Mobile-based Hospital Bed Management with Near Field Communication Technology

A Case Study

Meng Chun Lam
Center for Artificial Intelligence Technology (CAIT)
Faculty of Information Science and Technology
Universiti Kebangsaan Malaysia
Bangi Selangor, Malaysia
lammc@ukm.edu.my

Masri Ayob
Center for Artificial Intelligence Technology (CAIT)
Faculty of Information Science and Technology
Universiti Kebangsaan Malaysia
Bangi Selangor, Malaysia
masri@ukm.edu.my

Jun Yang Lee
iFAST Fintech Solutions
Kuala Lumpur, Malaysia
junyang0822@gmail.com

Norizal Abdullah
Center for Artificial Intelligence Technology (CAIT)
Faculty of Information Science and Technology
Universiti Kebangsaan Malaysia
Bangi Selangor, Malaysia
norizal.abdullah23@gmail.com

Faizal Amri Hamzah
Department of Emergency Medicine
Hospital Canselor Tuanku Muhriz
UKM Medical Center
Kuala Lumpur, Malaysia
vit_ron@yahoo.com

Siti Sarah Mohd Zahir
Department of Emergency Medicine
Hospital Canselor Tuanku Muhriz
UKM Medical Center
Kuala Lumpur, Malaysia
sarahirissa821@gmail.com

***Abstract*—Bed management is one of the most crucial tasks in a hospital. A desktop-based (PC) information technology system has been widely adopted to assist this operation. The fixed location and the limited amount of available PCs shared among staff for different routine tasks can cause delays in bed information updating and therefore delays to the bed management processes. With the penetration of smartphones, a mobile-based application becomes a reliable alternative solution for bed management to complement the existing system. Smartphones offer a few benefits, especially mobility because users can update the information from any place and at any time. Our aim was to study the applicability of a mobile-based application for assisting bed management operation. The application consisted of ward-based bed information visualization, bed information updating, and ward information updating modules. Observation and interviews with expert users were performed to outline the required functions of the application. On a Likert 1-5 scale, the mobile application achieved a mean score of 3.45 for usefulness, 3.40 for ease of use, and 3.42 for satisfaction. Meanwhile, the respondents were also concerned about the mobile data consumption of the app, which took up 45.8% of the negative feedback. On the positive side, the respondents agree that the mobile application helps them in the bed management operation.**

Keywords-bed management; mobile application; usability study; hospital management

I. INTRODUCTION

The increase of human population density put pressure on hospitals in providing adequate services to accommodate patients. One of the most important facilities in a hospital is the number of available hospital beds. Limited or problematic bed capacity can cause overcrowded situations in outpatient departments due to the prolonged waiting time of bed assignment to patients. The shortage of beds or inefficient bed management in hospitals is a common problem. Some of the common factors that cause bed shortage or delays in the process of patient discharge are: family members being unable to accompany patients home upon discharge, patients waiting for family members to collect their medications and documents, and delays of information in the communication to the bed manager on the status of beds [1]. To overcome this issue, Hospital Canselor Tuanku Muhriz (HCTM) improved the patient discharge process by introducing a discharge lounge. The patient who is in good condition is directed to the discharge lounge with the approval of a doctor. Patients are waiting comfortably to be taken by their family members within the lounge facilities. Hence, the bed in the ward will be

Corresponding author: Meng Chun Lam

available for new patients. Unfortunately, the process of updating the bed utilization status is often delayed due to the limited availability of personal computers (PCs) for the staff. The existing bed management system in HCTM is a web-based system. The system is integrated with other common operations or modules including patient registration, admission, discharge, bills, medication, etc. The staff has to access the system via a PC, the fixed location and amount of available PCs limits the staff's accessibility. Hence, the staff members often need to queue for using the shared PCs which are utilized for various routine tasks. Also, all the modules are web-based, and the user interface of the system is not designed for mobile view. Therefore, it is not a mobile-friendly system because the user interface does not show and align probably in a smartphone. A potential solution is to enhance the bed management system to maximize resource utilization and avoid hospital overload. A bed management information system can be helpful [2]. It allows bed managers to make easier, faster, and more accurate decisions.

The number of smartphone users is growing rapidly. With the advent of smartphone and Internet technology, smartphone-based applications have been applied to areas such as banking [3], environmental monitoring [4], and healthcare services [5]. Near Field Communication (NFC) is a wireless sensor technology available in a smartphone, using contactless short-range communication devices. It consists of two main components: a tag that contains information and a reader-writer that is able to extract and put information from and to the tag [6]. NFC is a set of standards for smartphones and similar devices for creating radio communication when brought in proximity, normally no more than a few centimeters [7]. NFC is available on a smartphone where the reader is placed into the phone's shell. The bed information can be embedded in the NFC tag and thus it allows instant information access when the equipped smartphone is in its proximity. This paper aims to identify the applicability of a smartphone-based mobile application with NFC technology to facilitate the bed management process at the HCTM. The developed Bed Management Mobile Application (BMMA) is a high-fidelity prototype that allows a non-technical person like a nurse or a doctor to instantly see the flow, user interface, and test the bed management mobile application. Thus, users can judge how well it meets their expectations and facilitates their work. The contribution of this research is the BMMA using the NFC approach and its evaluation.

II. BACKGROUND

Hospital bed availability is an important asset, especially for Intensive Care Units (ICUs), Coronary Care Units (CCUs) or emergency departments. It is an essential hospital job to coordinate the allocation of patients over the unoccupied hospital beds [8].

A. Mobile Application in Health Care

Utilizing mobile applications for hospital management including the research to study the level of acceptance of mobile health applications [9] is an open research subject with many areas of interest [9-14]. Even though the smartphone is a popular device, capable of performing technology-based tasks, its use might not be welcome in a hospital. Authors in [9] confirmed that a mobile health application is generally accepted by the public to be integrated with the existing system of a hospital. Their study suggested eight factors that need to be considered when implementing mobile applications which were Hedonic Motivation, Performance, Expectancy, Social Influence, Effort Expectancy, Price Value, Habit, Facilitating Conditions, and Behavior. To increase the effective and efficient care of the hospital, authors in [10] proposed a Bring-Your-Own-Device (BYOD) concept to allow hospital staff to use their own devices to access the hospital system. The BYOD guideline included role-based access control, apps to work on internal or virtual private networks, it required apps to use a minimal cache, and enforced automatic logoff to prevent data leakage. An example of a developed mobile application included mPHASiS [11]. It has been developed and utilized to monitor the vital signs of patients based on several sensors. It can notify medical personnel in case of emergencies, hence manually and frequently checking on the patient can be reduced. Authors in [12] designed a smartphone program-based system to help doctors to track Alzheimer's disease patients' condition. The application alerts the patient when to consume medicine based on the schedule provided by the doctor. A mobile application for diabetes patients [13] can be seen as a personal health care system. It is a tool to record daily test results and track long term health condition changes. Authors in [14] concentrated on mobile application design to deliver an efficient health care system. By using this app, users can find in-city hospital information, cabin data, make cabin booking payments, accept smart tips on selecting the right hospital, locate a physician, call for emergency services, receive information on first aid and notifications from the drug alarm system, calculate their Body Mass Index (BMI), receive information on health care, data about support and drugs, prescription reminders, etc.

Such mobile applications will be an essential part of the next generation of ubiquitous and pervasive healthcare systems. This study aims to have an initial exploration of the feasibility of applying a smartphone-based mobile application for managing beds at HCTM.

B. Current Situation

HCTM, previously known as Pusat Perubatan Universiti Kebangsaan Malaysia, is a hospital merged with the Hospital of Universiti Kebangsaan Malaysia and the Faculty of Medicine, Universiti Kebangsaan Malaysia. In order to understand the situation and the operations of the Hospital, a series of interviews and discussions with different members of the staff including nurses, doctors, and information technology officers were conducted. There are many clinical systems that have been designed for the HCTM to ensure a smooth procedure flow for the hospital operations. One of the known modules is the bed management system. It is used to view and update the status of beds in wards. The system allows the hospital staff to view the availability of a bed in a ward and handle the admission and the discharge process of a patient. After a few discussions and meetings with the information technology officer and the end-users (nurses), it was realized that the running functions fulfilled the requirements of the daily

bed management operation. However, no work has been done in the form of a smartphone-based mobile application in any module of the existing HCTM system. In HCTM, a bed manager from each ward is responsible to update the information/status of bed availability. The PC in the ward is the main terminal for accessing the bed management system. It is shared with the other staff members. Sometimes, the bed manager was forced to wait the other users to complete their tasks on the PC. Hence, a physical logbook still exists to keep track of the record and the information from there is put in the system later, when the PC is not occupied. The ward receives a bed booking start with the requests from the clinic or the emergency department. The bed manager at the ward should record or start the reservation using the existing desktop-based bed managing system. In this step, the bed manager is required to select and record the patient information and other relevant information such as the doctor in charge, diet preferences, etc. in the system. However, the manager is often unable to do it on the spot in the desktop-based system because the PC in the ward might not be available. Hence, managers are forced to record the information in the logbook and put the information in the system later. The manual recording is causing the information to be not transparent and delayed. In other words, the system does not show the real and updated information in a real situation, which could cause problems, e.g. it might confuse the nurses at the clinic and the emergency department on the bed availability in a ward. The system could show that there are beds available, when there are not. Therefore, nurses have to keep calling the ward to get the latest bed information. In addition, after the patient arrives in the ward, the bed manager should update the status of the bed from reserved to occupied. The bed managers are also nurses that have the responsibility to take care of the patients once they arrive in the ward. They will accompany and settle down a patient at the bed before they update bed information. Once the patient is in the good condition and ready to discharge, the in-charge doctor would write the discharge summary and the nurse will make the bed available in the system.

All the process should be done through the system because the captured information will be used for decision making. The consequences of delayed and inaccurate information can be a crowded Emergency Department (ED) with patients waiting for a bed in the ward, delays in the clinical process for patients, miscommunication between different departments/wards and wrong decision making from the management team. HCTM has been looking for a way to reduce the bed turnaround time. One of the solutions that they have looked into was improving the patient bed management workflow. In this research, focus is given on the exploration of using a mobile application to assist the bed management process.

C. Existing Bed Management System

Three existing bed management systems [16-18] were analyzed and compared with the developed and proposed Bed Management Mobile Application (BMMA). Table I provides a comparison of system features and functions between the previous systems and the proposed mobile application. Most of the existing systems are desktop-based. Some system interfaces are simple and neat. However, they are not following the current design trend, while the developed BMMA follows the Material Design [15] which is a mobile design principle that provides smooth interaction with the mobile application. The advantages and limitations in the comparison served as guidelines to develop the BMMA.

TABLE I. COMPARISON OF THE PROPOSED APP AND PREVIOUS SYSTEMS

Features/Functions	Wise Bed Manager [16]	BedWatch®Bed Control System [17]	Blueberry In-Patient Management System [18]	Developed BMMA
Display bed information	Main function	Main function	Sub-function	Main function
Color-code bed allocation	✓	✓	✓	✓
Summarize ward's bed information	✓	X	✓	✓
Summarize discipline's bed information	X	X	X	✓
Mobile application	X	✓	X	✓
User interface	Outdated design	Simple and neat	Outdated design	Material Design [15]
Complexity	Easy to use with drag and drop function	Easy to use with predefined input method	Time-consuming. Requires a lot of information from users	Easy to use with predefined input method
NFC technology	X	X	X	✓

1) Wise Bed Manager

Wise Bed Manager is a web-based system developed by Wise Technologies Ltd. The system displays online information of beds and patients based on the room number through a web browser. Icons or illustration of bed and color code were utilized to arrange the user interface element in a tidy way. The Wise Bed Manager system is easy to use, and the information is straightforward and easy to understand. The system also has a drag-and-drop function that makes patient access to the ward easier through the system [16].

2) The BedWatch® Bed Control System

BedWatch® Bed Control is a multi-platform bed management system. The system can show the current state of a bed via devices connected to the Internet such as computers, smartphones, and tablets. Through these devices, users can view and update information such as the bed status in a ward. It helps different types of users as it can engage with a number of different parties such as nurses, bed managers, and cleaners. The status of the bed can be updated in a short time because the person dealing with the bed can make updates with a smartphone [17].

3) The Blueberry In-Patient Management System

The Blueberry In-Patient Management System is a web-based system developed by Blueberry Consultants Ltd. The system includes functions such as bed management, patient tracking, and letter issuing. The system is complex and requires users to input different types and varying amounts of information. It has a simple graphical user interface and provides user convenience in accessing the ward, patient, and bed information [18].

III. METHOD

A bed management mobile application with NFC technology for the HCTM was designed and developed. The purpose of the mobile application is to complement the existing bed management system in the hospital in order to improve bed management efficiency. The main function of the mobile application consists of updating and viewing the bed status based on discipline and ward. The following subsection discusses the details of the bed management mobile application, includes the system architecture, entity-relationship diagram, and the user interface.

A. System Architecture

The system architecture is shown in Figure 1 The bed management mobile application used a simple two-tier architecture in which the application contains the presentation and application layer. A server is utilized to store data and information such as bed, ward, and staff information. Mobile applications are mainly used to present relevant data in a user-friendly user interface. An internet connection is important in enabling the communication between the mobile application and the user. Besides that, the NFC tag is available on the wall of the bed, so bed managers can easily access the tag and update the status of the bed, thus the bed's updating process is speeded up. Users of the system can be managers, doctors, and nurses. The nurse can view and update the bed status, while doctors and managers can only view the bed status.

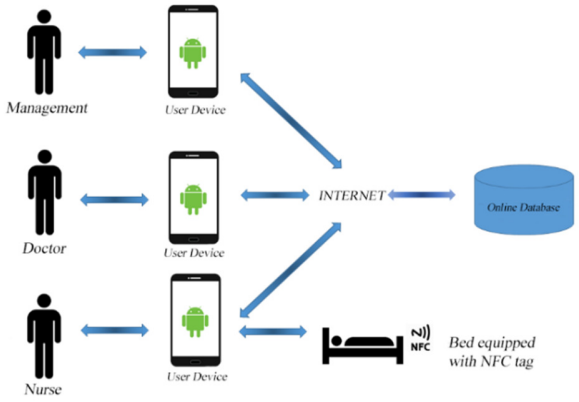


Fig. 1. The architecture of the bed management mobile application

B. Entity-Relationship Diagram (ERD)

The ERD is a graph that depicts the logical structure of a database. After the entities in the bed management mobile application are identified, the diagram is provided to show the relationships between the entities. Attributes of the entities are also indicated in the diagram. Figure 2 shows the ERD for the design of the proposed app. Its entities are: Bed, Ward, Patient, Additional Information, NFC, and Staff. The relationship between entities can be identified. For example, one patient will have one bed and one bed will have one NFC tag in the hospital. Also, one ward will have many staff members, much additional information, and have many beds.

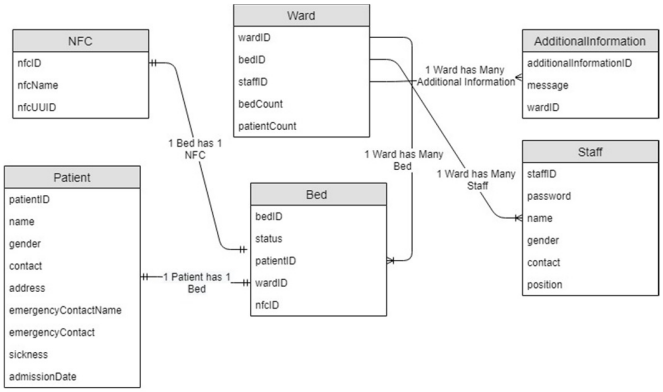
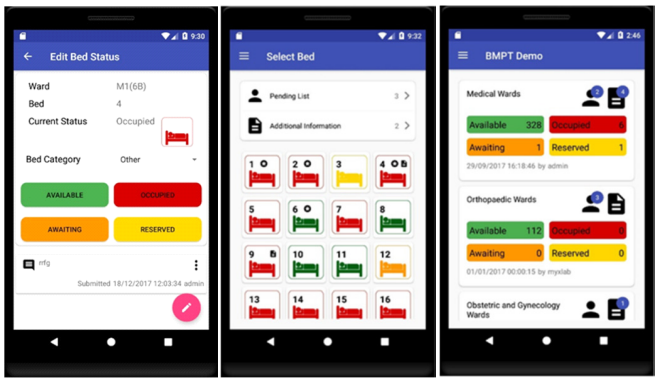


Fig. 2. The ERD

C. Bed Management Mobile Application

The BMMA is built on the Android platform. The main functionality includes: 1) the ability to view the status of beds based on discipline and ward, 2) the ability to update the status of a bed, 3) the ability to obtain the "Pending List" and the "Additional Information" of a bed. The pending list function allows the nurse to select the current number of patients pending to be admitted into the ward. Through the application, another user can also view the number of pending lists of the ward without the need to call a certain ward for bed availability confirmation. The additional information allows the nurse to add a short information message to a bed or ward (e.g. "the fan is not working"). Figure 3 shows the screenshots of the BMMA. With the use of NFC tags, users can scan the tag through their smartphone and get the information of the bed from the server based on the bed's ID information stored in the tag.



(a) (b) (c)

Fig. 3. User interface of the BMMA: (a) Landing page, (b) bed information based on a specific ward, (c) user interface for bed status update

IV. EXPERIMENTAL DESIGN

The main goal of the experiment is to gather early feedback about the developed BMMA for the HCTM. A 5-point Likert scale (ranging from 1 for Strongly Disagree to 5 for Strongly Agree) with questions about its usefulness, ease of use, and satisfaction was used [19]. The ease of use and usefulness are the two main factors that affect the user's intention to use new technology [20, 21]. Open-end questions about the positive and negative aspects of the mobile application were also asked. The invited participants were 150 and the assessment was conducted on a voluntary basis. At first, the operation of the BMMA in checking and updating the status of beds was demonstrated. The session continued with 20 minutes of exploration of the BMMA among the participants themselves. The participants could freely check or update bed status using the BMMA during that session. Finally, the participants were asked to answer the five-point scaled questionnaire and the open-end questions. A follow-up face to face interview section was also conducted after a week of usage with three selected levels of participants, namely a junior nurse, a senior nurse, and a head nurse.

V. RESULTS AND DISCUSSION

From the 150 participants, 113-136 complete responses were received analogous to the different sections of the questionnaire. For example, 113 participants answered the question regarding their phone operating system, 136 participants responded to the working experience question and 127 participants fully answered the TAM question along with the satisfaction factor. They all were nurses of different levels (executive, junior, senior, and head nurses). As shown in Table II, the age of the participant ranged from 23 to 48. In terms of working experience, 63% of the participants had more than 10 years of experience. 82% of the participants were using Android phones and Samsung, Oppo, VIVO, and Xiaomi were the most preferred brands. The rest of the 18% of the participants were iOS users.

TABLE II. DEMOGRAPHIC DATA OF PARTICIPANTS

Items	Category	Number of complete responses (n=115-135) n (%)
Age	21-30	42 (31)
	31-40	61 (45)
	41-50	32 (24)
Working experience (years)	1-5	33 (24)
	6-10	18 (13)
	11-15	25 (19)
	16-20	53 (39)
	21-25	6 (5)
Operating system	Android	94 (82)
	iOS	21 (18)
Mobile service provider	Celcom	48 (36)
	UMobile	32 (25)
	Maxis	27 (20)
	Digi	14 (10)
	Others	14 (10)

A. Usability Results

To measure the level of performance of each factor, a set of merits was adapted from [22]. A mean score falling between 1.0-2.32 is considered poor and requires improvement, 2.33-3.65 represents the average and requires consideration to make improvements, and 3.66-5.0 is considered good. A total of 127 received questionnaires were considered fully answered. The results are shown in Table III. The Cronbach's alpha value for each factor is more than or equal to 0.9 while the suggested benchmark is 0.7 [23]. Therefore, all the items used to measure the constructs are reliable. The mean for all three factors was between 3.40-3.45. The mean score received from the user's evaluation for the usefulness factor was 3.45, for the ease of use was 3.40, and for satisfaction it was 3.42. Based on the questionnaire result, the developed BMMA lied in the average zone and required attention for further improvement.

B. Subjective Feedback

The follow-up face to face interview section confirmed the average result of the questionnaire. In general, the feedback received from the interview section was divided into two parts: the app and app requirement perspectives. In terms of the app perspective, the users expected the developed BMMA to be linked to the existing web system. Hence, the users required inputting the information either in the web or in the app platform to avoid the repeating process. Other than that, the BMMA did not have not a role-based restriction, thus they were worried about the possibility the bed status information to be updated by unauthorized parties. For example, only the responsible nurses in the medical ward should able to update the bed status for the medical ward, while the nurses from other wards should be able to only view the bed status. Due to the above reasons, users thought it of not being user-friendly. In terms of the app requirement perspective, the users were worried about the internet/data connection when using the BMMA in their daily tasks, due to the limited internet coverage by the mobile internet service provider or the fact that the signal might be not sufficient. Besides that, the phone capacity such as storage, battery, processor and the operating system were the factors that they were concerned about. Many users asked questions about the iOS version. They were also worried of the public reception of the fact that they would be using the phone while working. This feedback from the interview section was supported by the result of the open-end questions. A total of 48 feedbacks were received from the open-end question related to the negative feedback and the results are shown in Table IV. Even though there were a few limitations required to be solved, users are looking forward to the complete version of BMMA. Considering the positive feedback (Table V), 46.4% of participants thought that the mobile application was easy, 23.2% found usefulness in its flexibility and transparency regarding bed information (23.2%) among wards. A mobile app system would certainly be helpful in daily tasks of the 10.7% while 8.9% commented that it would speed up the information update and browsing process.

This research aimed on the exploration and the possibility of using a mobile application to assist the bed management process in HCTM. A major goal was to find the acceptance of the staff in the use of a mobile application in their daily operations and the major challenges to implement the mobile application operation. A prototype was developed for the proof of concept and to get early feedback about utilizing the mobile

app system in the HCTM in the near future. Therefore, the current version of BMMA in this study provided limited functionality: it focused on viewing and updating the bed status. Information regarding patient, doctor, meal, and medical data was not able to be associated in this version. To make it more practical, the BMMA should have all the functions of the existing system. Nonetheless, the current developed BMMA served well as a tool to allow nurses to imagine the use of smartphone-based application in the bed management process.

TABLE III. EVALUATION RESULTS

Construct		Mean + SD	Cronbach's alpha
Usefulness		**3.45 ± 0.63**	**0.94**
U1	The application helps me to accomplish tasks more quickly.	3.37 ± 0.63	
U2	The application makes the ward information exchange in the discipline ward convenient.	3.55 ± 0.57	
U3	The application saves time.	3.44 ± 0.68	
U4	The application helps me to do my job more easily.	3.41 ± 0.67	
U5	The application meets my job needs.	3.41 ± 0.65	
U6	The application is useful in my job.	3.50 ± 0.59	
Ease of use		**3.40 ± 0.58**	**0.90**
EU1	I can use the application easily without written instructions (manual).	3.39 ± 0.62	
EU2	I find it easy to get the application to do what I want it to do.	3.34 ± 0.58	
EU3	It is easy for me to remember how to update the bed status using the application.	3.43 ± 0.57	
EU4	I find this application easy to learn.	3.43 ± 0.62	
EU5	I find this application easy to use.	3.43 ± 0.54	
Satisfaction		**3.42 ± 0.56**	**0.91**
S1	The application works the way i want it to work.	3.29 ± 0.55	
S2	I can read the text in this application clearly	3.50 ± 0.52	
S3	I am satisfied with the interface of the application.	3.39 ± 0.52	
S4	I like the color theme of the application.	3.50 ± 0.53	
S5	I feel i need to have the application.	3.48 ± 0.65	
S6	The application is pleasant to use.	3.45 ± 0.57	
S7	I am satisfied with the use of the application.	3.33 ± 0.56	

TABLE IV. NEGATIVE FEEDBACK

Negative factors	Number (N =48) n (%)
Internet/mobile network data	22 (45.8)
Added workload	8 (16.7)
iOS	3 (6.3)
Not user-friendly	3 (6.3)
Phone hanging	2 (4.2)
Role-based access	2 (4.2)
Lack of device	2 (4.2)
Phone storage	2 (4.2)
Misunderstanding from outsiders	2 (4.2)
Cost	1 (2.1)
Battery	1 (2.1)

The participants are looking forward to the complete version of the BMMA. It certainly solves the problem of limited desktop computer access of the existing web-based system. Nurses can access the bed management system through their smartphones with an internet connection. A pilot version of the BMMA was launched and evaluated. The role-based restrictions, the integration with the existing web system, and other important functionality issues are in the app's design. The bring-your-own-device (BYOD) policy [10] will be adopted to ensure the protection of patient data.

TABLE V. POSITIVE FEEDBACK

Positive factors	Number (N =56) n (%)
Easy	26 (46.4)
Updated and transparent information	13 (23.2)
Helpful	6 (10.7)
Saves time	6 (10.7)
Speeds up task	5 (8.9)

VI. CONCLUSION

A smartphone-based mobile application, the Bed Management Mobile Application (BMMA), is proposed to complement the existing web system in Hospital Canselor Tuanku Muhriz (HCTM) regarding bed management. BMMA allows the user to view and update the bed information anytime and anywhere which is a more convenient approach than the existing PC-based system. A feasibility study of applying mobile application in HCTM has been carried out. Based on the study's findings the main OS platform using by the nurses in HCTM is Android while the participants mostly used the four major mobile network service providers in Malaysia. Hence, the future mobile application development should consider internet connectivity of these four providers inside the HCTM's buildings. Other than that, the usability questionnaire received an average result. However, users gave an overall positive feedback and agree that the mobile application will be helpful for them in executing their routine tasks in bed management. They are looking forward to having a mobile application to help them.

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REFERENCES

[1] W. J. Phua, M. Y. H. Low, N. Venkatarayalu, J. Koh, "NFC-based smart notification system for hospital discharge process and bed management", IEEE International Conference on Service Operations and Logistics, and Informatics, Singapore, July 31-August 2, 2018

[2] E. Iadanza, A. Luschi, A. Ancora, "Bed management in hospital systems", in: World Congress on Medical Physics and Biomedical Engineering 2018, Springer, 2019

[3] Z. U. Rehman, F. A. Shaikh, "Critical factors influencing the behavioral intention of consumers towards mobile banking in Malaysia", Engineering, Technology & Applied Science Research, Vol. 10, No. 1, pp. 5265-5269, 2020

[4] S. Zafar, G. Miraj, R. Baloch, D. Murtaza, K. Arshad, "An IoT based real-time environmental monitoring system using Arduino and cloud service", Engineering, Technology & Applied Science Research, Vol. 8, No. 4, pp. 3238-3242, 2018

[5] A. S. M. Mosa, I. Yoo, L. Sheets, "A systematic review of healthcare applications for smartphones", BMC Medical Informatics and Decision Making, Vol. 12, Article ID 67, 2012

[6] A. Z. Z. Zay, R. M. Nor, M. J. M. Razi, T. Mantoro, M. A. Ayu, "NFC based attendance: More than just a touch", Jurnal Teknologi, Vol. 78, No. 9-3, pp. 69-78, 2016

[7] A. D. Potgantwar, V. M. Wadhai, "A standalone RFID and NFC based healthcare system", International Journal of Interactive Mobile Technologies, Vol. 7, No. 2, pp. 73-79, 2013

[8] F. Noonan, J. O'Brien, E. Broderick, I. Richardson, J. Walsh, "Hospital bed management practices: A review", 12th International Joint Conference on Biomedical Engineering Systems and Technologies, Prague, Czech Republic, February 22-24, 2019

[9] M. K. A. Azzam, M. B. Alazzam, M. K. Al-Manasra, "MHealth for decision making support: A case study of EHealth in the public sector", International Journal of Advanced Computer Science and Applications, Vol. 10, No. 5, pp. 381-387, 2019

[10] S. U. A. Ayubi, A. Pelletier, G. Sunthara, N. Gujral, V. Mittal, F. C. Bourgeois, "A mobile app development guideline for hospital settings: Maximizing the use of and minimizing the security risks of "Bring your own devices" policies", JMIR mHealth and uHealth, Vol. 4, No. 2, Article ID e50, 2016

[11] P. Kulkarni, Y. Ozturk, "mPHASiS: Mobile patient healthcare and sensor information system", Journal of Network and Computer Applications, Vol. 34, No. 1, pp. 402-417, 2011

[12] E. Z. Pirani, F. Bulakiwala, M. Kagalwala, M. Kalolwala, S. Raina, "Android based assistive toolkit for Alzheimer", Procedia Computer Science, Vol. 79, pp. 143-151, 2016

[13] F. Zhou, H. I. Yang, J. M. R. Alamo, J. S. Wong, C. K. Chang, "Mobile personal health care system for patients with diabetes", in: Aging Friendly Technology for Health and Independence, Vol. 6159, Springer, 2010

[14] A. Imteaj, M. K. Hossain, "A smartphone based application to improve the health care system of Bangladesh", International Conference on Medical Engineering, Health Informatics and Technology, Dhaka, Bangladesh, December 17-18, 2016

[15] I. G. Clifton, Android user interface design: Implementing material design for developers, Addison-Wesley, 2015

[16] Wise Technologies, Wise bed manager, available at: http://www.bed-manager.com

[17] The BedWatch, Bed control system, available at: http://www.bedwatch.com/products/bed-control/

[18] Blueberry Health, Blueberry in-patient management system, available at: https://www.blueberry-health.co.uk/patientcaresystems/projectexamples/inpatientmanagementsystem

[19] A. M. Lund, "Measuring usability with the use questionnaire", Usability Interface, Vol. 8, No. 2, pp. 3-6, 2001

[20] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology", MIS Quarterly, Vol. 13, No. 3, pp. 319-340, 1989

[21] M. H. Alanazi, B. Soh, "Behavioral intention to use IoT technology in healthcare settings", Engineering, Technology & Applied Science Research, Vol. 9, No. 5, pp. 4769-4774, 2019

[22] H. Mohamed, H. M. Judi, N. Sahari, M. N. Yaman, N. A. Abdul, "Penilaian kualiti penyampaian perkhidmatan pasca siswazah: Satu kajian di sebuah universiti awam", Journal of Quality Measurement and Analysis, Vol. 14, No. 1, pp. 45-54, 2018 (in Malay)

[23] R. F. DeVellis, Scale development: Theory and applications, Sage, 2016