RaspiMonitor: A Raspberry Pi Based Smart Home Monitoring System

Mrinal Sharma
School of Digital Technologies,
Middlesex University Mauritius
Uniciti, Flic-en-Flac, Mauritius
m.sharma@mdx.ac.mu

Ameerah Assotally
School of Digital Technologies,
Middlesex University Mauritius
Uniciti, Flic-en-Flac, Mauritius
a.assotally@mdx.ac.mu

Girish Bekaroo
School of Digital Technologies,
Middlesex University Mauritius
Uniciti, Flic-en-Flac, Mauritius
g.bekaroo@mdx.ac.mu

***Abstract*—Novel technological infrastructure such as smart homes have undergone major developments during recent years. Owing to the numerous benefits brought about by smart homes, research on the topic has been increasing at an exponential rate, bringing quality properties such as security, usability, reliability, and others. Despite their various advantages, smart homes have not been in a positive spotlight regarding security and reliability. The main reason that people are hesitant towards adopting an implemented intelligent system at their domicile is due to the lack of trust they allocate to the electronics. As such, this paper provides insights on an innovative and low-cost smart home monitoring system named RaspiMonitor. While the central aim of the system is to offer a robust smart home architecture which discreetly caters for the safety and security of its environment, it also helps in reducing energy wastage. The RaspiMonitor was carefully designed using dynamic web-based services in addition to an evaluation which quantified its usability and acceptance through the Technology Acceptance Model (TAM) with 6 constructs. Results in principle portray acceptance of the system with a mean score of 4.47. This indicates that a robust hardware and software architecture such as the RaspiMonitor is useful, convenient, and easy to use.**

Keywords—RaspiMonitor, Smart Home, Internet-of-Things, Intelligent Environments, Raspberry Pi, Technology Acceptance

I. INTRODUCTION

Internet of Things (IoT) and Intelligent Environment (IE) services are becoming increasingly popular, due to mostly every object being available for easy plug and play IP connectivity. Amongst, smart homes are regarded as "killer applications" for their consumer appeal, reachability, and marketability [1]. Intelligent Environments have real-life applications in industries, such as agriculture, trading, retailing, financing, legal, transportation, government, or healthcare amongst others [2]. Thus, a smart home can be defined as an IE that is able to procure and apply knowledge it has on its users and their space to dynamically meet the core aim like comfort, automation, or efficiency [3]. Typical smart homes offer the owner tools that help in controlling smart devices via a mobile app or a web app. The smart home devices propose security, peace of mind, and convenience to the user through a host of devices as quality properties [4]. With growing amount of interest in this field, it is important to distinguish and select between a thriving combination of sensors to achieve better results. The quality properties of these systems also add a layer of complexity since there are more variables to cater for. However, to be able to apply the knowledge and offer features like efficiency and comfort, there are some compromises to be made in terms of quality attributes. For example, the user friendliness, security, and reliability are all affected in diverse ways when first being designed. Budgeting, product quality, and resources are some of the constraints that must be accommodated for before the project's development cycle starts. Since there are very few contributions from research in this area the development of RaspiMonitor was initiated which would address the gaps with quality properties. The aim was to create a smart home monitoring system that caters for the security and safety of its environment, with sensor integration and data fusion for the user to be aware of their usage pattern.

A prominent issue with smart home products is that the data collected is sent to remote servers for processing and the local home network are mostly vulnerable to attacks. Thus, to address these compromises made on quality attributes, the proposed solution aims at offering a robust smart home architecture which provides usability, reliability, and security as quality properties amongst others. Additionally, limited work has been found on this topic, therefore, this paper could potentially inspire other research work. Through a usability assessment such as Technology Acceptance Model (TAM), detailed insights can be availed from best design practices. Therefore, adoption and user experience of these systems can be improved from results obtained. The results of the usability evaluation performed through TAM is discussed in this study and can be helpful to other research in this area whist still building on top of the limitations pointed out in the conclusion.

The paper structure is as follows: Section II explores and reviews few studies carried out in the smart home domain. Section III describes the proposed system. Section IV and V describe the evaluation methodology and results respectively. Finally, Section VI concludes the study and points towards possible future research.

II. RELATED WORKS

Since IoT is a vast research area, various related studies have been conducted in the past that relate to this research. For instance, a previous study implemented and explored a low-cost and multi-faceted home automation system based on Arduino microcontroller [5]. This system has capabilities of integrating appliances and equipment automation. Additionally, it can provide thermal comfort control and energy management using a Wi-Fi router and voice enabled light controls. Another study made a case for a cost effective and energy efficient IoT system [6]. The system provided continuous environment monitoring through an Arduino board and a Raspberry Pi based solution over Wi-Fi. It also makes efficient power management decisions that help reducing energy wastage via a mobile app. Moreover, a recent systematic literature review [7] discussed different smart homes design strategies. In the same study, a smart home modification process was also proposed, meant for addressing quality properties of the home, particularly useful for elderly people. In cases where IE systems are using open systems, they can be the target of DoS or DDoS attacks. Additionally, in cases where there is a data breach, there can be multiple open ends that may expose the user's behaviour, habits, and privacy.

After reviewing the papers [5]-[7] the trade-off between user-friendly interface and data security could be noted. Smart homes must include a network of sensors that are strictly considered and implemented to help or assist the user. Thus, this study attempts at modelling a smart home system that considers and addresses multiple quality properties, namely: security, reliability, user control, usability, efficiency, and context completeness. Additionally, their acceptance is essential to study.

III. SMART HOME DESIGN & DEVELOPMENT

Due to lack of trust, security and reliability in existing systems, a cheap, innovative, and user-friendly smart home system named RaspiMonitor was designed and developed. The prototyping methodology was used to develop RaspiMonitor since it prevents issues such as delays and reworks during development. The proposed solution also presents a dynamic web interface implemented using Model-View-Controller (MVC), hosed on a Raspberry Pi that provides access to unprecedented statistics by applying Artificial Intelligence techniques. The k-means clustering algorithm was implemented in python for the AI part. Graphs of the electricity consumption (processed in the background by the Raspberry Pi) to predict the usage and alert the user through advice or alerts on saving energy. This assists the user in making better energy conservation decisions in the future and have access to unprecedented, detailed knowledge. Also, notifications by the system provided insights into usage and tips to improve efficiency. The system assures a safe environment through monitoring of the house by the usage of sensors that check for any noxious contents (air quality) or intrusion. Table I provides detail on RaspiMonitor hardware and their use. All information from the sensor, user, and server is stored in an encrypted folder to which only the root user has access to. This provides increased security and integrity of the data. Additionally, the Raspberry Pi is segregated from the Internet, which keeps the smart home network safe from potential hackers and a minimum amount of data is gathered that helps in reducing traceability to the original user. The user interface is customisable and data confidentiality as well as protection mechanisms have also been assured. The purpose of providing these features is for the user to be in control of their home and collected data. This project improves on existing products by providing customer personalisation, analytics, flexibility, and energy saving features from post-processing analysis through AI.

Fig. 1 and Fig. 4 below depict a couple key screen of the web application, which can be used to monitor the home environment in real time through interactive charts, notifications and manage users. Fig. 2 illustrates the system's architecture diagram and communication. Fig. 3 represents the actual system with completed circuit. During the initial stages of this process, the components were configured and individually tested for any fault. Description for the sensors are as follows:

TABLE I. HARDWARE USED FOR RASPIMONITOR

Device	Model	Use
Raspberry Pi	Pi 4 Model B	Hosts the webserver & MySQL. Wirelessly links with the Arduino to receive and store sensor data.
Arduino Nano	With ATmega328	Acts as interface to send sensor related data to the Raspberry Pi.
CT Sensor	SCT013	Reads the intensity of current passed through its conductor to calculate power.
Gas Sensor	MQ-2 & MQ-6	Monitors air quality for hazardous gas or LPG.
PIR	HC-SR505	Constantly monitors for any intrusion (physical) in the area.
Transceiver	NRF24L01+	Sends & Receives data from sensor to Raspberry Pi wirelessly.

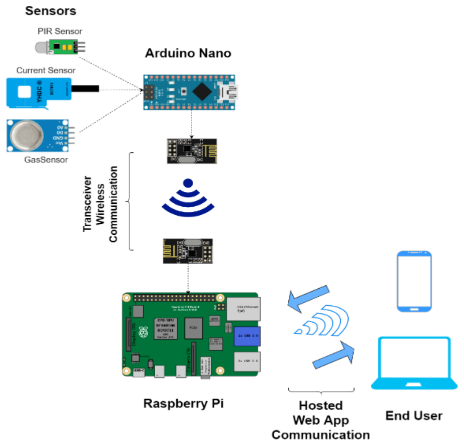

Fig. 2. RaspiMonitor Architecture Diagram

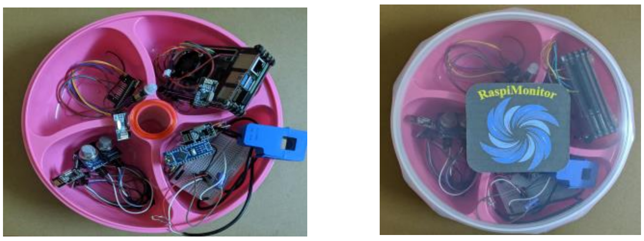

Fig. 3. RaspiMonitor

IV. EVALUATION

Once the project was fully implemented and tested, the final phase was to conduct its user evaluation to quantitatively

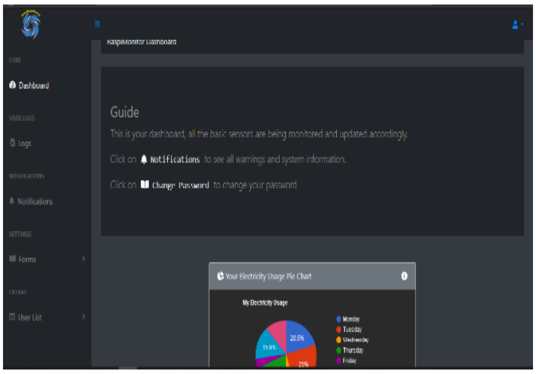

Fig. 1. Web App Dashboard

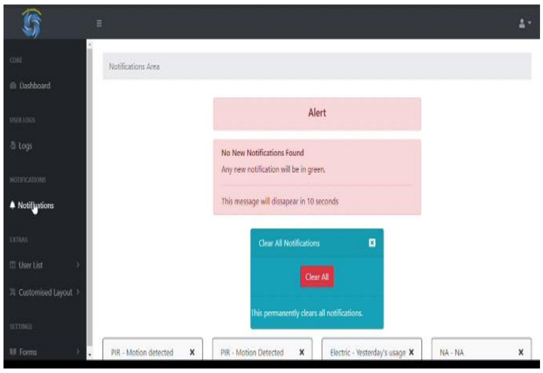

Fig. 4. Notifications Area.

assess its acceptance. The aim of this part of the study was to quantify the overall work using a tried and tested model. This was planned and carried out sequentially consisting of 5 phases, namely:

A. *Design the Study Structure*

For evaluating acceptance of RaspiMonitor, the Technology Acceptance Model (TAM) was selected as it has been backed by numerous researchers and experiments throughout the years [8]. Another advantage with TAM is that it can be combined with other key constructs that link to the studies' requirements. The goal was also to create a comprehensive adoption model that combines aspects of the TAM and assesses how far the features provided by RaspiMonitor might be accepted by the users [9][10]. Within TAM, the constructs investigated were perceived ease of use (PEOU), perceived usefulness (PU), continuance intention to use (CIU), and actual use (AU) were adopted from previous studies [11]-[13]. It has also previously been argued that TAM can be combined with different constructs with weights to complete an acceptance evaluation [14]. Thus, for the TAM questionnaire an adapted evaluation methodology was designed as data collection instrument by analysing previous studies like [15]-[19]. This implies that through the adapted model a good measure for the technology acceptance of the project can be achieved whilst ensuring quality with statistically reliable results [20]. The constructs used as part of the TAM questionnaire are defined in TABLE II. below:

TABLE II. TAM ATTRUBUTES DEFINITION

Attribute	Definition
Perceived Convenience (PC)	The level of convenience toward time, place, and execution that users feel while carrying out an action on the application.
Perceived Ease of Use (PEOU)	The level to which users feel using the technology will be effortless.
Perceived Usefulness (PU)	The level to which users feel that utilisation of a certain technology will help in enhancing the action success.
Attitude Towards Using (ATU)	Attitude that one feels, usually positive, toward the application.
Continuance Intention to Use (CIU)	The level of willingness users have to continue using the application in the future.
Actual Use (AU)	The frequency of actually using the technology.

Prior to conducting the study ethics compliance for evaluation of research projects were studied and adopted. Then, a pilot study was undertaken in order to finalise the evaluation process and procedures.

B. *Recruit Participants*

Following the finalisation of the evaluation process, participants were individually recruited for the study via email or WhatsApp. During this procedure a brief on the study was provided to the participant before requesting for their informed consent using online form. There were 40 participants that agreed to take part in the study, which fulfilled the minimum number of users required for this TAM survey [21].

C. *System Interaction*

After giving their consent, participants were asked to navigate and comprehend the solution. As users interacted with the solution, the interaction was captured through screen-record, for post-interaction analysis. This was done to achieve observational evaluation which helps in identifying any usability problems and in pointing out prospects for improvement with the user interface. During this process notes on any possible issues were taken whist the users acted naturally.

D. *Data Collection*

After interacting with the application, the participants were asked to complete filling of the questionnaire. The questionnaire consisted of 2 main sections dedicated to capture the demographic details and the TAM constructs. All 6 constructs were graded on a Likert-5 scale with request to additional open-ended questions via a suggestions area. The scale was labelled as, 1 - Strongly Disagree, 2 - Disagree, 3 – Neither Agree Nor Disagree, 4 - Agree, 5 - Strongly Agree.

E. *Data Analysis*

Once the data was successfully collected it was thoroughly checked for its reliability and integrity. After the compilation process, the data was imported on IBM SPSS to perform statistical analysis [18][22][23]. The software enabled easy representation of data, through the constructs shown in TABLE III. Key statistics and graphs were also generated to better represent the results. The results have been shared and discussed in the section V.

TABLE III. TAM ATTRUBUTES, CONSTRUCTS, & STATEMENTS

Attribute	Item	Statement
Perceived Convenience	PC1	Using RaspiMonitor is comparable to other smart home systems in my experience.
	PC2	Using RaspiMonitor fits well with the way I like to engage with web apps.
	PC3	Using RaspiMonitor fits my lifestyle.
Perceived Ease of Use	PEOU1	I think learning to use RaspiMonitor was easy.
	PEOU2	I think navigating for what I want through RaspiMonitor was easy and flexible.
	PEOU3	I think becoming skilful at using RaspiMonitor is easy.
	PEOU4	I think using RaspiMonitor is easy.
	PEOU5	My interaction with RaspiMonitor would be clear and understandable.
Perceived Usefulness	PU1	Using RaspiMonitor enhances my awareness on environment of my home.
	PU2	Using RaspiMonitor would better assist me control my electricity usage.
	PU3	I think using RaspiMonitor is very beneficial for me.
	PU4	I find RaspiMonitor useful tool to help people assess their home security and wellness.
Attitude Towards Use	ATU1	It is a positive influence for me to use RaspiMonitor.
	ATU2	Developing a Smart Home Monitoring System via RaspiMonitor was a good idea.
	ATU3	Developing a Smart Home Monitoring System via RaspiMonitor was a wise idea.
	ATU4	Developing a Smart Home Monitoring System via RaspiMonitor was a pleasant idea.
Continuance Intention to Use	CIU1	Assuming I had access to RaspiMonitor, I intend to use it.
	CIU2	Given that I had access to RaspiMonitor, I predict that I would use it
Actual Use	AU	How often do you use a smart home monitoring system?

V. RESULTS & DISCUSSIONS

The results collected represented a demographic of 16 females and 24 males, which is respectively 40% and 60%. As for age distribution, 57.5% of participants were within the age group 18-24 years pursuing an undergraduate degree, 20% of participants were in the age group 25-39 years, 15% were in the group 40-59 years and 7.5% were 60 years plus with at least an undergraduate degree. These are graphically represented in Fig. 5. The participants owned a smartphone and had access to internet. They also used both as part of their daily lives. The upcoming sections will lay emphasis on the results obtained and will provide a comprehensive critical analysis of the outcome derived from the 6 TAM constructs.

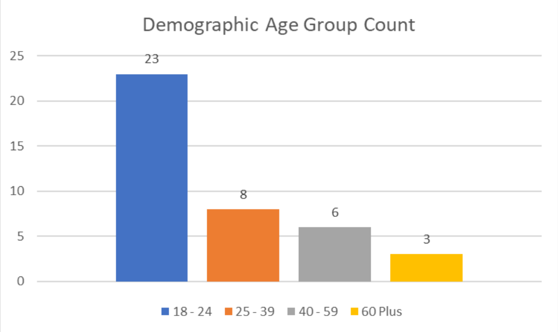

Fig. 5. Demographic Age Group

A. *Perceived Convenience*

Overall, the participants found RaspiMonitor convenient to use with an average score (avg. pts. in Table IV) of 4.22. PC2 achieved the highest mean score showing that participants liked the way they engaged with the web app. PC2 and PC3 collected the highest average score of 4.45 and 4.35 each, showing that participants recognised that RaspiMonitor can be used in their everyday life to track their daily electricity consumption, minimise risks at home caused by LPG gas leakage and contribute to an overall safe environment. On the other hand, PC1 recorded the lowest mean of 3.85 where 35% of the people were neutral. A reason to this might be due to the lack of awareness and use of smart homes in the demographic. Also, the most common use of smart devices among participants involved safety cameras, automatic door, irrigation system or lighting. For PC2, 7.50% people were neutral about the use of the website. Doing the study online may have contributed to this condition, hence resulting in usage difficulties. PC3 recorded 10% neutral reaction which can be due to the absence of desired features of user. Some participants did mention that water consumption monitoring could have been a major improvement to the system. Results are depicted in Table IV.

TABLE IV. PERCEIVED CONVENIENCE RESULTS

Construct Statement	1	2	3	4	5	Avg. Pts
	Percentage (%)					
PC1: Using RaspiMonitor is comparable to other smart home systems in my experience.	2.5	0.0	35.0	35.0	27.5	3.85
PC2: Using RaspiMonitor fits well with the way I like to engage with web apps.	0.0	2.5	7.5	32.5	57.5	4.45
PC3: Using RaspiMonitor fits my lifestyle.	2.5	0.0	10.0	35.0	52.5	4.35

B. *Perceived Ease of Use*

As portrayed Table V, the scores indicate that the participants faced little to no difficulty at not only using but also understanding the way of manipulating the web app. With 70% participants strongly agreeing that learning to use RaspiMonitor was easy, as seen in PEOU1. It can be concluded that the User Interface was properly built to the users liking using Nielsen Heuristic, HCI Theories and suits different user persona as well. PEOU2 and PEOU5 recorded the lowest average of 4.55. For the construct PEOU2 had 2.50% of responses as disagree and 7.50% neutral. The flow of navigation could have been disrupted because of unstable internet connection thereby affecting the user experience quality. However, when taking into consideration the 7.50% being neutral responses when evaluating clarity and understanding of interaction with RaspiMonitor, it can be concluded that some features of the web app and their configuration might not have contributed to the ease and flexibility in navigation. Since the system was not fully installed in the participant's house, the person might be confused about the source of data being shown. Both PEOU3 and PEOU4 showed positive response with above 90% participants agreeing or strongly agreeing to the ease of use of RaspiMonitor. A goal of HCI learning is to have a much richer vocabulary in talking about positive user experiences and the design characteristics that contribute to them – e.g., learnability, memorability, consistency, etc. Therefore, these user experience concepts and expressions embedded into the web application reflected into the real-world user experience during evaluation and were captured with the use of the PEOU construct.

TABLE V. PERCEIVED EASE OF USE RESULTS

Construct Statement	1	2	3	4	5	Avg. Pts
	Percentage (%)					
PEOU1: I think learning to use RaspiMonitor was easy.	0.0	0.0	5.0	25.0	70.0	4.65
PEOU2: I think navigating for what I want through RaspiMonitor was easy and flexible.	0.0	2.5	7.5	22.5	67.5	4.55
PEOU3: I think becoming skilful at using RaspiMonitor is easy.	0.0	0.0	10.0	22.5	67.5	4.58
PEOU4: I think using RaspiMonitor is easy.	0.0	0.0	7.5	25.0	67.5	4.60
PEOU5: My interaction with RaspiMonitor would be clear and understandable.	0.0	0.0	7.5	30.0	62.5	4.55

C. *Perceived Usefulness*

For this construct, PU1, PU2 and PU4 achieved a mean score of 4.60, as shown in Table VI, thereby asserting itself as a useful system. In PU1, all participants agreed or strongly agreed to the fact that RaspiMonitor enhances the awareness of their home environment. PU2 and PU4 recorded 95% participants who agreed or strongly agreed each with 5% being neutral. One of the reasons for which participants were unbiased towards the assistance provided by RaspiMonitor to control electricity, is because the system did not monitor the energy consumption of specific appliances. As improvements it was suggested that the system should monitor appliances consuming excess power. Construct PU3 recorded the lowest mean with a score of 4.43 among which 7.50% participants were neutral towards how the use of RaspiMonitor was beneficial to them. As mentioned in the previous sections, since the system was not fully installed at user's domicile, the advantages of the smart home monitoring system were hard to determine for the users.

TABLE VI. PERCEIVED USEFULLNESS RESULTS

Construct Statement	1	2	3	4	5	Avg. Pts
	Percentage (%)					
PU1: Using RaspiMonitor enhances my awareness on environment of my home.	0.0	0.0	0.0	40.0	60.0	4.60
PU2: Using RaspiMonitor would better assist me control my electricity usage.	0.0	0.0	5.0	30.0	65.0	4.60
PU3: I think using RaspiMonitor is very beneficial for me.	0.0	0.0	7.5	42.5	50.0	4.43
PU4: I find RaspiMonitor useful tool to help people assess their home security and wellness.	0.0	0.0	5.0	30.0	65.0	4.60

D. *Attitude Towards Use*

The average score for this construct is 4.61, and with the observation study in parallel a positive attitude was noted among the participants whist using the interface. The highest mean score was 4.68 and was achieved by ATU2 where 67.50% participants strongly agreed that the development of RaspiMonitor was a good idea as shown in Table VII. With a score of 4.45, ATU 1 was the lowest average score where 10% of participants were neutral towards the positive influence of using RaspiMonitor. The reason for this might be because the evaluation allowed participants to interact directly with only the web app and not with the hardware. Therefore, the participants have not experienced the complete use of the smart home experience provided by RaspiMonitor. Overall, for this construct, since the percentage of participants who strongly agreed or simply agreed to statements ATU2, ATU3 and ATU4 cumulate to at least 97.50%, it can be concluded that the development of RaspiMonitor was a good, wise, and pleasant idea.

TABLE VII. ATTITUDE TOWARDS USE RESULTS

Construct Statement	1	2	3	4	5	Avg. Pts
	Percentage (%)					
ATU1: It is a positive influence for me to use RaspiMonitor.	0.0	0.0	10.0	35.0	55.0	4.45
ATU2: Developing a Smart Home Monitoring System via RaspiMonitor was a good idea.	0.0	0.0	0.0	32.5	67.5	4.68
ATU3: Developing a Smart Home Monitoring System via RaspiMonitor was a wise idea.	0.0	0.0	0.0	35.0	65.0	4.65
ATU4: Developing a Smart Home Monitoring System via RaspiMonitor was a pleasant idea.	0.0	0.0	2.5	30.0	67.5	4.65

E. *Continuance Intention to Use*

With an average score of 4.38, the participants' willingness to continue using the application in the future was confirmed, as shown in Table VIII. The construct CIU2 had the best mean score with 4.43. 60% participants were very confident that they would use RaspiMonitor if they had access to it. However, the first construct, which evaluates the user's intention rather than the user's confidence, bares a score of 4.33 with 2.5% strongly disagreeing to using the system. Participants pointed out the lack of some features which they would prefer having in their smart home. The most requested characteristic was the implementation of smart switch for unused devices. Detection of water wastage was also a desired feature. People with garden suggested the addition of a soil moisture sensor for better crop harvest. Lastly, some participants proposed that whenever abnormal levels of carbon dioxide are recorded, the needful emergency services to be called automatically.

TABLE VIII. CONTINUANCE INTENTION TO USE RESULTS

Construct Statement	1	2	3	4	5	Avg. Pts
	Percentage (%)					
CIU1: Assuming I had access to RaspiMonitor, I intend to use it.	2.5	2.5	7.5	35.0	52.5	4.33
CIU2: Given that I had access to RaspiMonitor, I predict that I would use it.	0.0	2.5	12.5	25.0	60.0	4.43

F. *Actual Use*

The average score of 2.23 in Table XI indicates that most users were non-smart home users. While 10% of the participants used smart homes frequently and always found the tool interactive but criticised lack of range of sensors and a CCTV operational system. 47.5% of the non-smart home users expressed their positive interest to try it at least once.

TABLE IX. ACTUAL USE RESULTS

Construct Statement	1	2	3	4	5	Avg. Pts
	Percentage (%)					
AU: How often do you use a smart home monitoring system?	47.5	12.5	20.0	10.0	10.0	2.23

G. *General Discussions*

The overall scores of the constructs indicate that the development of this project created a positive impact. For the 6 constructs evaluated within TAM in this study an overall mean score of 4.47 was obtained. Fig. 6 summarises the average score of each TAM construct and this indicates the acceptance of the smart home monitoring system by the participants. Overall, a positive impact on the usability of the system was recorded, hence the trustworthiness is also validated due to their linked relationship [13]. The partakers found the smart home system convenient, easy to use, useful, and showed a positive attitude towards using it. They also expressed their positive intention to use a similar tool in the near future. Therefore, the smart home systems' usability was accepted by the users. Even though the application of TAM derived insightful findings on the acceptance of RaspiMonitor, different limitations undermine the findings revealed. A larger sample size would have been more representative for the application of TAM. The larger sample size would also help to study further aspects, such as the corelation between acceptance and participant' knowledge and usage of IT. Additionally, another limitation to the study is that users spent limited time with the system.

As for the hardware costs to build the project, the overall expenses accounted for less than £95. For a future version, video monitoring and other sensors such as thermal, water flow, and humidity could be implemented. The evaluation study can be extended to investigate on the use, trust, performance, and quality allocated to the system like investigated in [23]. Moreover, the cyber-security of the system should also be evaluated for the quality properties deployed. The Raspberry Pi is not a full-fledged server, it does not have SSL keys for web browser to server encryption. This can be added as an additional security layer. Furthermore, the use of solar powered batteries could be beneficial to power the Arduino Nanos since they consume only five volts. Finally, introducing other emerging technologies such as Blockchain, Cloud Computing or Big Data to solve constraints experienced in current systems can be the way forward [24]. Also, future research could lie in proposing a detailed IoT requirements gathering framework which caters for quality properties.

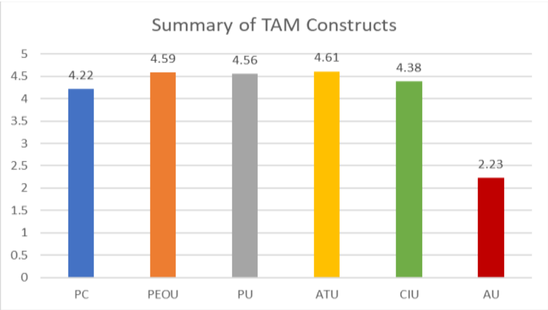

Fig. 6. TAM Constructs Summary

VI. Conclusion & Future Works

This paper explored the implementation and technology acceptance of a smart home monitoring system named RaspiMonitor. Due to the lack of multiple quality property systems, an innovative, reliable, cheap, and trustworthy Smart Home Monitoring System was developed. RaspiMonitor was evaluated using the TAM which measured its usability and acceptance. This was done to validate the work since successful delivery of such systems is a complex and challenging feat to achieve. The evaluation was conducted involving 40 participants with a mix of age groups. Following the TAM analysis, results reveal an overall mean score of 4.47. Limitations with the TAM survey was that the participants only interacted with the system for a short amount of time. This can be further investigated as future work, where the system is fully installed in their domicile and tested for longer including the user's lifestyle The cyber-security of the system was also not tested, this could have been achieved througha framework. Although the system did not face any security issues during the tests performed further investigation can be made by testing or evaluating the systems' cyber security.

References

[1] J. Shin, Y. Park and D. Lee, "Who will be smart home users? An analysis of adoption and diffusion of smart homes", Technological Forecasting and Social Change, vol. 134, pp. 246-253, 2018.

[2] N. Shahid and S. Aneja, "Internet of Things: Vision, application areas and research challenges", 2017 International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), 2017.

[3] T. Perumal, M. Sulaiman, K. Sharif, A. Ramli and C. Leong, Development of an embedded smart home management scheme", International Journal of Smart Home, 2013.

[4] T. Gunawan, I. Yaldi, M. Kartiwi and H. Mansor, "Performance Evaluation of Smart Home System using Internet of Things", International Journal of Electrical and Computer Engineering (IJECE), vol. 8, no. 1, p. 400, 2018.

[5] S. Gunputh, A. P. Murdan and V. Oree, "Design and implementation of a low-cost Arduino-based smart home system," 2017 IEEE 9th International Conference on Communication Software and Networks (ICCSN), pp. 1491-1495, 2017.

[6] L. Mehdi, Y. Ouallou, O. Mohamed and A. Hayar, "New Smart Home's Energy Management System Design and Implementation for Frugal Smart Cities", 2018 International Conference on Selected Topics in Mobile and Wireless Networking (MoWNeT), 2018.

[7] C. Ma, O. Guerra-Santin and M. Mohammadi, "Smart home modification design strategies for ageing in place: a systematic review", Journal of Housing and the Built Environment, 2021.

[8] W. King and J. He, "A meta-analysis of the technology acceptance model", Information & Management, vol. 43, no. 6, pp. 740-755, 2006.

[9] C. Gross, M. Siepermann and R. Lackes, "The Acceptance of Smart Home Technology", Lecture Notes in Business Information Processing, pp. 3-18, 2020.

[10] E. Rogers, Diffusion of Innovation, 5th ed. New York: The Free Press, 2003.

[11] V. Venkatesh and F. Davis, "A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies", Management Science, vol. 46, no. 2, pp. 186-204, 2000.

[12] V. Venkatesh and M. Morris, "Why Don't Men Ever Stop to Ask for Directions? Gender, Social Influence, and Their Role in Technology Acceptance and Usage Behavior", MIS Quarterly, vol. 24, no. 1, p. 115, 2000.

[13] C. Acemyan and P. Kortum, "The Relationship Between Trust and Usability in Systems", Proceedings of the Human Factors and Ergonomics Society Annual Meeting, vol. 56, no. 1, pp. 1842-1846, 2012.

[14] T. Cheney, "An Acceptance Model for Useful and Fun Information Systems", Human Technology: An Interdisciplinary Journal on Humans in ICT Environments, vol. 2, no. 2, pp. 225-235, 2006.

[15] B. Hensel and G. Demiris, "Technologies for an Aging Society: A Systematic Review of “Smart Home” Applications", Yearbook of Medical Informatics, vol. 17, no. 01, pp. 33-40, 2008.

[16] Y. Zhai, Y. Liu, M. Yang, F. Long and J. Virkki, "A Survey Study of the Usefulness and Concerns about Smart Home Applications from the Human Perspective", Open Journal of Social Sciences, vol. 02, no. 11, pp. 119-126, 2014.

[17] M. Hubert, M. Blut, C. Brock, R. Zhang, V. Koch and R. Riedl, "The influence of acceptance and adoption drivers on smart home usage", European Journal of Marketing, vol. 53, no. 6, pp. 1073-1098, 2019.

[18] A. Santokhee, G. Bekaroo and D. Roopowa, "Hazard Perception Training and Assessment of Young Drivers in Mauritius: Investigating the Acceptance of the MauHazard Tool," 2019 Conference on Next Generation Computing Applications (NextComp), pp. 1-6, 2019.

[19] A. Thanacoody, G. Bekaroo, A. Santokhee and S. Juddoo, "Analyzing the Prospects and Acceptance of Mobile-Based Marine Debris Tracking", Smart and Sustainable Engineering for Next Generation Applications, pp. 256-267, 2019.

[20] P. Legris, J. Ingham and P. Collerette, "Why do people use information technology? A critical review of the technology acceptance model", Information & Management, vol. 40, no. 3, pp. 191-204, 2003.

[21] G. Bekaroo, R. Sungkur, P. Ramsamy, A. Okolo and W. Moedeen, "Enhancing awareness on green consumption of electronic devices: The application of Augmented Reality", Sustainable Energy Technologies and Assessments, vol. 30, pp. 279-291, 2018.

[22] R. Ibrahim, N. Leng, R. Yusoff, G. Samy, S. Masrom and Z. Rizman, "E-learning acceptance based on technology acceptance model (TAM)", Journal of Fundamental and Applied Sciences, vol. 9, no. 4, p. 871, 2018.

[23] Y. Ramessur and G. Bekaroo, "Promoting Events within Communities in Mauritius: Exploring the Use and Acceptance of NuLendroit Mobile Application," 2020 3rd International Conference on Emerging Trends in Electrical, Electronic and Communications Engineering (ELECOM), pp. 100-105, 2020.

[24] S. Gill et al., "Transformative effects of IoT, Blockchain and Artificial Intelligence on cloud computing: Evolution, vision, trends and open challenges", Internet of Things, vol. 8, p. 100118, 2019.