Factor of Technology Acceptance of Clinicians in Central Infusion Pump Monitoring System: A Case Study at Ruamjairak Hospital in Thailand

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Abstracts: This study investigates into the Central Infusion Pump Monitoring System, utilizing technology to oversee Infusion Pump operations and proactively prevent adverse drug events. The purpose of this study was to find the factors affecting the acceptance of technology in the use Central Infusion Pump Monitoring System by medical personnel at Ruamjairak Hospital in Thailand. It would be beneficial in terms of management and the decision to use a Central Infusion Pump Monitoring System. The sample consisted of 69 individuals that use infusion pump and working in Ruamjairak hospital for not less than 6 months. An online questionnaire was used to collect data by studying personnel factors, technological factors. brand factors, organizational factors, and price factors. The statistics used in this study were Spearman's Rank Correlation Coefficient and the influence on the adoption Central Infusion Pump Monitoring System technology was determined using Stepwise Multiple Regression Analysis. The results find that technological factors, brand factors, price factors, and organizational factors exhibit a significant relationship with the adoption of technology for Central Infusion Pump Monitoring System. The regression coefficients, ordered by influence from most to least, are as follows: technology factor 0.545, brand factor 0.182, price factor 0.137, and organizational factor 0.136. Importantly, personnel factors were found to have no impact on the adoption of technology for Central Infusion Pump Monitoring System. The technological factors, brand factors, price factors, and organizational factors affect with statistical significance at the 0.05 level.

Keywords: Infusion Pump, Central Infusion Pump Monitoring System, Technology Acceptance Model, Unified Theory of Acceptance and Use of Technology, Drug Libraries, Barcode Scanning, Data Management.

1. INTRODUCTION

Adverse drug events (ADEs) are injuries or harm that are related to drug use. No matter what dose of drug is used[1]. Adverse drug events are often the most common cause of patient harm from treatment, with intravenous medication errors being the most likely to cause harm. Case study of pediatric patients experiencing adverse drug events 54% were caused by medication errors in intravenous administration and 60% of life-threatening risks were caused by intravenous drug treatment. Case study in the UK found that 56% of medication errors were due to intravenous medication errors. Moreover, it had been found that adverse drug events that occur while using infusion pump are often caused by incorrect settings[2].

Infusion Pump is a medical equipment used for the administration of intravenous nutrients and drugs which requires accuracy in order for the preset volume and flow rate into the vein correctly. It is a medical equipment for giving solutions od medicines to patients in cases where they want to control or determine the amount given each time, a certain amount and for a specified period of time[3]. An example of a miss-setting of infusion pump found in public reports is a case where morphine was administered at 90 mg/hr instead of 9.0 mg/hr, causing 10 times more than intended. In the neonatal intensive care unit (NICU), the flow rate setting was changed from 3.2 ml/hr to 304 ml/hr instead of 3.4 ml/hr. Inadvertently setting the nitroglycerin dosing unit from mcg/min to mcg/kg/min resulted in 60 times more dosing than intended. In terms of drug concentration, it was found that setting the wrong drug concentration resulted in an overdose. In term of flow rate, an incorrect flow rate setting was found with an in fusion set for more than 24 hr, which may have been incorrectly set to an infusion within 1 hr. The above is an example of an error that occurs when setting up an infusion pump. Therefore, a smart infusion pump has been developed that can reduce medication errors. The technology in the medical device can compile a list of many types of drugs (Drug

libraries), calculate the normal concentration of the drug, can set the amount of medication given each time (Dose Limits), select the dosing unit such as mcg/kg/min, units/hr[2]. Emergency Care Research Institute (ECRI) is a not-for-profit organization that uses applied science research to find the best standard care, equipment and medicine to improve patient health, manufacturer product recalls, warnings, and legal adjustments to services or products[4]. Where ECRI states that infusion pump can determine the dose limits are considered smart infusion pump that safer than device that cannot set dose limits[2]. That is a reason to use a smart infusion pump. In term of central infusion pump monitoring system (CIMS), carious technologies are combined, such as monitoring the operation of many infusion pump and multiple beds together. At the same time, additional technology can be used to reduce errors in medication errors such as using barcode scanning. When there is a CIMS, it will reduce the user's workload and be able to mange other tasks more efficiently[5].

Ruamjairak Hospital in Thailand is a private tertiary hospital, a large general hospital with 100 beds. Its mission is to provide medical serviced of international quality by a multidisciplinary team with modern medical equipment, warm and friendly service to create satisfaction and impression of recipients[6]. Therefore, there must be modern medical equipment, advance technology, safe for patients, convenient and fast, saving time for users and service recipients. This hospital therefore must have a smart hospital system that uses technology to support service management within the hospital, reduce steps, facilitate service providers and service recipients[7]. Starting from registering patients, recording examination results, recording treatment results, prescribing medicine, charging service fees, until to discharging patients from the hospital. All of these entries were recorded electronically[8]. As the hospital has just opened its first day of operation which is September 9,2022. Therefore, the medical equipment system is still incomplete and still lacks many types of tools necessary for treatment. In particular, there must be a large number of medical equipment within the hospital, such as infusion pump. To meet its mission, the hospital required a large number of smart infusion pump. When there are a large number of equipment, a center can be established to monitor the operation of smart infusion pump. Because it is a system that has never been installed in a hospital before, it must be understood and learned again, causing doctors, nurses, related staff to be un familiar with it and not wanting to learn. This causes the use of central infusion pump monitoring system to be ineffective, causing delays in operations of errors while treating patients. This is something that should not happen and can be corrected before any accidents occur.

From the background and importance of the problem of using central infusion pump monitoring system of medical personnel at Ruamjairak hospital in Thailand. The researcher, who is a biomedical engineer at this hospital, therefore had the idea of using technology acceptance theory to study the factors affecting acceptance by doctors, nurses, staff who use it. The results of the study were then used to improve and develop the management of infusion pump with the aim of making medical personnel accept the use of central infusion pump monitoring system.

2. MATERIEL AND METHODS

2.1. Central Infusion Pump Monitoring System (CIMS)

CIMS have become an important part of the development of medical equipment and devices using the IOT (Internet of Things). Technology of this system is an important component of infusion pump, with the development of a variety of operating systems and tools. In particular, real-time signal transmission is very important because it can affect the patient's situation. Real-time data transmission is therefore the core of central monitoring system in terms of safety and efficiency in patient care[9]. CIMS can wirelessly connect the infusion pump to a center by connecting a number of infusion pump per center, monitoring the operation of multiple infusion pumps per bed, simultaneously monitor multiple beds, recording patient information at center and connecting to the infusion pump that is in use with that patient. Additional technology can be used to reduce errors in giving the wrong medicine and miss-setting by using a barcode scanner at infusion pump, then sending the data back to the center and starting the infusion pump. Centralize notifications as they occur and show the status of running machines. When there is a CIMS, it will reduce the user's workload and be able to manage other tasks more efficiently. The CIMS can store intravenous solution

data as a treatment history, alert history, fluid balance data and display the results as graphs, procedure history. A list of medicines can be added to the center and there is a Dose Error Reduction System (DERs) and the information can be forwarded to infusion pump[5].

2.2. Technology Adoption

2.2.1. TAM

This technology acceptance model tests the acceptance behavior of individuals to determine whether user's intention to use a particular system is influenced by perceived usefulness and perceived ease of use. It can be said that perceived usefulness and perceived ease of use are the main factors influencing attitude toward using, which affects behavioral intention to use the system and actual usage behavior in order[10].

2.2.2. UTAUT

The unified theory of acceptance and use of technology was developed by combining theories that study various human behaviors together, indicating that humans accept the use of technology (Use Behavior) more or less depending on the influence of providing support. Resources and guidance on how to use that technology (Facilitating Condition) and the influence of behavior that shows the intention to use technology (Behavior Intention) [11].

2.3. Studied Factors Literature Review

Table 1. Content Review of Studied Factors Hypothesis

Literature Review				Studied Factors				
Title	Year	Theory	Factor	Human	Technology	Brand	Organization	Price
Nurses views on accepting the creation of a nurses' health monitoring system [12]	2017	TAM	Human	✓				
Nurses' perceptions, acceptance, and use of a novel in-room pediatric ICU technology: testing an expanded technology acceptance model [13]	2016	TAM	Social Influence Facilitating Condition				✓ ✓	
Understanding the Attitudes of Clinicians and Patients Toward a Self-Management eHealth Tool for Atrial Fibrillation: Qualitative Study[14]	2020	TAM	Human	✓				
The Use of UTAUT and Post Acceptance Models to Investigate the Attitude towards a Telepresence	2020	UTAUT	Human Trust in Technology Social Influence	✓		 ✓	 ✓	

Robot in an Educational Setting[15]								
Factors influencing the adoption of mHealth services in a developing country: A patient-centric study[16]	2020	UTAUT	Human Social Influence Facilitating Condition Price	✓			✓ ✓	✓
Nurses' Acceptance of Smart IV Pump Technology[17]	2010	User Experience	Human Implementation Technical Performance Learnability-Memorability Work performance Errors	✓	✓ ✓ ✓ ✓ ✓			

From studying related research and separating variables of interest that may affect the acceptance of the central infusion pump monitoring system, this research was born. Figure 1 shows the framework of the research.

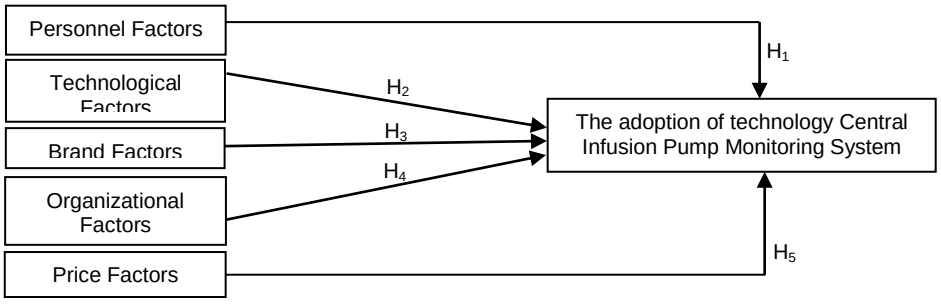

Figure 1. Research hypothesis model.

2.4. Data Collection

The research collected data from primary sources by using questionnaires to collect data from people who used infusion pump within Ruamjairak hospital. Data collection began between July – August 2023. This research has been considered by the Human Research Ethics Committee, Office of Research Ethics, Rangsit University, on August 11, 2023. Certification document number COA. No. RSUERB2023-117 Project code RSU-ERB2023.134.1807. After receiving approval from the Human Research Ethics Committee of Rangsit University, the researcher began collecting data by sending a letter requesting permission to collect data, attaching the research outline and research tools, to the director of Ruamjairak hospital.

The questionnaire is in Thai language and has 3 parts. Part 1: Questionnaire regarding personnel factors of respondents, 7 questions. Part 2: Questionnaire about factors affecting acceptance of the CIMS, 22 questions. The questions are in the form of a rating scale, five-point Likert's scale ranging from strongly agree (5) to strongly disagree (1), asking about the 4 factors studied, there were 12 questions on technology factors, 4 questions on brand factors, 3 questions on organizational factors, 3 questions on price factors. Part 3: 1 additional suggestion is open-ended questions that allow for the freedom to express opinions about the CIMS.

Questionnaire quality was checked by 3 experts with more than 7 years of experience using infusion pumps, by

testing validity and reliability. The Index of Item-Objective Congruence (IOC) was between 0.80-1.00 for all questions and tested the confidence with Cronbach's alpha coefficient by experimenting with a group that had the same characteristics as the study population such as people who used infusion pump and worked within the hospital. The value is between 0.70-1.00, that can be used to collect data and analyze for further research results.

From a population of 80 people, a sample of 67 people was obtained, but when data were collected from online questionnaires, a total of 71 sets were obtained. The questionnaires were checked for completeness, and people who did not meet the criteria were excluded, resulting in 69 respondents.

2.5 Data Analysis

When collecting data from questionnaires from a sample of 69 sets, the questionnaires were checked for completeness. Then the obtained data was analyzed in the form of statistical data for explaining the data using the IBM SPSS Statistics 29 program. Data analysis with test statistics as follows: frequency distribution, percentage, mean, standard deviation, Mann-Whitney U test, Kruskal-Wallis's test, Spearman's rank correlation coefficient test, stepwise multiple regression analysis.

3. RESULTS AND DISCUSSIONS

Table 2. Demographic Data of Respondents

Characteristics	Frequency	Percent (%)
1. Gender		
Male	11	15.5
Female	60	84.5
Total	71	100.0
2. Age (years)		
18 – 25	30	42.3
26 – 35	28	39.4
36 – 45	9	12.7
46 – 55	4	5.6
> 55	0	0.0
Total	71	100.0
3. Type of Position		
Doctor	6	8.5
Nurse	61	85.9
Practical Nurse	2	2.8
Technologist	1	1.4
Biomedical Engineer	1	1.4
Total	71	100.0
4. Department		
OPD	48	67.6
IPD	22	31.0
Back Office	1	1.4
Total	71	100.0
5. Work experience (years)		
< 1	7	9.9
1 – 5	46	64.8
6 – 10	5	7.0
>10	13	18.3
Total	71	100.0
6. Experience in using infusion pump (years)		
No Experience	2	2.8
< 1	10	14.1
1 – 5	43	60.6
6 – 10	4	5.6
>10	12	16.9
Total	71	100.0
7. Period of work at Ruamjairak hospital (months)		
<6	0	0.0
≥6	69	100.0

Total	69	100.0

The demographic characteristics of the 71 responses, about 84.5% are female, and 15.5% are male. Respondents were most to be 18-25 years old, accounting for 42.3%, 26-35 years old, accounting for 39.4%, 36-45 years old, accounting for 12.7%, 46-55 years old, accounting for 5.6%. Type of position, respondents were most to be nurse, accounting for 85.9%, doctor, accounting for 8.5%, practical nurse, accounting for 2.8%, technologist, accounting for 1.4%, biomedical engineer, accounting for 1.4%. The majority of the department where the respondents work are OPD, accounting for 67.6%, IPD, accounting for 31.0%, back office, accounting for 1.4%. The work experience of most respondents were 1-5 years, accounting for 64.8%, more than 10 years, accounting for 18.3%, less than 1 year, accounting for 9.9%, 6-10 years, accounting for 7.0%. In terms of experience in using infusion pump, the majority of respondents had experience for 1-5 years, accounting for 60.6%, more than 10 years, accounting for 16.9%, less than 1 year, accounting for 14.1%, 6-10 years, accounting for 5.6%, no experience, accounting for 2.8%. Those with no experience in using infusion pump will be excluded. The duration of work at Ruamjairak hospital was found that all respondents had a work period of 6 months onwards, accounting for 100.0%. Those who worked at Ruamjairak hospital for less than 6 months will be excluded. From the analysis of the personal data of 71 respondents, 2 respondents were eliminated, remaining 69 respondents. It was found that the majority of respondents were female, aged between 18-25 years, the job type was a nurse, work in OPD, 1-5 years of work experience, 1-5 years of experience in using infusion pump, working at Ruamjairak hospital for 6 months onwards.

Comparing the level of opinions on the factors of adoption of the CIMS within Ruamjairak hospital, classified according to each topic, it was found that personnel factors did not affect the CIMS adoption, males had higher opinions on the factors of CIMS adoption than females, with males having the average opinion level was 4.18$\pm$1.062 points. Ages 18-25 years had the highest level of opinion on the CIMS adoption factor, with an average level of opinion equal to 4.12$\pm$0.854 points. Biomedical Engineer had the highest level of opinion on the CIMS adoption factor, with an average level of opinion equal to 4.14$\pm$0.889 points. Back office had the highest level of opinion on the CIMS adoption factor, with an average level of opinion equal to 4.14$\pm$0.889 points. Work experience of 6-10 years had the highest level of opinion on the CIMS adoption factor, with an average level of opinion equal to 4.16$\pm$0.852 points. Experience in using infusion pump 6-10 years had the highest level of opinion on the CIMS adoption factor, with an average level of opinion equal to 4.19$\pm$0.800 points. From the analysis of the opinions of the respondents, it was found that the overall opinions of the respondents were at a high level with an average of 4.04. The factor with the highest average is the technological factors with an average of 4.19, followed by the price factors with an average of 4.16, next is the organizational factors with an average of 4.00, and last is the brand factors with an average of 3.81, were presented in Table 3.

Table 3. The results of the opinion level analysis on technological factors, brand factors, organizational factors, price factors show the mean and standard deviation.

Variables	Level of in Fluence		
	$\bar{X}$	S.D.	Meaning
Technological Factors	4.19	0.916	High
Brand Factors	3.81	0.895	High
Organizational Factors	4.00	0.855	High
Price Factors	4.16	0.814	High
Total	4.04	0.902	High

Table 4. The results of the analysis of the relationship between technological factors, brand factors, organizational factors, price factors and the CIMS adoption within Ruamjairak hospital.

Variables	CIMS Adoption		
	Spearman's Correlation	Sig.	Meaning

Technological Factors	0.553	<0.001	Moderate
Brand Factors	0.652	<0.001	Moderate
Organizational Factors	0.568	<0.001	Moderate
Price Factors	0.642	<0.001	Moderate
Total	0.604	<0.001	Moderate

When considering the correlation coefficient between variables, it was found that technological factors, brand factors, organizational factors, price factors were related to the CIMS adoption within Ruamjjairak hospital. All variables have a moderate relationship with statistically significant at the 0.05 level, were presented in Table 4.

Table 5. The results of stepwise multiple regression analysis of technological factors, brand factors, organizational factors, price factors

Variables	B	SE	β	t	Sig.
(Constant)	-4.63×10^{-5}	0.002		-0.027	0.979
Technological Factors (X_1)	0.545	0.001	0.546	1056.293	<0.001
Brand Factors (X_2)	0.182	0.000	0.296	651.976	<0.001
Organizational Factors (X_3)	0.136	0.000	0.203	371.433	<0.001
Price Factors (X_4)	0.137	0.000	0.208	367.824	<0.001
$R = 1.000$ $R^2 = 1.000$ Adjusted $R^2 = 1.000$ SE = 0.002					

From technology factors, brand factors, organizational factors, price factors affect the acceptance of CIMS. Therefore, the researcher studied the influence on CIMS adoption based on the Unified Technology Acceptance Theory (UTAUT)[11], were presented in Table 5. Because the constant has a value of -4.63×10^{-5} which is a value close to zero, the researcher does not use it in the equation and uses the coefficients of the predictors to write it as an equation predicting the CIMS adoption within Ruamjairak hospital (Y) as follows:

$$Y = 0.545X_1+0.182X_2+0.136X_3+0.137X_4 \quad (1)$$

Where Y is CIMS adoption within Ruamjairak hospital, X_1 is technological factors, X_2 is brand factors, X_3 is organizational factors, X_4 is price factors.

From the study of factors affecting the adoption of CIMS within Ruamjairak hospital, which includes personnel factors, technological factors, organizational factors, price factors. It was concluded that technological factors, organizational factors, price factors influence the adoption of CIMS within Ruamjairak hospital with statistically significant. Except for personnel factors, there were no statistically significant differences and therefore had no influence on the adoption of CIMS. From the analysis of the data, each factor had important points that could be used to discuss the results to answer the research objectives as follow.

Personnel factors: It was found that gender, age, type of position, department, experience in the position, experience in using infusion pump although difference, but not significantly difference with statistically significant. Therefore it has no influence on the adoption of CIMS with contradicts the UTAUT theory which has auxiliary variables that include gender, age, experience, willingness to use that affect the adoption of the technology[11]. From a review literature, it was found that females are more anxious and less self-confidence than male when using technology[18]. Younger generations are more likely to purchase new products and can provide more information about their user experiences than older generations, based on factors such as memory, enthusiasm, using of new products, Among the older generation, when using any product for a long period of time, it causes habituation and it is difficult to switch to other or new products[19].

Technological factors: The technology of infusion pump and CIMS is important and influences the adoption of CIMS within Ruamjairak hospital. From the analysis of the respondents' opinions, it was found that the majority of respondents give importance to increasing safety in patient care and increasing the work efficiency of users, which is consistent with the review literature that states that many hospitals and clinics are choosing to invest in and deploy new technologies such as mart infusion pump and barcode medication administration technology (BCMA) to reduce medication errors and increase patient safety[17]. In a specialized hospital, Ondo state, Nigeria, it was found that when work efficiency increases, resulting in greater acceptance of technology, training should be provide and users should be able to use the technology continuously[20]. When a tool has various technologies that are beneficial to patients and can increase the work efficiency of the user, there should be other measures to help support the user to accept and use those technologies. This research discuss acceptance of use central infusion pump monitoring system (CIMS).

Brand factors: Since Ruamjairak hospital uses only one brand of infusion pump, it cannot be compared with other brands unless respondents use personal experience. Therfore, the researcher asked for opinions on the quality and reliability of the brands being used. From the analysis of the opinions of the respondents and the influence of the factors, it was found that the majority of respondents gave importance to the CIMS with a drug libraries system. This means that most users find that the CIMS that has drug libraries system of this brand is high quality and trustworthy. And from all questionnaire responses in this factor, it was found that the overall influence score was at a high level. It means users find this brand to be high quality and trustworthy. It is considered that the majority of users have trust in this brand's technology and influence the adoption of CIMS. Which is consistent with the review literature that says trust has direct effect on the behavioral intentions of patients who will choose to use or not use the service. Moreover, it was found that trust affects the perceived usefulness. Therefore, it can be said that trust affects the adoption of the technology in the field of health services[21].

Organizational factors: From the analysis of the respondents' opinions and the influence of the factors, most of the respondents gave importance when their supervisors wanted to use the CIMS. This is consistent with the review literature that states that following a reference group (Subjective Norm) that influencers expect users to adopt the technology will increase their intention to use the technology[22]. At least among people of the same culture, there will be an exchange of experiences in using technology together, which increases the intention to use it and leads to acceptance of the technology[23]. Because Ruamjairak hospital does not yet have CIMS, but has arranged a budget and prepared to install the CIMS. Once the installation is complete, there must be training in use and measures to encourage users to use CIMS. Therefore, having supervisors encourage users to use CIMS helps increase adoption of the technology.

Price factors: From the analysis of the respondents' opinions and the influence of the factors, it was found that the majority of the respondents gave importance to the cost-effectiveness of using CIMS. Consistent with the review literature that says Price Value refers to the level of price that is acceptable and the best value when paid[24]. While using technological services, users tend to compare the purchase price with long-term discounts, so users are more likely to adopt technology when a large discount is available[25].

CONCLUSIONS

From the results of the study, data were collected from 69 respondents who worked at Ruamjairak hospital and used infusion pump, there are factors affecting the acceptance of CIMS, where supervisors or executives and biomedical engineers of the hospital can apply the factors that influence the adoption of CIMS within Ruamjairak hospital in terms of management, deciding to use the CIMS. Those who are generally interested can use the research process and results as a source of information for research and application in finding appropriate management factors in other areas.

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