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RESEARCH ARTICLE

Technology Acceptance Model: A Case Study of Palm Vein Authentication Technology

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ABSTRACT Biometric authentication is a new technology that verifies an individual' s identity via their unique physical or behavioural characteristics including Palm Vein or hand geometry. Despite its potential benefits and growing popularity in the public and private sectors, end-user adoption of the technology has been relatively slow. This study aims to investigate the major factors that influence Palm Vein biometric authentication devices through Technology Acceptance Model (TAM). In addition to the major TAM constructs, we postulate that the trust in the device, the users' perception of risks involved, their perceived enjoyment during device utilization and their innovative nature to have a significant influence on their final adoption behaviour. Data was collected from 100 voluntary participants by offering them a chance to interact with a palm vein scanner connected to a coffee machine which was used for access authentication. The goodness-of-fit of the data to the model is validated and the proposed model and the hypotheses are evaluated using Structural Equation Modelling (SEM). The results confirm the influence of users' risk perception, trust, and enjoyment factors on biometric technology adoption. Furthermore, this study shows that while risk perceptions and privacy concerns were found to be the primary hindrance to users' intention to accept Palm Vein technology, building a sense of trust among its users and designing an endearing system has a substantial role in increasing their level of technology acceptance.

INDEX TERMS Technology acceptance model, palm vein biometric authentication, structural equation modeling.

I. INTRODUCTION

With the rapid advancement in technology and information systems, businesses are attempting to make efficient use of these advancements and convert them into the products and services, which make our daily lives simpler. However, studies show that such devices would only be considered effective and businesses are successful if the general public finds the device to be useful and easy to use [1]. Hence, studies are being conducted in such areas to equip businesses and organizations with the right set of tools to understand their target customers and develop their products and services tailored to their needs. These studies have shown that despite being able to assist people in performing their regular jobs faster and more efficiently, people would still tend to reject these technologies. Consequently, there is a widely accepted need to understand the various factors that may affect the acceptance of new technology. biometric authentication systems have been around for a while and are known for providing one of the safest means of authentication and identification. Such systems, including facial recognition and fingerprint recognition, have also made their way into our personal devices, merely because of the simplicity and the security they offer. The Palm Vein Scanner is one of such biometric authentication systems and operates based on the uniqueness of the vein network situated below the palm.

Previous studies on the application of technology acceptance models for various biometric authentication

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TABLE 1. Construct definition.

Constructs	Definition
Perceived Usefulness (PU)	The extent to which individuals believe how useful the technology would be [1].
Perceived Ease of Use (PEOU)	The degree to which individuals perceive how easy it is to use the technology [1].
Attitude Towards Usage (ATU)	The degree to which an individual evaluates and associates the target system with [10].
Personal Innovativeness (PI)	The willingness of an individual to try out any new information technology.
Perceived Enjoyment (PE)	The degree to which the activity of using technology is perceived to be enjoyable in its own right apart from any performance consequences that may be anticipated [11].
Perceived Risk (PR)	The degree of risks inherent with using a certain technology.
Trust (T)	The degree of consumer's faith in the system components and the implementing organization that the system would adhere to its stated governance and principles.

applications have identified many external factors to drive users' intention to use such technologies. Perceived Trust, and demographic intention have also been highlighted as an influential factors toward the users' acceptance and satisfaction of biometric systems [2]. Some concerns about data usage and storage in biometric technology, as perceived privacy, have been identified to impact an individual's intentions [3], [4]. The acceptance of biometric technologies was found to be less desirable if the system usage is voluntary and not mandatory [5]. Ahmad and Hariri [6] suggested that the users' ability to use the biometric technology, termed as self-efficacy and sense of security are contributing factors in the acceptance of biometric technologies in online banking.

Coventry [7] explored trust and ease of use factors in acceptance of biometric authentication in ATM machines based on faster authentication and transaction security. The extension on TAM with external factors implemented by Miltgen [8] showed that compatibility, users' innovativeness, facilitating conditions, and trust in the technology influence users toward accepting the biometric technology. However, Alalwan [9] illustrated the feasibility of using facial recognition biometric in outdoor concerts and found that the system's accuracy and privacy of the information is of less concern among the users, while the ease of use and perceived usefulness influence more towards the use of biometric authentication in such scenarios.

Over the years, many user acceptance models have been theorized to explain the acceptability of biometric authentication by customers. Technology Acceptance Model (TAM), originally developed by Davis [1] has been widely used to understand the acceptance of information systems (IS) in general workplaces, which helps to study various factors impacting the successful implementation of these technologies. TAM has been validated by various researchers for the acceptance of biometrics as well as other technologies. TAM has the following basic components: Perceived Usefulness (PU), Perceived Ease of Use (PEU), and Attitude Towards Usage (ATU), which lead to the intention of use, and actual usage. The procedure of this method has been illustrated in Fig. 1. In Table 1 the meaning of these basic construct and some other constructs used in this work can be found.

TAM theorizes that the acceptance of any information system is highly dependent on two factors, PU and PEU. These factors describe how the new system is useful from users' perspectives, and how effortlessly the system can be operated. The various extensions of TAM, such as TAM2 and

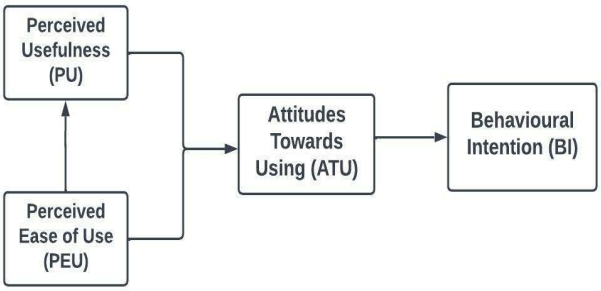

FIGURE 1. Original technology acceptance model (TAM).

Extended TAM [12], have been successful to indicate the factors that determined the users' acceptance of new technologies. Thus, TAM and its extended versions have been used to study the IS for various sectors, such as healthcare systems, banking systems and ATMs [7], mobile devices, access control and surveillance, and distance learning. Besides TAM and its extensions, other theoretical models, such as Theory of Reasoned Action (TRA) [13] and diffusion of innovations (DOI) [14] have been presented to understand the users' intention to use the new technology [15].

Recently, a breakthrough has occurred in the biometrics authentication industry. The biometrics authentication is the measurement of a human being via unique physical characteristics. Common examples of physical characteristics are the face, palm [16], fingerprint [17], retina [18], iris [19], [20], and voice data [21]. A comprehensive comparison of these methods has been provided in [22]. Stylios [23] proposed a new model integrating TAM and DOI to study the factors influencing the adoption of behavioral biometrics and continuous authentication. Hizam [24] introduced Perceived System Quality into TAM to study factors affecting users' adoption intentions towards biometric facial recognition system.

This study aims to propose a model capable of predicting the acceptance of Palm Vein biometric authentication by identifying the potential factors, helping users to make decision on the acceptance or rejection of biometric technologies. In case of acceptance of biometric technologies for human authentication, along with the original TAM constructs, various other factors, such as risk, trust, innovativeness, and enjoyment [4], [8], [9], [7] play significant roles due to the nature of user interaction required to use the system and the nature of the information that the user is providing to the system. Understanding the impact of these factors are very

critical and help businesses and organizations to successfully implement biometric technologies. This paper aims to validate TAM for studying palm vein biometric technology by introducing external constructs such as Perceived Enjoyment (PE), Perceived Risk (PR), Trust (T), and Perceived Innovativeness (PI) to derive their relations with the acceptance of the technology. For this study, a Palm Vein Scanner was integrated into a coffee machine to grant access to users validated through biometric authentication. Participants were asked to enrol and authenticate themselves to access the machine. A survey questionnaire, based on a 5-point Likert scale has been used to collect feedback from 100 participants based on their interactions with the Palm Vein Scanner. The data collected was modelled using Structural Equation Modelling (SEM) to validate the relationships among the different constructs in the proposed model.

TAM was introduced by Davis [1] in 1989 and builds on top of the Theory of Reasoned Action (TRA). While TRA was used to study the relationship between attitudes and behaviour with human action, TAM provided a framework to study the factors affecting technology adoption. TAM postulates that technology adoption is governed by users' behavioural intentions which in turn are influenced by their perception of its usefulness and ease of use. Over the years, TAM has been continuously studied and has undergone multiple iterations such as TAM2 [12] and TAM3 [25]. While the main constructs remained the same, studies have extended TAM to introduce several new constructs to study the factors that indirectly influenced technology acceptance through Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). This provides TAM with the flexibility to be employed to study even the latest technologies by introducing relevant external variables. To have a more comprehensive understanding of TAM, most prominent relevant papers and their limitations have been mentioned in Table 2.

Given the current scenario where contactless technology is taking a central stage, palm vein biometric authentication technology provides a simple, yet highly secure means of identification and authentication. However, studies have shown that people tend to weigh in on a lot of factors when deciding to accept technology. Since Palm Vein biometric authentication technology is novel, there is much research on what factors could influence the user's acceptance behaviour. This is the problem that this research stands to solve. The contributions of the research are two-fold. Primarily, the research identified the main factors that influence biometric technology adoption among its users and secondarily, the study discusses how vendors or manufacturers of such devices could leverage this information to develop devices with a higher level of user acceptance. The contributions of the paper can be summarized as follows:

- This paper applies TAM with four external constructs including Perceived Risks, Perceived Enjoyment, Trust, and Personal Innovativeness, which studies the users' acceptance of a Palm Vein Scanner embedded in a self-service machine.
- An on-site data collection is conducted with 100 voluntary participants while interacting with the Palm Vein scanner.
- The evaluation of the proposed model has been performed via suggesting corresponding hypotheses and applying Structural Equation Modelling SEM and CFA.

In this paper, Section I discusses the biometric data, human authentication, application of biometric authentication, and related literature. Section II discusses the TAM for biometric authentication systems, research model of the proposed Structural Equation Modelling (SEM) structure is based on the gaps in the literature to study the factors affecting the acceptance of Palm Vein authentication. Section III discusses the methodologies used to conduct the survey, data collection, data analysis techniques used in model designing, and testing. Section IV evaluates and discusses the results from data analysis, which is followed by Section V where the hypotheses and research questions are evaluated. Afterwards, Section VI discusses the potential sources of errors and factors that could affect the research objectives. Some potential threads to validity have been illustrated in Section VII. In the end, Section VIII concludes the report, which is followed by some hints for further direction for future research in Section IX. In the Appendix, the survey questionnaire, SEM analysis in AMOS used in the research and figures have been given for further understanding.

II. RESEARCH DESIGN AND HYPOTHESES

The proposed model to study the above-mentioned research questions is shown in Fig. 2. This model demonstrates the relations among the various constructs to test the users' acceptance of biometric technology for authentication purposes.

A. TAM AND BIOMETRIC

Various studies have substantiated the use of TAM to explain the users' acceptance of information technologies [3]. Extending TAM to biometric technology was also done in the past to study the important antecedents to the users' behavioural intentions to incorporate biometric devices into their daily lives [27], [26]. Therefore, TAM can be extended similarly to explain the factors that affect the users' acceptance of the Palm Vein authentication technology [28]. Grounded in its two main constructs, PU and PEU, TAM postulates that the usefulness and the ease of using an information system positively affect the users' attitude towards accepting a technology. This can, in turn, create a positive influence on their behavioural intention towards using it. TAM further states that the ease of operating an information system has a direct impact on the users' perception of its usefulness. This is indicated by the arrow originating from PEU and ending at PU in the research model, Fig. 2.

Thus, we hypothesize the basic TAM relations to be valid in case of biometric Palm Vein technology, as visualized in Fig. 3.

TABLE 2. Previous biometrics studies in TAM.

Reference	Title	Findings	Limitations
[26]	Towards Understanding User Perceptions of Biometrics Authentication Technologies	• Found PU and PEOU as significant drivers of BI to use biometric for authentication. • Found PU as the most significant contributor to adoption decision. • Found young people more likely to adopt biometric devices.	• Limited data (74) to derive conclusive decisions. • Studied user's adoption behavior towards biometric devices in general.
[7]	Usability and biometric verification at the ATM interface	• Provided an overview of biometric technology, different types and use cases. • Used focus groups to gauge users' attitude toward biometric technology in general. • Conducted dynamic anthropometry study to comprehend the physical restrictions that a device must work under. • Conducted field trials where Iris based ATM devices were used to replace traditional signature methods.	• The evaluation of consumer attitude towards biometric technology was conducted using surveys with a lack of empirical validation. • The research did not focus much on the major factors the contributed to biometric technology adoption.
[8]	Determinants of end-user acceptance of biometrics: Integrating the "Big 3" of technology acceptance with privacy context	• Provides an in-depth study into determinants of biometric technology adoption. • Integrates TAM, DOI and UTAUT with trust-privacy research field. • The results were theoretically and empirically validated.	• Scenario based where the respondents were provided with a hypothetical scenario to obtain their response. • Mainly targeting young adults (15-25).
[23]	Key factors driving the adoption of behavioral biometrics and continuous authentication technology: empirical research	• Proposed a new model integrating TAM and DOI to study the factors influencing the adoption of behavioral biometrics and continuous authentication. • Introduced and validated new constructs – Security and Privacy Risks (SPR), and Biometric Privacy Concerns (BPC)	• Data was collected online and participants were made to examine an online banking scenario. • Research was focused on behavioral biometrics and continuous authentication on mobile devices.
[24]	User Behavior Assessment Towards Biometric Facial Recognition System: A SEM-Neural Network Approach	• Perceived System Quality and Social Influence into TAM to study factors affecting user's adoption intention towards facial recognition system. • The data was collected online from users with prior experience in using facial recognition systems for home security purposes. • The proposed model was empirically validated using SEM and ANN.	• The research was focused on the direct influence of various factors on behavioral intentions to usage when there could be indirect influence among constructs

- H1: PU will have an influence on users' ATU of the Palm Vein biometric Scanner.
- H2: PEU will have an influence on users' ATU of the Palm Vein biometric Scanner.
- H3: PEU will influence PU of the Palm Vein biometric scanner.
- H4: There exists a relationship between the users' ATU towards the Palm Vein biometric scanner and their Behavioural Intentions (BI) to use it.

B. TRUST AND ATTITUDE TOWARDS USAGE

Major factors impacting the acceptance of biometric authentication technology is the secure authentication and concern on the usage of personal biometric information [4]. With the need to provide safe and secure means for authentication and personal identification, biometric technology has taken the centre stage as one among the safest authentication and identification techniques. Since these devices collect and handle sensitive personal information, they come under heavy scrutiny from the general public and is often susceptible to data misuse, leaks and threats from adversaries [7]. Thus there is a need for implementing organizations to build a foundation of trust among the target users. A study [29] extending TAM towards internet banking, an area where data of similar nature is transacted showed the role of trust in predicting and explaining internet banking acceptance by prescribing and confirming the customers' need for security and privacy as its primary antecedents. Similarly, researchers [30] have incorporated UTAUT2 with Trust and Personal Innovativeness in an attempt to study the factors affecting cryptocurrency adoption and have suggested that consumers tend to have a strong affinity for adopting Cryptocurrency, if they perceive that using the technology is beneficial and allows them to execute a task successfully. Therefore, Trust is hypothesized to have a major influence on the users' attitude to use the Palm Vein Scanner. Thus, we set following hypothesis:

- H5: Trust will have a direct effect on users' Attitude Towards Usage of the Palm Vein Scanner.

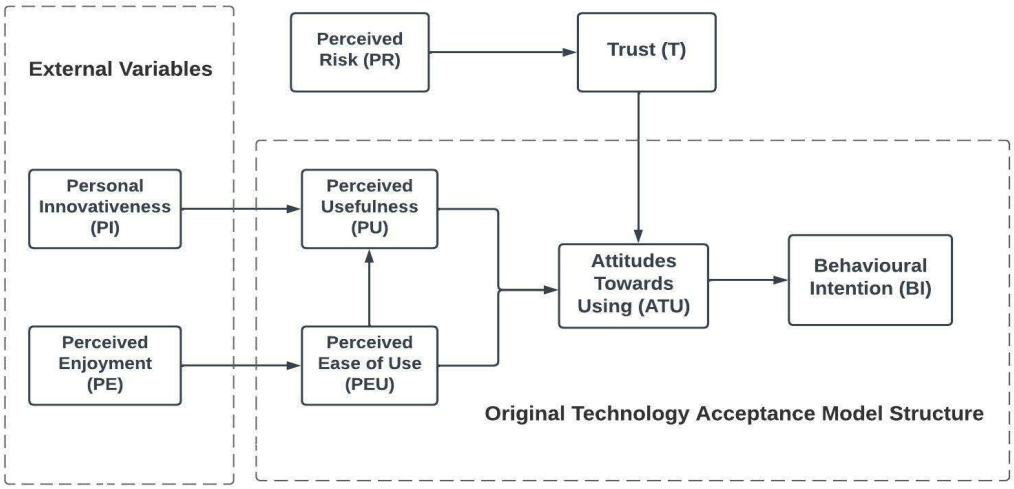

FIGURE 2. Proposed extension of TAM structure. In this model, the original TAM has been extended with four external variables to acquire more accurate information about the users' interactions with the novel technology of Palm Vein Scanner, developed by Aervision Pty Ltd.

C. PERCEIVED RISK AND TRUST

The biometric data are often collected by exposing the human body parts to different sensors and radiations, such as exposing the eye to a scanner for iris recognition [4], which is often considered risky by users, especially when the users must expose their vital organs to unknown elements associated with the device. The Palm Vein Scanner also employs a similar method of data collection, which includes exposing one's hand to Near-infrared spectroscopy (NIRS) rays that some users may find risky. Such perceived health risks may deter users from accepting the biometric authentication technology, which could lead to its failure. In addition to the health risks associated with these devices, users could also run the risk of losing control over their sensitive biometric information. They might perceive a breach of their privacy, by considering the possibility of devices being compromised and the biometric information stored in them being made public. Such risks are inherent in devices handling biometric information and manufacturers tend to put stringent measures to safeguard their users' safety and privacy.

Further research [8] has shown how Trust in technology and privacy concerns influenced users' behavioural intentions to adopt biometric technology through Perceived Risks. The study was able to identify trust in technology, personal innovativeness, and the Perceived Usefulness of the technology as specific drivers while risks associated with trust in the device as inhibitors of biometric technology adoption. They have found evidence to state that people were found to be willing to adopt biometric technology in their day-to-day lives if the system provided ways to mitigate these concerns and kept the biometric data secure from adversaries. Thus, we can hypothesize that Perceived Risk (PR) associated with biometric devices can have a direct negative impact on the users' BI to use the Palm Vein authentication technology in such a manner that the higher the users' perceive the risk associated with using the device, the less likely they would be to adopt it.

- H6: Users' perception of risks associated with the device (PR) will have a direct effect on the T that users have on the Palm Vein Scanner.

D. PERSONAL INNOVATIVENESS AND PERCEIVED USEFULNESS

Innovativeness, or individuals' desire to use new technologies has always been identified as the main motivation behind the users' acceptance of new technologies [8]. Such individuals have been found to exhibit a positive attitude towards the usefulness of new technologies and can easily adapt to new technology [8].

- H7: Individuals' Personal Innovativeness (PI) will have a direct effect on their PU of the Palm Vein Scanner.

E. PERCEIVED ENJOYMENT AND PERCEIVED EASE OF USE

In the study conducted by Venkatesh [31], he proposed that intrinsic motivation, in the form of Computer Playfulness, as one of the anchors that adopters would pivot themselves while developing BI to adopt a technology. PE is defined as the degree to which the act of utilising technology is perceived to be enjoyable in and of itself, regardless of any potential performance effects [11]. Studies have been able to identify a link between users' PE while using technology and their PEU [31] and some have even found a direct relationship between PE and BI to use a technology [9]. To understand this further, [32] tried to differentiate how technology acceptance models influenced utilitarian and hedonic information systems. The study was able to show that, for hedonic systems, PE and PEU had a stronger influence on user's behavioural intentions than perceived usefulness. This ultimately showed how PE was able to capture how the hedonic aspects of an information system influenced final usage intentions. Thus,

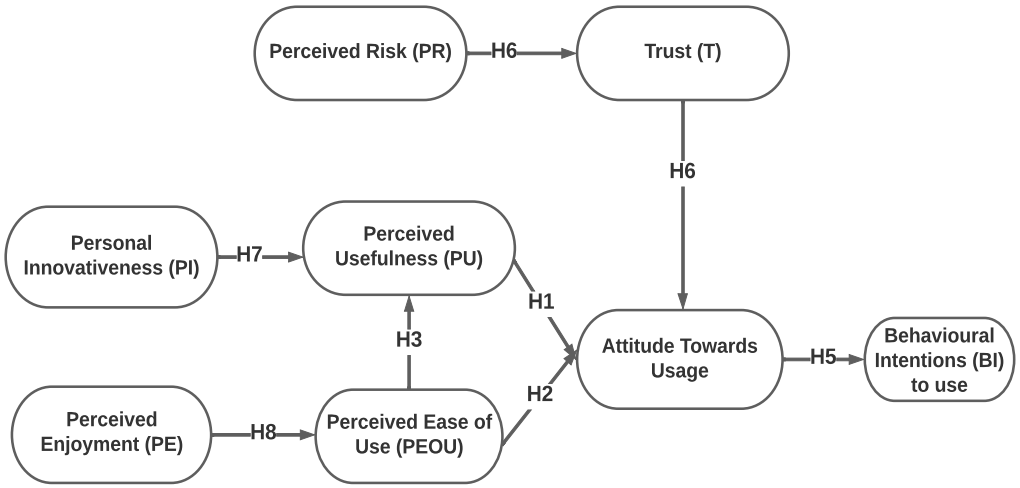

FIGURE 3. Proposed extension of TAM structure: Hypotheses.

in this study, we intend to capture similar influences by hypothesizing that a similar relation exists while using the Palm Vein Scanner. Being a niche and developing aspect of the now-ubiquitous biometric authentication systems, most people would welcome the opportunity to experience using their Palm Vein as a means to authenticate access, which in turn would compliment their PEU of the device.

- H8: PE of the users will have a direct influence on their PEU of the Palm Vein Scanner.

F. RESEARCH METHODOLOGY

To understand the relationship between the constructs (latent variables) mentioned in the proposed model, a quantitative correlation research design using SEM has been used to analyze the statistical relationships between these variables. Structural Equation Modelling (SEM) has been commonly used to study the relationships between variables to confirm a research study design. SEM produces a visual representation of these relationships between the variables for interpretation. SEM is a combination of factor analysis and regression models. It is also useful to represent those hypotheses that cannot be tested directly. The SEM model can analyze the regression paths simultaneously [4] and variables are confirmed to have relationships if they vary together.

III. RESEARCH METHOD

To study the users' perception of the Palm Vein authentication technology, a Palm Vein Scanner is installed on a coffee vending machine. The principle that the palm vein scanner works on is the fact that deoxidized haemoglobin returns to the heart through the veins, which have different rates of absorbency than oxygenated arteries. When the near-infrared light illuminates the palm, the deoxidized haemoglobin in the palm veins absorbs this light. This reduces the reflection rate and causes the veins to appear as a black pattern. The palm vein scanner, as a biometric authentication device, identifies unique biological traits. False Acceptance Rate (FAR) is <0.00001 and False Rejection Rate Comparison (FRR) is approximately 0.01. The Common Criteria for Information Technology Security is an international standard (ISO/IEC 15408) for computer security certification. The designed survey was entirely based on the users' experience of the Palm Vein Scanner. Due to the nature of this study, the survey had to be conducted on-site. Especially, with the focus on the constructs like PEU and PE, the option of the online survey was strictly inconsiderable. A focused group of participants were invited to use the Palm Vein Scanner to register themselves and identify themselves to get access to the coffee vending machine. After experiencing the Palm Vein authentication, the participants were asked to complete a survey questionnaire to collect their feedback.

A. MEASUREMENT DEVELOPMENT

A survey has been instrumented (see Appendix) that included 16 questions based on the constructs of the model to collect data for the purpose of evaluating the research questions and testing the relevant hypotheses. Direct measurement of these latent variables is not practical. Thus, survey statements are used as indicators to measure latent variables. These questions have been designed in reference to questions from related papers [2], [33], [5]. A 5-point Likert scale [34], 1=Strongly Disagree, 2=Disagree, 3=Not Sure, 4=Agree, and 5=Strongly Agree, has been used that indicates the users' point of view towards the statements of the questionnaire. The numbers of indicators per construct used in the questionnaire are given in Table 3.

B. DATA COLLECTION

This research was conducted after granting ethics approval from Deakin University, under the ethics number of SEBE-2021-06. After extensive research in relevant fields, a comprehensive survey was designed. The survey was distributed among 100 participants from a focused group of individuals and students at Deakin University on Burwood campus. It is

TABLE 3. The number of indicators for each construct.

Construct	Number of Questions (Indicators)
Perceived Usefulness (PU)	2
Behavioural Intention (BI)	2
Attitude Towards Using (ATU)	2
Personal Innovativeness (PI)	2
Perceived Ease of Use (PEU)	2
Trust (T)	2
Perceived Risk (PR)	2
Perceived Enjoyment (PE)	2
Total	16

TABLE 4. Demographic information of the participants. Each number shows how many participants filled out the survey categorized by their age range, gender and level of education.

Gender	Male	53
	Female	47
Education Level	High School	28
	Diploma	24
	Undergraduate	25
	Post Graduate	19
	Doctorate	4
Age_range	18-24	64
	25-34	23
	35-45	11
	46-60	2

worth mentioning that considering the fact that this data collection procedure has been done on campus, the number of participants is much more comparing most of the studies undertaken in similar contexts of different bio-authentication methods, such as [35], [36], which has 38 and 15 participants, respectively. No specific selection criteria have been chosen for inviting people to participate in this study. The demographic information of the participants has been given in Table 4:

In order to obtain the informed consent of the participants, the Plain Language Statement was given to all participants and the procedure of using the Palm Vain Scanner was explained clearly to them. Then, they were asked to sign the consent form. Furthermore, in case they change their mind, we had a withdrawal form to be signed and consequently excluding that participant from the data collection. For this purpose, a Palm Vein Scanner, shown in Fig. 4, has been mounted on a coffee vending machine. The participants were asked to use the Palm Vein authentication system by enrolling themselves on the system with the help of their Palm Vein for identification. Their feedback on the Palm Vein authentication system was collected with the help of the survey questionnaire, which focuses on different constructs as given in Table 3. The responses for each indicator is converted to numerical values based on the 5-point Likert scale. The data is then fed into IBM SPSS Statistics 28.0. Indicators with missing responses are checked in the ''Variable View'' tab.

C. DATA PRE-PROCESSING

This survey results could contain missing values because of blank responses from the participants. Two approaches

FIGURE 4. A Palm Vein Scanner is highly reliable, easy to configure, cost-effective biometric authentication and access control device.

have been applied to compensate for this issue. If any of the indicators are missing any value, then that record is discarded from the study. Another approach is to replace the value of the missing indicator with the average of responses for indicators under the same latent variable for that record. Once the missing records are replaced or removed, the dataset is then saved into SPSS Statistics format ''.sav'' so that it could be fed into IBM SPSS AMOS 26.0 software for further analysis. It is worth mentioning that we initially had collected feedback from 100 participants via questionnaire, which led to too high correlations between the two constructs. After extensive troubleshooting, it dawned on us that it is attributed to the fact that 15 of our participants had chosen one response for all questions. For instance, all responses have been chosen as ''Not Sure'' or ''Agree''. These responses had caused high correlations and after removing these responses, 15 questionnaires, from our analysis the acquired results were meeting the mathematical expectations. In this study, we have used a questionnaire with 5 options including strongly disagree, agree, not sure, agree and strongly agree for every question. During the data collection, often most participants reacted with a Not Sure option for most questions. This basically demonstrates the participant's unfamiliarity with Palm Vein Authentication technology, and they are not sure about it in the survey. This can only be overcome by educating the participants on the nuances of the technology which is resource-intensive and outside the scope of this research.

IV. MEASUREMENT MODEL

The Confirmatory Factor Analysis (CFA) technique has been implemented to test the reliability and validity of the collected data. Reliability of the individual indicators from the survey has been measured with Cronbach's alpha value, whereas convergent validity and discriminate validity of the constructs have been measured with Composite Reliability (CR) and Average Variance Experienced (AVE) indexes. The cut-off thresholds are set at 0.7 for the acceptance of the reliability of

TABLE 5. Cronbach' alpha Scores, Average variance extracted (AVE), Divergent validity (DV), and composite reliability (CR) for the proposed model.

Indicators		Constructs	Standard Loadings	Cronbach Alpha	AVE	DV	CR
ATU1	<—	ATU	0.782	0.646	0.509	0.713	0.672
ATU2	<—	ATU	0.637				
BI1	<—	BI	0.669	0.667	0.504	0.710	0.670
BI2	<—	BI	0.749				
PE1	<—	PE	0.86	0.873	0.777	0.881	0.874
PE2	<—	PE	0.902				
PEU1	<—	PEU	0.778	0.706	0.548	0.741	0.708
PEU2	<—	PEU	0.701				
PI1	<—	PI	0.762	0.80	0.674	0.821	0.805
PI2	<—	PI	0.876				
PR1	<—	PR	0.707	0.711	0.563	0.750	0.720
PR2	<—	PR	0.791				
PU1	<—	PU	0.731	0.653	0.488	0.698	0.655
PU2	<—	PU	0.644				
T1	<—	T	0.831	0.766	0.625	0.791	0.769
T2	<—	T	0.748				

independent variables [34], 0.6 for composite reliability [37] and 0.5 for average variance extracted indexes [37].

Table 5 shows the Cronbach's alpha, average variance extracted, discriminant validity and composite reliability scores obtained for the proposed model. The value of the composite reliability of latent variables was more than 0.7 and AVE score was greater than 0.5. It can be concluded that all variables in this study model were reliable. The discriminant validity of latent variables has been assessed by comparing the discriminant validity score for a latent variable against the correlation with other latent variables.

Also Table 5 indicates that each construct used in the proposed model has strong internal reliability. Cronbach's alpha scores for PE, PI, T, PEU, and BI were obtained above the ideal score of 0.7. Other constructs in the model such as ATU, PR and PU were found to have Cronbach's alpha score of just around 0.65. AVE score for all constructs in the model was obtained in the range of $0.5 - 0.8$, which were above the ideal 0.50 value, except for PU construct, which was computed at 0.481. Also, composite reliability for external constructs such as PE, T, and PI was obtained in the range of $0.7 - 0.8$, which were above the ideal 0.6 value. For other constructs, this score was computed at just around 0.5, suggesting a moderately acceptable construct validity.

SEM analysis has been performed using IBM AMOS 26.0 and the model evaluation indexes are obtained, as shown in Table 6. With the current sample size that we have obtained, the model was able to validate 6 out of 8 relations, which suggests that the proposed model was a good fit and can be further used to predict the users' acceptance of Palm Vein authentication by acquiring more data samples. The regression weights could be used to test the hypotheses. The structural model for the proposed construct has been estimated using the Maximum Likelihood Estimation (MLE) technique to analyze the relationship among the latent variables of the research model. The standardized direct and indirect effects of each estimator onto their related latent variable were obtained, as shown in Table 7. The significance of relationships between the latent variables as described in the proposed model was tested by calculating the t-value, as obtained in Fig. 5.

TABLE 6. Model fit indexes obtained for the proposed model.

Fit Metrics	Threshold	Model Score
Ch-square DOF	≤ 3	1.358
Comparative Fit Index (CFI)	≥ 0.90	0.928
Normalized Fit Index (NFI)	≥ 0.90	0.782
Goodness of Fit (GFI)	≥ 0.80	0.846
Adjusted Goodness of Fit (AGFI)	≥ 0.80	0.782
Parsimony Normalized Fit Index (PNFI)	> 0.50	0.626
Parsimony Comparative Fit Index (PCFI)	> 0.50	0.743
Root Mean Square Error of Approximation (RMSEA)	≤ 0.08	0.068

V. RESULTS

After doing the analysis, in this section the results of our conducted analysis is presented.

A. MODEL FIT

Model evaluation in SEM has been analyzed by using the goodness-of-fit index, also known as Chi-Square (X2) test, which helps to evaluate the model against the collected data. Various other evaluation metrics have been used to assess the model such as the degree of freedom of the Chi-Square index (X2/df), the Root Mean Square Error of Approximation (RMSEA), and Comparative Fit Index (CFI). The cut-off value for RMSEA is 0.08 or less while that for CFI is 0.80 or more according to Hair [38] to ensure acceptable fitness. Model fit indices obtained for the proposed model were RMSEA = 0.068, CFI = 0.928, NFI = 0.782, GFI = 0.846, AGFI = 0.782, PNFI = 0.626, and PCFI = 0.743 suggesting a good model fit.

B. HYPOTHESES TESTING

The hypotheses from the proposed SEM model were tested to assess the relationships between the various constructs and illustrate their influence on the acceptance of Palm-Vein biometric Authentication in Self-Serving Machines. Table 8

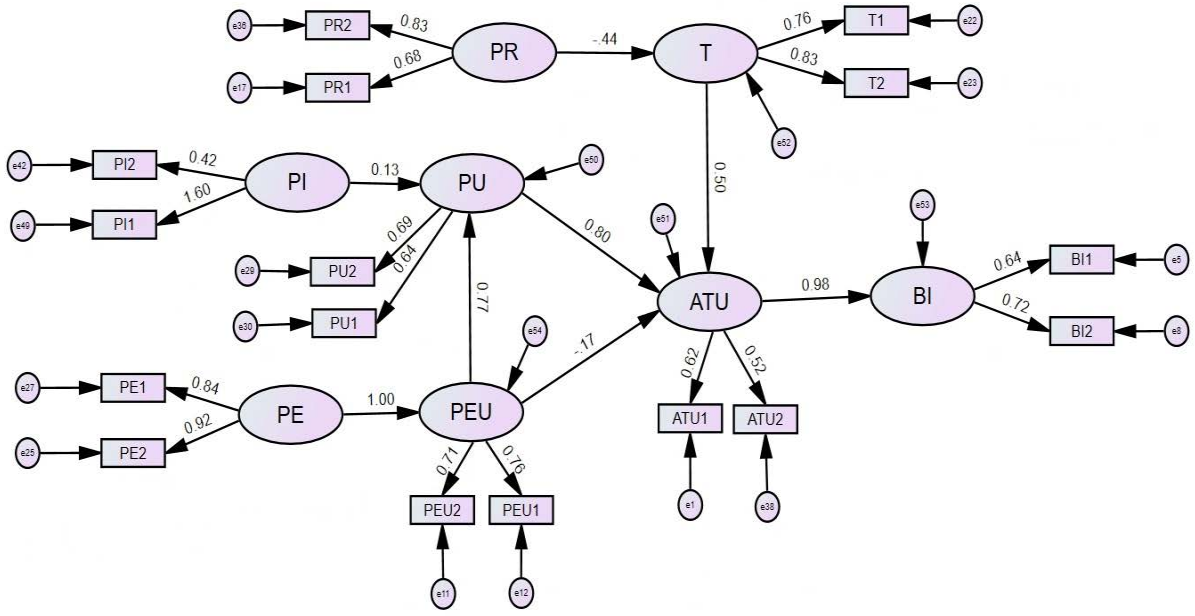

FIGURE 5. Results of structural modelling analysis for the proposed model.

TABLE 7. Direct and indirect effects between the constructs.

Direct Effect									Indirect Effect								
	PI	PE	PR	PEU	PU	T	ATU	BI		PI	PE	PR	PEU	PU	T	ATU	BI
PEU	0	0.998	0	0	0	0	0	0	PEU	0	0	0	0	0	0	0	0
PU	0.109	0	0	0.742	0	0	0	0	PU	0	0.74	0	0	0	0	0	0
T	0	0	-0.42	0	0	0	0	0	T	0	0	0	0	0	0	0	0
ATU	0	0	0	-0.03	0.628	0.495	0	0	ATU	0.068	0.435	-0.208	0.466	0	0	0	0
BI	0	0	0	0	0	0	0.983	0	BI	0.067	0.427	-0.204	0.428	0.617	0.487	0	0

TABLE 8. Results from the structural model and hypothesis testing.

Relationship	Estimate	S.E.	t-value	p-value	β	Hypothesis	Significance
ATU <— PU	0.717	0.349	2.052	0.04	0.63	H1	Significant
ATU <— PEU	-0.025	0.207	-0.122	0.903	-0.03	H2	Insignificant
PU <— PEU	0.442	0.143	3.101	0.002	0.74	H3	Significant
BI <— ATU	0.977	0.233	4.19	***[1]	0.98	H4	Significant
ATU <— T	0.912	0.119	7.645	***	0.5	H5	Significant
T <— PR	0.552	0.117	4.72	***	-0.42	H6	Significant
PU <— PI	0.204	0.117	1.746	0.081	0.11	H7	Insignificant
PEU <— PE	-0.325	0.148	-2.199	0.028	0.997	H8	Significant

[1] Note: *p-value < 0.05; **p-value < 0.01; ***p-value < 0.001, denotes the significance level for relationships between the constructs.

shows the assessment of the hypotheses against t-values and the lane coefficients on significance level (P) of 0.05 with a two-tailed test. This t-value is used to test the acceptance or rejection of the proposed hypotheses. The hypotheses are accepted if t-value was greater than the value of (0.1946) from the T-Distribution for the degree of freedom (df) of 96. Perceived usefulness significantly affected attitude (p=0.04, β=0.63) and thus concluded the acceptance of the H1 hypothesis. Similarly, perceived usefulness was significantly affected by perceived ease of use (p=0.002, β=0.74), implying acceptance of the H3 hypothesis. BI construct was significantly affected by attitude (p=***, β=0.98) and trust(p=***, β=0.5) constructs while perceived risk also significantly impacted trust (p=***, β=−0.42), and thus, hypotheses H4, H5, and H6 were all accepted. Likewise, perceived ease of use was significantly affected by perceived enjoyment (p=0.028, β=1.0) suggesting that hypothesis H8 is also accepted. On the contrary, hypotheses H2 and H7 are rejected as the relationship impact of personal innovativeness on perceived usefulness (p=0.903, β=−0.03) and perceived ease of use on attitude (p=0.081, β=0.11) were not significant.

C. DIRECT AND INDIRECT EFFECTS

The path coefficient values shown in Table 7 represent the direct and indirect effects of various constructs in the proposed model. BI construct was observed to be directly affected by ATU (0.983), while it was also indirectly affected by all other constructs, PI (0.067), PE (0.427), PR (−0.204), PEU (0.428), PU (0.617) and T (0.487). PEU and T constructs were found to be affected directly by one construct each, PE (0.998) and PR (−0.42) respectively and had no indirect effects from any other constructs. PI (0.109) and PEU (0.742) constructs were found to have a direct effect on PU, while simultaneously being affected indirectly by PE (0.74). PR construct also had a direct but negative effect on T. Lastly, ATU was found to be affected directly by PEU (−0.03), PU (0.628) and T(0.495), while all other constructs, PI (0.067), PE(0.427), PEU (0.877), PR(−0.204) and T (0.487) affected ATU indirectly. These indirect effects from the constructs onto BI construct indicate the influence of these different constructs towards the overall acceptance of Palm Vein Scanner.

VI. DISCUSSION

This section discusses the validity of relationships between various constructs from the proposed constructs based on the significance. The research is able to validate the usefulness of TAM in explaining users' intention to accept biometric Palm Vein technology by introducing Trust, Perceived Risks, Perceived Enjoyment and Personal Innovativeness in addition to the TAM constructs. For a device associated with biometric Palm Vein technology, the perceived risks associated with it are found to have a significant influence on the trust the users placed on it. Furthermore, Trust in the device is found to have a significant role in users' acceptance of Palm Vein biometric scanner such that a unit increase in trust can be translated to an almost equal increase in their attitude towards using the device. In the end, the analysis results prove the adoption of Palm Vein Scanner by users, which guarantees the success of manufacturing this technology.

A. BIOMETRICS AND TAM

This study was conducted to assess the main factors that governed the users' intentions to adopt Palm Vein biometric Authentication System as a means to authenticate access to restricted services. Using TAM as the foundation, the research was able to validate all except the relation between Perceived Ease of Use and Attitude Towards Usage. Consistent with previous research [27], [39], this study was able to validate Perceived Usefulness as an antecedent to Attitude Towards Usage of the Palm Vein Scanner ($\beta = 0.63, p < 0.05$). As biometric devices find their primary application in personal identification and providing security to sensitive elements, it seems obvious that its users would consider its usefulness as the main contributor to their decision to adopt the scanner for actual use. This further highlights the need to make these devices efficient by providing quicker transactions with lower false positive rates. This study was also able to validate the impact Perceived Ease of Use has over Perceived Usefulness ($\beta = 0.74, p < 0.005$). Since the Palm Vein Scanner requires its users to initially register their palm with the device, the onboarding process while setting up the device could considerably influence the users' Perceived Usefulness of the device. This shows how the device's design, by facilitating a clean User Interface (UI) and by using components that can facilitate quicker and seamless transactions can indirectly contribute to its successful adoption. Furthermore, in accordance with TAM, Perceived Usefulness was found to significantly influence users' Attitude Towards Usage of the Scanner ($\beta = 0.63, p < 0.05$), which in turn was found to have a significant relation with the users' Behavioural Intentions to use the device ($\beta = 0.98, p < 0.001$) in their day-to-day lives. However, the relation between Perceived Ease of Use and ATU was found to be insignificant ($p > 0.05$). The direct positive relation between PU and ATU shows that an increase in the usefulness of the device would positively influence the users' ATU. This, in addition to the insignificant relation observed between PEU and ATU emphasizes how users' tend to focus primarily on the usefulness of biometric devices over and above their ease of usage when deciding to adopt them for daily use.

B. PERCEIVED EASE OF USE AND PERCEIVED ENJOYMENT

Perceived Enjoyment was introduced by Venkatesh [31] to conceptualize system-specific intrinsic motivation when studying the determinant of PEOU. He postulated that with increasing experience with the device, users' perceived ease of use would be influenced more by the unique user-system interaction than the initial system-specific attributes. The study was able to find a significant relation between Perceived Enjoyment and Perceived Ease of Use ($\beta = 0.997, p < 0.05$). This relation depicts how an individual's intrinsic motivation tends to have a sway over how they perceive the Palm Vein Scanner to be easy to use. As the system use may become more monotonous with increasing experience, individuals tend to loose their intrinsic motivation and might perceive the system to be more demanding [31]. Therefore, design features aimed at creating a sense of enjoyment while handling the system can enhance the perceived ease of use of the Scanner.

C. TRUST AND PERCEIVED RISK

The results further revealed an obvious significant, negative relationship between Trust and Perceived Risks ($\beta = -0.42, p < 0.001$). This signifies how people's perception of risks associated with biometric devices can influence their final intention to adopt the technology indirectly through trust. Similar studies have shown an increase in consumers' risk perceptions can deteriorate their intentions to adopt IT systems [40], [41], [42]. With biometric systems, studies have shown psychological risks to be of greater

importance [43]. These risks are often associated with privacy and identity issues and with the rise in awareness among the general public around such matters, organizations need to put stringent measures and policies in place to mitigate their perception of associated risks and enhance their feeling of trust in the devices. In addition, the use of certain electronic components as part of the device can also create a sense of health risks to its consumers. This can be alleviated by employing government mandated industry standard components and creating awareness among the public about the health risks involved, if any.

D. TRUST AND ATTITUDE TOWARDS USAGE

The study was able to find a positive significant relationship between Trust and Attitude Towards Usage ($\beta = 0.5, p < 0.001$) to use Palm Vein Scanner. This shows that trust in these systems can lead to greater acceptance rates among its consumers by nourishing an environment that encourages its adoption. Most of the uncertainty surrounding the adoption of biometric devices come from Trust. Studies have shown trust to be an excellent tool in creating a sense of security around accepting e-commerce platforms [44]. Since biometric Authentication Systems are expected to handle sensitive biometric information, the trust that the consumers put in these devices are of paramount importance and has been found to play a pivotal role in consumers' attitude to use such systems [45]. Consequently, while developing such systems, measures must be taken to safeguard the users' security and privacy so as to enhance users' trust in the device. When faced with uncertainty, trust can motivate consumers to adopt a technology which could often lead to circumstances where they might learn about the devices' benefits and perceive the device to be useful [8].

E. PERSONAL INNOVATIVENESS AND PERCEIVED USEFULNESS

Personal Innovativeness was introduced by Agarwal and Prasad (1998) and was adopted from Innovation Diffusion Theory. The results from the research was not able to find enough information in the data to find statistically significant relationship between Personal Innovativeness and Perceived Usefulness ($p > 0.05$). This could perhaps be attributed to the fact with regards to biometric devices, consumer's level of enthusiasm towards the technology, almost never tends to have an influence on their adoption behaviour over and above that of its actual usefulness. Since these devices are meant to handle sensitive private information, people tend to be weary about the consequences of using such devices and might develop a conservative approach towards its adoption behaviour.

VII. THREATS TO VALIDITY

During this study, several gaps in the study were identified, which could impact the motives of this study. Such gaps have been discussed in this section.

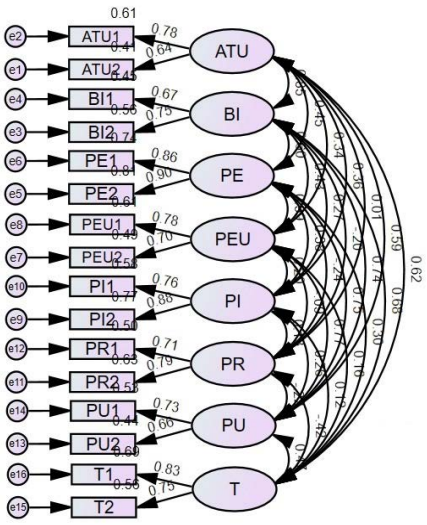

FIGURE 6. Confirmatory factor analysis.

A. THE NOT SURE RESPONSES

One of the major drawbacks of using a 5-point Likert scale was found to be the selection of the non-polarized answer "Not Sure" to a significant number of questions in the questionnaire, mostly related to the latent variables Trust, Perceived Risk, Attitude Towards Usage and Behavioural Intention. These high number of "Not Sure" responses resulted in higher correlation between the latent variables although the correlation does not define if there is a positive or negative dependency between the latent variables. After reviewing the survey responses, 11 participants were re-interviewed to understand their perspective of the Palm Vein authentication system. It was found that the limitation in knowledge about the functioning of the Palm Vein Scanner and the security measures involved in the system design were the main reasons for the non-polarized answers for survey questions related to Trust and Perceived Risk variables. In case of the variables Attitude Towards Usage and Behavioural Intention, it was found that the users are reluctant towards using a new biometric authentication system without prior knowledge, privacy concerns and lack of trust, which therefore resulted in "Not Sure" responses. This was also reported in [7] where they found out through focus groups that there is a general lack of awareness among the public which is often exhibited through a low level of trust.

B. NATURE OF RESPONDENTS

A potential limitation to the study of the acceptance of biometric technology is dependent on the socio-demography of the participants [46], [47], where biometric systems are perceived differently by demographically different population. Hence, instead of analysing the users' acceptance of Palm Vein biometric in general, the study should also incorporate the demographic insights.

FIGURE 7. The questionnaire used in the data collection procedure.

C. 5-POINT LIKERT SCALE

It has been observed that the participants are selecting ''Not Sure'' options more often for the questions regarding to PR and T because the participants are not aware of how the Palm Vein Scanner is operating. Consequently, individual knowledge based decisions have been found to be major reasons behind the survey participants to opt for idle answers like ''Not Sure'', ''Not Applicable'', ''Undecided'' etc. These answers are usually used as middle option in odd-ordered Likert scale. These responses do not give clear ideas about the user's preference on the research objectives. Therefore, an even-ordered Likert scale can be recommended, which returns only polarized responses and helps to draw relations between the latent variables in a research.

VIII. CONCLUSION

The Palm Vein biometric authentication is one of the secure alternatives to replace the traditional authentication methods. This research has contributed to bridge the gaps in the existing literature on acceptance of biometric authentication applications for general purposes. The study has also emphasized on the usability of TAM model in studying the users' perception and attitudes towards adoption of Palm Vein technology in self-service applications. Some of the constructs from the proposed artefact have been beneficial to highlight the factors affecting the acceptance of biometric authentications. Perceived Risk, Perceived Enjoyment and Trust have been found to be an important factor that could be used to predict the acceptance of such biometric technologies. The data

were collected with the help of on-site survey and analyzed using IBM SPSS Statistics and IBM SPSS AMOS to find the relation between Palm Vein system adoption and external factors Trust, Perceived Risk, Perceived Enjoyment and Personal Innovativeness. This survey reveals that for a Palm Vein authentication technology to be accepted by general users, the focus should be on making it easy to operate and be useful such that it could be used to increased productivity or services for individuals. Statistically significant evidence was found to indicate that Perceived Usefulness, Perceived Risk and Perceived Enjoyment are predictive of the users' intention to use the Palm Vein biometric authentication such that Palm Vein authentication are perceived to be useful by users who are interested in new technologies and enjoy using these types of technologies. On the other hand, the impact of Personal Innovativeness on Perceived Usefulness and overall acceptance of Palm Vein Scanner is not conclusive. More study needs to be done to identify and study the direct and indirect influences of these variables. Thus, further research is recommended by using the results of this result to investigate the complete application of TAM for Palm Vein authentication and its extensions.

IX. FUTURE WORK

Based on the research outputs, it can be observed that there is still room for model improvement. One of the main limitations of the model were the lack of sufficient data to verify the validity of the model. The model could be enhanced by expanding the data sample size, which could provide more flexibility for the constructs and their relations and possibly obtain an improvement in the model fit. The proposed research model was able to find a significant relationship between Trust and user's Attitude Towards Usage of the Palm Vein Scanner. The model can thus, further be extended to study the antecedents of Trust and Perceived Risks associated with using such biometric devices. This can be developed to understand the primary motivators that users take into account while gauging the extent of risks associated with the device and their level of trust.

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APPENDIX

The confirmatory factor analysis has been illustrated in Fig. 6. Besides, following the questionnaire, given in Fig. 7, has been used to survey the demographics of participants and their experience with the Palm Vein authentication system. The scale used to collect the responses from the participants in the questionnaire has the following options: 1 (Strongly disagree), 2 (Disagree), 3 (Not sure), 4 (Agree), and 5 (Strongly Agree).

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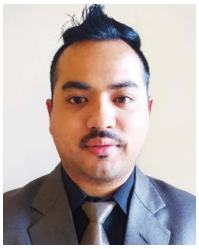

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