studies on models such as TAM and diffusion of innovation (DOI) model. TAM states that an information system adoption is determined by its perceived ease of use and perceived usefulness (Davis, 1989). Perceived usefulness is the degree which a user believes that the information systems will enhanced his or her job performances. Perceived ease of use is the degree to which a person believes that using the information system requires little effort. Perceived usefulness of an information system is in turn influenced by its perceived ease of use. TAM is commonly applied to information systems such as Mobile Internet, 3G, online banking, e-commerce, and m-commerce (Chong, Darmawan, Ooi, & Lin, 2010; Gerpott, 2011; Wei et al., 2009).

Although TAM is commonly used to examine users' decisions to adopt information systems, m-commerce is different from many past information systems studied (Chong et al., 2010). m-commerce, for example, can be used for businesses purposes such as mobile banking, but at the same time it also offers entertainment to users such as mobile gaming and listening to music on their mobile phones. Therefore users' enjoyment when interacting with m-commerce may determine their intentions to adopt m-commerce. As m-commerce involves communications through wireless medium, issues related to security and privacy might arise for consumers. Furthermore, most mobile devices are very personal to the users, and unlike computers which could be shared by different friends or family, mobile devices such as a smart phone is usually owned by one individual. Thus the mobile device will have information on the user's location via GPS, appointments from

emails and calendars, friends on their social networking applications on their phones, resulting in higher privacy and security risks. The question remains whether users who know the risks are still willing to use m-commerce due to the advantages offered by it. When conducting m-commerce transactions, connections such as 3G might invoke cost to the users as well. Therefore the role of cost in influencing user's m-commerce adoption needs further investigations. Similar to the Internet, m-commerce is also influenced by network externalities, and users might be more willing to adopt it if their peers are using it. Therefore network influence might play an important role in m-commerce adoption. Unlike e-commerce which is quite mature in certain countries, m-commerce is still relatively new in countries such as China, for example. Therefore the variety of services offered by m-commerce might not be as extensive when compared to services offered by e-commerce applications. Based on these different characteristics of m-commerce, this research aims to extend the TAM, and include additional variables such as perceived enjoyment, trust, cost, network influence, and variety of services.

### 2.3. Neural network

Neural network is a "massively parallel distributed processor made up of simple processing units, which have a natural propensity for storing experimental knowledge and making it available for use" (Haykin, 2007, p. 2). A neural network resembles the brain of human, and it can acquire new knowledge from its environment through the learning process. The knowledge acquired will then be stored by the synaptic weights (Haykin, 2007). Using sample data, the learning algorithm will then modify the synaptic weights of the neural network in an orderly manner in order to attain the desired design objective (Haykin, 2007).

There are several advantages of the neural network when compared to the traditional statistical methods. A neural network can be linear or non-linear, and this allows us to examine non-compensatory decision processes. The input and output mapping can also be achieved without assuming any particular distribution for the input or output (Garson, 1998). Neural network's adaptivity also means that it can respond to structural changes in the data generation process, and can be easily re-trained to deal with environmental changes (Chiang, Zhang, & Zhou, 2006; Garson, 1998). Neural network have shown to outperformed traditional compensatory models such as logistic, multiple, and discriminant regression analyses (Chiang et al., 2006; Garson, 1998). Although studies such as economics (Kaastra & Boyd, 1996), consumer choice (Chiang et al., 2006; Hu, Shanker, & Hung, 1999), and customer loyalty (Hsu, Shih, Huang, Lin, & Lin, 2009) have applied neural network, its applications in information systems research remain sparse (Shmueli & Koppius, 2010). This study will therefore first use structural equation modelling (SEM) to identify the variables that have significant relationships with m-commerce adoption, followed by employing the non-compensatory neural network model to predict m-commerce adoption based on the significant adoption factors.

## 3. Hypotheses development and model development

### 3.1. Perceived ease of use

Perceived ease of use is defined as the degree to which the user believes that using m-commerce requires little effort (Jeyaraj, Rottman, & Lacity, 2006; Lederer, Maupin, Sena, & Zhuang, 2000). Although users nowadays may be familiar with using mobile devices such as mobile phones, m-commerce applications may be new to many consumers. This is especially when there are many new m-commerce applications and features that are being introduced to the users at a very rapid pace. Features such as conducting financial transactions on a mobile device might be a difficult task for an inexperience and new user. One challenge faced by m-commerce application developers is the trade-offs between the ease of use and functionality of m-commerce applications, and an application's ease of use maybe sometimes be done at the expense of m-commerce's features and functions. Besides considering the application's ease of use, physical features of mobile devices such as their small display screen, difficulty in keying data can also hinder m-commerce adoption. Perceived ease of use has been studied in various information systems related to m-commerce such as e-service (Featherman, Miyazaki, & Sprott, 2010), multimedia messaging service (MMS) (Hsu et al., 2009), wireless technology (Wu, Cheng, Yen, & Huang, 2011), Mobile Internet (Kim, Chan, & Gupta, 2007), and instant messaging (To, Liao, Chiang, Shih, & Chang, 2008). The following hypothesis is therefore proposed:

**H1.** Perceived ease of use has a positive and significant relationship with m-commerce adoption.

### 3.2. Perceived usefulness

Kim et al. (2007) defined perceived usefulness as "the total value a user perceives from using a new technology" (Kim et al., 2007). Perceived usefulness emphasized on task accomplishment, and it reflects the desire of a user's willingness to engage with the information system as a result of external rewards" (Kim et al., 2007; Venkatesh, Morris, Davis, & Davis, 2003). Jeyaraj et al. (2006) in their meta-analysis study on information systems adoption decisions found that perceived usefulness is one of the most frequently studied as well as significant adoption factor.

Although m-commerce offers flexibility when compared to e-commerce, users may also use internet in their personal computers to conduct activities such as sending email, reading news, or watching videos. The main advantage offered by m-commerce as argued by researchers such as Chong, Chan, et al. (2011) is its ability to offer these services without the constraints of wired connections. However, users will only appreciate m-commerce if they consider m-commerce's offerings being more useful than its alternative such as e-commerce. Past literatures by Wei et al. (2009) and Chong, Chong, Ooi, and Lin (2011), and Leong, Ooi, Chong, and Lin, 2011 have found that perceived usefulness plays an important role in influencing a user's decision to adopt mobile internet activities and m-commerce. This research therefore hypothesizes that:

**H2.** Perceived usefulness has a positive and significant relationship with m-commerce adoption.

### 3.3. Perceived enjoyment

Perceived enjoyment is found to have play an important role in determining the acceptance of information systems (Thong, Hong, & Tam, 2006). m-commerce in particular, does not only provide applications for business use, but at the same time it offers applications for games, video sharing and social networking. Therefore users who experienced enjoyment from using these applications are more likely to adopt them (Kim et al., 2007). Related studies include those by Ha, Yoon, and Choi (2007) and Teo (2001) who found that perceive enjoyment has a positive influence on the adoption of mobile games and the internet. Venkatesh, Thong, and Xu, 2012 in their recent study extended the unified theory of acceptance and use of technology (UTAUT), and included hedonic motivations in their UTAUT2 model which measure the fun, enjoyment, and entertainments of using mobile internet. With the support of existing literatures, it is hypothesize that:

**H3.** Perceived enjoyment has a positive and significant relationship with m-commerce adoption.

### 3.4. Trust

Trust in this study focused on the trust on m-commerce application providers, and whether consumers trust the reputation, security, and privacy of the providers to conduct m-commerce activities. m-commerce is much newer when compared to e-commerce, and users therefore have less experience in engaging with m-commerce when compared to e-commerce. Furthermore, personal information is being stored on users' mobile devices, and the security and privacy risks in m-commerce can therefore be quite high. Coupled with the lack of clear regulations, face-to face interactions, and potential information that can be accessed by the vendors, users may not to be to trust m-commerce sufficiently to subscribe to it (Chong et al., 2010; Wei et al., 2009). The risks are much higher when monetary transactions such as mobile purchasing or mobile banking are involving. Extending TAM with trust has been conducted by past researcher such as Gefen, Karahanna, and Straub (2003) and Lee and Wu (2011). Gefen et al. (2003)'s study found that trust plays an important role in influencing users' online purchasing intensions. In study conducted by Luarn and Lin (2005), they found that issues related to security and privacy has more significant influence than the original TAM variables of perceived usefulness and perceived ease of use. The following hypothesis is therefore proposed:

**H4.** Trust has a positive and significant relationship with m-commerce adoption.

### 3.5. Cost

Costs involved in m-commerce include the subscription fees, cost of device, and cost to download certain applications. Wei et al. (2009) in their study claimed that cost can be a hindrance to the successful development of m-commerce. Studies from Ong, Poong, and Ng (2008), Xin (2004), and Agarwal, Wang, Xu, and Poo (2007) have all shown that cost can have negative relationships with consumers' intentions to adopt 3G, which is essential for m-commerce. Xin (2004), for example, found that one of the reasons why short messaging service (SMS) is widely used by people is due to its low costs in enabling users to communicate. However, one may also argue that as the price of mobile devices and 3G subscriptions become more affordable to users, it may not play a part in affecting users' m-commerce adoption decisions. The key concern in this study is not the direct price or cost of m-commerce, but whether user views that m-commerce is worth its values. Many mobile device users are young consumers such as students, and they may be more price sensitive compared to other consumers. Therefore cost may play a vital role in the adoption of m-commerce especially when m-commerce users consist of many young users. Therefore this research hypothesizes that:

**H5.** Cost has a negative and significant relationship with m-commerce adoption.

### 3.6. Network influence

Network perspective is said to be an appropriate theory for studying the use of communication systems as it helps to facilitate interactions among users (Rice, Grant, Schmitz, & Torobin, 1990). In m-commerce, network influence is important due to several reasons. In many applications, users are only using the m-commerce application if there are more users connecting or using the application (e.g. mobile gaming and social networking applications). Wei Xin, a mobile phone application developed in late 2011, has already seen millions of Chinese downloaded the application. Using Wei Xin, users can send and receive text messages, instant voice messages, photos, group messages, and share their locations. These messages can be sent to other users within 1000 m radius of their GPS phones. Application such as Wei Xin shows the important of network influence affecting the success of an m-commerce application. Tscherning and Mathiassen (2010) in their study on iPhone adoption supported the importance of network influence on a user's adoption decision. This study therefore hypothesizes that:

**H6.** Network influence has a positive and significant relationship with m-commerce adoption.

### 3.7. Variety of services

Currently although m-commerce have many applications, its variety of services might not be comparable to e-commerce websites (Chong, Chan, et al., 2011). In particular, although users can download entertainment applications such as games and social networking tools, higher value added services such as mobile purchasing, mobile advertisements, mobile learning, and mobile banking activities remain limited (Wei et al., 2009). m-commerce application providers faced an important challenge. They need to ensure that there are enough applications to attract more users, and at the same time, software developers are only willing to write applications on a mobile platform provided that there are sufficient users. Therefore m-commerce providers need to understand would increasing the variety of services be sufficient to attract and retain m-commerce users, or will other factors such as cost and trust play a more prominent role in influencing their adoption decisions. This research therefore hypothesizes that:

**H7.** Variety of services has a positive and significant relationship with m-commerce adoption.

### 3.8. Research model

Based on the discussions above, a research model for this study is developed as shown in Fig. 1. The model shows that the adoption factors of perceived ease of use, perceived usefulness, perceived enjoyment, trust, cost, network influence, and variety of services will have a significant relationship with the consumer intention to adopt m-commerce.

## 4. Methodology

### 4.1. Sample and procedure

A survey questionnaire was used to examine the hypotheses in this study. Fifteen m-commerce users were invited to pre-test the survey. Data was collected from m-commerce users from two universities located at Zhejiang Province, China. This research used a convenience sample approach. The subjects include both undergraduate and graduate students enrolled in the universities' courses. All respondents had prior experience with m-commerce. A total of 376 surveys were collected from the m-commerce users.

### 4.2. Variable measurement

The variables used in this study are adopted from previous literature. Twenty-seven items were used to measure the seven

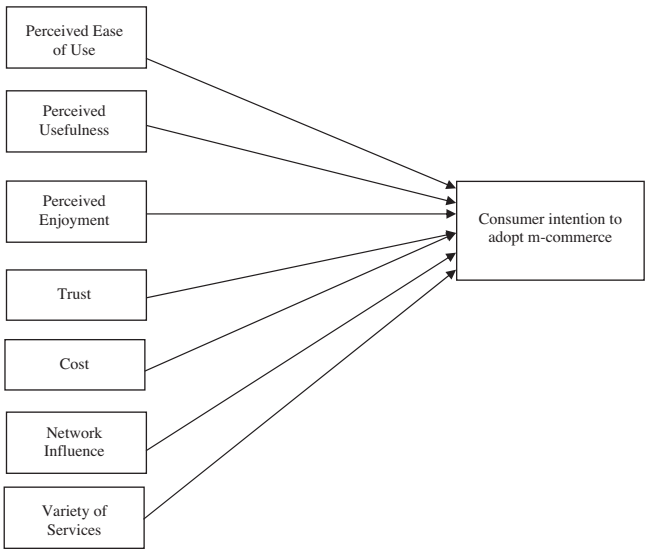


**Fig. 1.** Research model.

independent variables in this study, and three questions were used to measure the dependent variables. All items were measured on a seven point Likert Scale ranging from 1 (strong disagree) to 7 (strongly agree).

### 4.3. SEM-neural network approach

This research employs a multi-analytical approach by combining SEM and neural network. SEM is applied to verify the antecedents as predictors of m-commerce adoption. Although SEM is commonly used to verify hypothesized relationships, it has rarely been combined with other artificial intelligence algorithms (Hsu et al., 2009; Wong, Law, & Yau, 2011). As SEM is only examining liner model, it may sometimes oversimplify the complexities involved when users are making technology adoption decisions. In order to address this issue, neural network approach was incorporated in order to identify the non-linear relationships in the research model. By employing neural network, this research is able to learn complex linear and non-linear associations between the adoption factors and m-commerce adoption decisions. Another advantage provided by neural network is that it able to perform more accurate predictions when compared to traditional regression techniques (Morris, Greer, Hughes, & Clark, 2004). However, neural network also has its limitation. One concern with neural network is its "blackbox" approach, thus making the technique unsuitable for hypotheses testing and examining causal relationships. When examining a model, it is often difficult for researchers to understand how the neural nets arrive at their results (Garson, 1998). In order to take a balance approach and make use of the advantages offered by both SEM and neural network, this research will first use SEM to examine the overall research model and hypotheses. Based on the SEM results, significant variables will be used as input to the neural network. Such technique will overcome the overfitting of the model which is a key limitation by neural network. This is one of the few m-commerce adoption studies which integrate SEM with the neural network. Past information systems adoption studies have often employed either SEM (e.g. Leong et al., 2011) or neural network (e.g. Morris et al., 2004) without considering integrating these two methods.

### 4.4. Assessment of measurement model

A two-step analysis was performed in order to first assess the measurement model, and then to examine the hypotheses by fitting the structural model. This research examines the construct reliability, convergent validity and discriminant validity of the constructs. The results are shown in Table 1.

The CR of all constructs were more than 0.70, therefore constructs reliability are confirmed (Hair, Black, Babin, & Anderson, 2010). Convergent validity was confirmed as the CR values are greater than AVE; and the AVE values are greater than 0.50 (Hair et al., 2010). Lastly, the discriminant validity of constructs are examined. As the MSV values are less than AVE, while the ASV values are less than the AVE, the constructs validity are confirmed. The goodness-of-fit of the overall confirmatory factor analysis (CFA) model was also examined. The results showed that the degrees of freedom ($X^2$/df) is 1.87, GFI = 0.90, CFI = 0.99, and RMSEA = 0.048, thus indicating an adequate model fit.

### 4.5. Structural model results

Table 2 shows results of the hypothesis testing. Based on the results, all hypotheses except H1 are accepted.

Trust is the most important variable in influencing consumers' decision to adopt m-commerce, followed by network influence, variety of services, cost, perceived enjoyment, and perceived usefulness.

## 5. Neural network analysis for m-commerce adoption

This research used the Tiberious 7.0.3 to build the neural network model. The significant independent variables from the SEM

**Table 1**
Reliability and validity.

| | CR | AVE | MSV | ASV | Variety of service | Perceived usefulness | Perceived ease of use | Perceived enjoyment | Trust | Cost | Network influence | m-commerce adoption |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variety of service | 0.979 | 0.922 | 0.781 | 0.632 | 0.960 | | | | | | | |
| Perceived usefulness | 0.980 | 0.941 | 0.629 | 0.525 | 0.721 | 0.970 | | | | | | |
| Perceived ease of use | 0.983 | 0.951 | 0.681 | 0.573 | 0.741 | 0.696 | 0.975 | | | | | |
| Perceived enjoyment | 0.990 | 0.962 | 0.667 | 0.555 | 0.767 | 0.637 | 0.674 | 0.981 | | | | |
| Trust | 0.981 | 0.896 | 0.856 | 0.677 | 0.836 | 0.728 | 0.811 | 0.775 | 0.947 | | | |
| Cost | 0.992 | 0.968 | 0.767 | 0.629 | −0.780 | −0.697 | −0.753 | −0.789 | −0.835 | 0.984 | | |
| Network influence | 0.994 | 0.983 | 0.830 | 0.665 | 0.824 | 0.793 | 0.787 | 0.741 | 0.835 | −0.808 | 0.991 | |
| m-commerce adoption | 0.969 | 0.913 | 0.856 | 0.744 | 0.884 | 0.789 | 0.825 | 0.817 | 0.925 | −0.876 | 0.911 | 0.955 |

*Note.* CR, composite reliability; AVE, average variance extracted; MSV, maximum shared squared variance; ASV, average shared squared variance.

**Table 2**
Structural results.

| Variables | Structural coefficients | Remarks |
|---|---|---|
| Perceived usefulness | 0.054* | Supported |
| Perceived ease of use | 0.046 | Not supported |
| Perceived enjoyment | 0.076** | Supported |
| Trust | 0.315** | Supported |
| Cost | −0.139** | Supported |
| Variety of service | 0.159** | Supported |
| Network influence | 0.270** | Supported |

* $p < 0.05$.
** $p < 0.001$.

**Table 3**
Full validation results of neural network model.

| Network | Training | Testing |
|---|---|---|
| 1 | 0.392 | 0.412 |
| 2 | 0.378 | 0.405 |
| 3 | 0.39 | 0.413 |
| 4 | 0.381 | 0.406 |
| 5 | 0.384 | 0.396 |
| 6 | 0.395 | 0.416 |
| 7 | 0.401 | 0.416 |
| 8 | 0.38 | 0.408 |
| 9 | 0.377 | 0.406 |
| 10 | 0.421 | 0.508 |
| Mean | 0.390 | 0.419 |
| Standard deviation | 0.013 | 0.032 |

**Table 4**
Normalized variable importance.

| Variable | Relative importance |
|---|---|
| Network influence | 1 |
| Trust | 0.396 |
| Perceived usefulness | 0.388 |
| Variety of service | 0.234 |
| Perceived enjoyment | 0.058 |
| Cost | 0 |

analysis were used to develop the neural network analysis. As there is no heuristic method for determining the hidden nodes in a neural network, this research follows the suggestions by Wang and Elhag (2007) to examine the network including one to ten hidden nodes. Ten hidden nodes neural network was used as it was complex enough to map the datasets without incurring additional errors to the neural network model. The input layer therefore consisted of the six independent significant variables from the SEM (e.g. perceived usefulness, perceived enjoyment, trust, cost, variety of service, and network influence), while the output layer consisted of one output variable (e.g. m-commerce adoption).

This research used a 10-fold cross-validation whereby 90% of the data was used to train the neural network, and the remaining 10% was used to measure the prediction accuracy of the trained network. Table 3 shows the root mean square error (RMSE) of the validations.

From Table 3, the average cross-validated RMSE for the training model was 0.399 while the testing model was 0.419. Therefore the network model is quite reliable in capturing the numerical relations between the predictors and outputs.

Sensitivity analysis performance which was calculated by the average importance of the input variables in predicting the output for the 10 networks was performed and shown in Table 4. The importance of the m-commerce adoption factor measures how much the network's model-predicted value changes for different values of the independent variables. The values shown in Table 4 are normalized importance values.

As shown in Table 4, based on the order of importance, network influence, trust, perceived usefulness, variety of service, and perceived enjoyment are found to be important predictors in the ten networks, while cost does not predict whether users will adopt m-commerce or not.

## 6. Discussion

The results from this study showed the causal relationships between the adoption factors proposed and m-commerce adoption, and the factors that predict the adoption of m-commerce. Based on the SEM result, trust is the most significant variable influencing the adoption of m-commerce. The result is consistent with past studies conducted by Wei et al. (2009) and Chong, Ooi, Lin, and Bao (2011). As m-commerce is much newer compared to e-commerce, consumers are concern with issues related to privacy and security. In particular, given that the respondents in this study are from China, there is an element of culture in terms of consumers not trusting transactions which do not have face to face interactions (Chong, Chong, et al., 2011).

Network influence is the second most important variable in this study. The result shows that consumers will only use m-commerce if they find the network valuable. In this context of m-commerce, they will only find it useful if there are many people in their social network that are using the application, as well as other users who are using the applications. Some of the popular m-commerce application such as Wei Xin needs to build up its users base quickly in order to make the application attractive. In Wei Xin, users can use the application to interact with people not known to them within 1000 m away from their location. One way which Wei Xin built up its user base was to target a popular instant messaging application known as QQ in China. QQ is the most popular instant messaging application in China and it belongs to the same company as Wei Xin. Thus Wei Xin's users are able to use the application via their QQ account. Wei Xin's popularity in China shows the importance of building network effect for m-commerce application.

Cost was found to have a negative and significant relationship with m-commerce. This shows that although many m-commerce applications are free, users are still concern with costs such as 3G payments and the cost of mobile devices. It is interesting to find that variety of service is also an important determinant of m-commerce adoption. This shows that consumers are only willing to adopt m-commerce if they are sufficient types of applications for them to interact with. The finding is consistent with the study conducted by Chong, Chong, et al. (2011). Thus although consumers may not adopt m-commerce if they just look at the cost factor, they are willing to adopt m-commerce and pay for the service if they find that there are variety of services, and these applications are useful and enjoyment to them.

Consistent with findings from Thong et al. (2006) and Ha et al. (2007), perceived enjoyment was found to be significant in influencing consumers' decision to adopt m-commerce. Unlike applications that are used for work (e.g. accounting software), m-commerce include applications such as games, videos and social networking. Therefore it is also used for entertainment purpose, and some researchers have even coined the term mobile entertainment (Leong et al., 2011). It is interesting to note that perceived enjoyment plays a more important role that perceived usefulness. Therefore in the context of m-commerce, consumers feel that entertainment will attract them more than its usefulness. Perceived ease of use was found to have no significant relationship with m-commerce adoption. This finding is similar to Chong, Chan, et al. (2011)'s study but contradicts with the findings from

Wei et al. (2009). One explanation for this is that users are now quite familiar with m-commerce devices and applications, thus they do not find that m-commerce is difficult to use. Although Wei et al. (2009)'s study found that perceived ease of use is important for m-commerce adoption, the study was conducted much earlier than Chong, Chan, et al. (2011), and consumers are now more familiar with mobile devices such as iPhone or android based mobile devices.

The findings also supported Shmueli and Koppius (2010)'s paper which stated that predicting consumers' intention to adopt m-commerce is different from understanding the causal relationships between the adoption factors and m-commerce adoption. Thus the neural network technique employed in this research showed that factors that can predict m-commerce adoption. The result from neural network shows that network influence is the most important predictor of m-commerce adoption. Unlike the causal relationship result provided by SEM, trust is only the second most important predictor of m-commerce adoption. This is followed by perceived usefulness, variety of services, and perceived enjoyment. In general, the significant variables in SEM play a part in predicting m-commerce adoption. However, one interesting finding from the neural network model is that cost is not a predictor of m-commerce adoption. Thus when predicting if a user will be an m-commerce adopter or non-adopter, cost will not be a factor that separates the two groups of consumers.

## 7. Implications

This study has several implications. Firstly, this research extended previous m-commerce adoption studies by improving on TAM. Factors such as perceived enjoyment, trust, cost, network influence and variety of services are included to extend TAM. Secondly, m-commerce application providers and use the results from this research to improve m-commerce adoption. For example, m-commerce application developers can emphasize on improving consumer trust. This can be achieved by improving the security and privacy of m-commerce. Furthermore, when designing m-commerce applications, it is important to ensure that the applications are useful, and at the same time they are enjoyable to use. Based on the neural network, cost will not be a predictor of m-commerce adoption. Thus instead of focusing on price strategies, m-commerce developers should emphasize on providing better variety of services, and design applications that are useful and offer entertainment values. Network influence is the most important predictor from the neural network result. Therefore an important strategy for m-commerce developers to consider is to build up their user base. As mentioned in the earlier section, this strategy has being employed by telecommunication provider such as YTL in Malaysia as well as Wei Xin which has seen the number of users reached 10 million in less than one year. Therefore consumers are more likely to use the application if there are sufficient numbers of people in the network.

Thirdly, this research has provided a multi-analytic approach in the study of information system adoption by integrating SEM and neural network. The application of neural network addressed the limitations of past information system adoption studies by developing a non-compensatory model to predict m-commerce adoption. While the neural network has good prediction accuracy, its application in technology adoption is scant (Garson, 1998). Although SEM and the neural network were applied individually in existing information system adoption studies, few of these studies have combined these two approaches. SEM is able to examine the causal relationships presented in the research. However, its predictive power lacks the ability of the neural network. However, using only neural network will not provide the causal analysis, and its difficulty of showing how the neural nets generate the results is one of the obstacles of using neural network in technology adoption studies. It is also often difficult to construct a neural network model when learning from data. By employing the results from the SEM, it provides a way to develop the neural network model with a good prediction performance. As stated by Scott and Walczak (2009), employing a multi-analytic approach demonstrated how combining two different data analysis approaches in either methodology, and the alternative analysis is able to improve the validity and confidence in the results. For example, the statistical significance results from the SEM is reinforce by neural network, and the neural network is then able to show which of these significant variables can be used to predict m-commerce adoption. The multi-analytical approach adopted is able to serve as a good reference for future m-commerce adoption studies, and it provided a new perspective on examining m-commerce adoption with this multi-method technique.

Lastly, this study is conducted in China, one of the world's largest mobile consumer markets. The findings from this study will be helpful to m-commerce providers who are planning to enter the Chinese market, and they can formulate appropriate strategies based on the results.

## 8. Limitations

This study has several limitations. Firstly, the data was only obtained from Chinese consumers. This limits the generalization of the findings to other countries. Future work can focus on conducting a multi-country comparison study on m-commerce adoption. Secondly, although we have provided a comprehensive adoption model by including various adoption factors, future studies can include variables not included in this study, e.g. consumer self-efficacy. Lastly, this research only examines consumer intention to adopt m-commerce. Future studies can examine consumers' continual usage intention, and compare the results with the intention to adopt m-commerce.

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