The Usability Factors of Cardiovascular Health Monitoring Mobile Application: A Conceptual Model

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Abstract. Cardiovascular disease (CVD) is one of the most prominent silent killers in the world. Further, treating the CVD health problems is considerably costly. In the era of digitization, CVD patients are able to monitor their heart conditions using CVD health monitoring applications on any mobile devices. In order for the applications to be usable, and are designed with, usability factors in mind, factors such as ease of use, ease of learning, efficiency, flexibility and attitude of users are deemed important in determining the usability factors of these type of mobile applications. This paper proposes the integration of usability factors into CVD monitoring application. Informed by extant literature on usability studies and mobile health applications and technology, this research develops a conceptual model called the Cardiovasular Health Monitoring Usability Model. The model aims to improve the usability factors of CVD monitoring application in enhancing the usability factors of such applications for the benefits of the patients and their cardiologists.

Keywords: Cardiovascular Health Monitoring, Heart Disease, Usability Factors Mobile Health, Human Computer Interaction

Introduction

Based on data from the World Health Organization (WHO), more than 75% of the deaths in the world are caused by cardiovascular disease (CVD) [1] [2]. The situation in Southeast Asia particularly in Indonesia is following a similar trend based on data from Ministry of Health, Government of Indonesia. CVD was reported as the highest cause of death in all ages and compared to other diseases contributing to 35% or 1.8 million of death statistics [3] [4]. One of the reasons for CVD high fatality rate is due to the high costs of medical treatment that reaches into tens of millions rupiah [3]. However, this is not exclusive to Indonesia only as the high costs of treating CVD is considerably expensive in other parts of the world as well.

With the advancement of technology, particularly with the ubiquity of smart phones and mobile applications, CVD healthcare is joining the bandwagon whereby a plethora of cardiovascular health monitoring applications are available and offered on major platforms such as Google Play for Android devices and Apple App Store for iOS based devices. These applications are typically available for purchase by users at reasonable price points. For example, the price of Cardio Visual application is around USD 2.84 - USD 9.62 per item while some others are available for free. These applications enable and facilitate heart patients and their cardiologists to maintain communications, as well as for the patients to be empowered to perform self-monitoring of their own heart conditions remotely and also cost effective to the patients [5]. Studies by [6] [7] indicate that mobile applications have the potential to facilitate the control and save the patient's health data that are both effective and intensive. Research about mobile health applications suggest that the usefulness of the applications can be understood and in accordance with the needs of the users and then only it can be considered as useful or of high usability [8]. Thus, usability factors such as ease of use, ease of learning, efficiency, flexibility and attitude of users are, important considerations to evaluate how well mobile health applications meet the patients' expectations and needs. However, there are lacks of research on how the usability factors are integrated into the CVD health monitoring applications in the context of developing countries [9] [10].

Further, different designers of healthcare software design their mobile applications differently and often do not conform to users' needs and to the expertise or requirements of healthcare professionals [11] [12] [13] [14]. Additionally, improper design of these healthcare software results in user resistance, error generation, and increased time and cost [14] [15]. These problems lead to patient safety issues. Several studies have reported the errors resulted from poor design of healthcare software [11] [12] [13] [14]. Many of these errors are related to usability problems that adversely affect users' interaction with a system [14] [16] [17] and hence, require more academic pursuits in this lacking research area as to close those research gaps. This paper begins with a brief discussion on the research methods. It continues with a review of literature on usability factors, CVD health monitoring technology and then proceeds with proposing and discussing the conceptual model which integrates usability factors into cardiovascular health monitoring application. The paper wraps with a brief conclusion and salient points for further research.

Materials and Methods

This research followed a literature review from relevant articles identified from several reputable online databases including Emerald, EBSCO, Science Direct, ProQuest and Google Scholar using keyword phrases "usability", "heart disease", "cardiovascular disease", "health monitoring" and "mobile applications". Articles published from the year 2010 until 2018 are considered relevant articles for analysis. The search results yielded 1,537 articles (refer Table 1).

Table 1. Number of Relevant Articles by Reputable Online Databases

Reputable Online Databases	Number of Relevant Articles
Emerald	284
EBSCO	224
Science Direct	470
ProQuest	210
Google Scholar	349
Total	1,537

The articles were read mainly for the abstracts, results, conclusions, number of citations and year of publication and are conducted using a similar protocol by [18]. Studies on usability factors, heart disease and health monitoring observe rapid interest and development among IS and HCI researchers in these research areas (refer Table 2). However, there is still a gap on research focusing on CVD health monitoring in the developing countries [10]. The literature from the usability factors and cardiovascular monitoring technology domains were analysed and synthesised in order to propose the Cardiovascular Health Monitoring Usability Model.

Table 2. Number of Articles by Year of Publication

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Number of articles	95	111	141	149	196	212	243	287	104

The collected relevant articles were analyzed using pertinent concepts related to this aim of this study: 1) usability factors, and 2) CVD health monitoring applications and technology.

a. Usability Factors

Usability is defined as measurement of the quality of a user's experience when interacting with a product or system [19] [20]. While, ISO 9241-11 defines usability as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction, in a specified context of use [21]. Usability factors for this research extends [21] standard definition of usability to include ease of use, ease of learning and attitude of users as illustrated in Fig. 1.

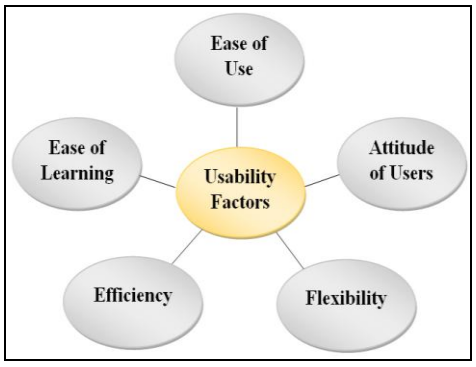

Fig. 1. The Common Usability Factors Identified from the Literature

According to some researchers such as [22], ease of use is the extent to which a person believes that using a particular technology will require as less effort as possible (i.e., cognitive and physical efforts in learning how to use the system). [23] argues that ease of use is which an invention is seen as being not too difficult to understand, learn or operate while [24] claims that interaction with the system is easy when getting the system to do what is required. [25] apply the aspect of ease of use into health monitoring applications and define ease of use as the application be easier to use by patients and doctors when compared to other applications. Ease of learning is the ease with which beginner-level users can learn to interact with the system [26] [27] [28] [15] [29] [30]. Efficiency is conceptualised as the degree to which specified users can achieve specified goals with accuracy and completeness in a specified context of use [7] [20] [26] [27] [30] [31]. Flexibility on the other hand provides many ways for users and systems to exchange information [32] [33]. Lastly, attitude of users is the evaluation to know the user's desire to use the product or not, and their satisfaction level in using the system [20] [30] [31] [34] [35]. Table 3 summarizes the usability factors from the perspectives of extant studies.

Table 3. Usability Factors

Usability Factors	Researchers
Ease of use	[22] [23] [24] [25]
Ease of learning	[26] [27] [28] [29] [30] [31]
Efficiency	[7] [20] [26] [27] [30] [31]
Flexibility	[32] [33]
Attitude of Users	[20] [30] [31] [34] [35]

Based on the findings summarised in Table 3, not many previous researchers have used all the five factors in studying about usability. Thus, to make the study on usability factors on CVD mobile applications more holistic and comprehensive, this research intends to integrate as many as possible usability factors. However, due to space limitations, this paper will cover only five of the usability factors, a person believes the interaction with the system is easy, for beginner-level users to interact with the system need less effort to understand it caused easy of learning, to achieve specified goals with accuracy and time efficiency, user can exchange the informations flexibly of the CVD health monitoring application. Lastly, it will positively influence of it will impact towards the attitude of users on their satisfaction level in using the CVD health monitoring application.

b. CVD health monitoring applications and technology

There are a number of relevant past studies on CVD health monitoring applications, technology and some relevant CVD applications on iOS: 4 applications relevant, Android: 8 applications relevant and other platform: 3 applications relevant, free and commercial apps are also reviewed (refer Table 4). However, very limited of these studies are focusing on the usability factors. Instead, the focus was mostly on the technological features of the CVD health monitoring factors. For example, [25] develop *Support-HF* which provides tablet computers for heart patients that are available commercially to monitor blood pressure and heart rate, weight, and pulse oximeter for oxygen saturation measurement. Another, researcher come up with *HeartMapp* as a point of monitoring system to connect between patients and care

providers on self-care and monitoring and improve communication with the providers [36]. [37] build *CHWs*, covers blood pressure monitoring, body mass index and weight. Meanwhile, researcher [38] develop *CONNECT*, covers to heart record, diagnosis of heart disease risk and its treatment. [39] develop *Mobile Pulse Waveform Analyzer* to cardiovascular health monitoring based on electrocardiogram (EKG), blood pressure and weight. Lastly, [40] build a Mobile Machine-Learning Model for Monitoring Cardiovascular Disease (M4CVD) specifically for mobile devices that facilitate the monitoring cardiovascular disease (CVD).

Table 4.
Previous Researchers and Available Applications on iOS, Android others Platform for CVD

Researchers / Developer	Application	Features	Usability Factors	Platform
[25]	The Support-HF	Blood pressure, weight and pulse oximeter self-monitoring; patient status, measurement graph report	Ease of use	Android
[36]	HeartMapp	Weight,CHF symptoms, vital signs, physical activity, and deep breathing exercise performance.	Ease of use and Ease of learning	Android
[37]	CHWs	Blood pressure monitoring, body mass index and weight.	Ease of use and Efficiency	The online CommCareHQ platform
[38]	CONNECT	Heart record, diagnosis of heart disease risk and its treatment.	Flexibility	Multi Platform
[39]	Mobile Pulse Waveform Analyzer	Cardiovascular health monitoring based on elektorkardiogram (EKG), blood pressure and weight.	Efficiency	iOS and Android
[40]	M4CVD	Wearable sensor, health records, electrocardiogram, blood pressure, galvanic skin response and accelerometers.	Efficiency	A commercial wearable ECG platform
Cardio-Visual LLC	Cardio Visual	Contains information about the cardiovascu-lar video	Ease of learning and Attitude of Users	iOS and Android (USD 2,84 - USD 9,62 per item)

Salina Akter	Basic Cardiology	Contains the discussion of the lesson sourced from the cardiologist	Ease of learning	Android (free)
Tonic Minds	Cardiovascular Risk Calculator	Applications that assume cardiovascular risk depend on the parameters that are inserted	Ease of use	Android (free)
Kmcpesh Medical apps	Cardiovascular Diseases Free	Contains a study of cardiovascular	Ease of use and Attitude of Users	iOS and Android (free)

Based on the findings summarized in Table 4, previous researchers and available applications on iOS, Android and others platform are not use many factors in studying about usability. Some use one (which is quite unlikely actually), some use two or less. So, researcher will use five of the usability factors to more holistic, comprehensive and can be used in multi platform.

The Proposed Cardiovascular Health Monitoring Usability Model

Based on the literature review findings presented in the previous section, this part of the paper discusses and proposes the integration of usability factors into the CVD health monitoring application.

The Cardiovascular Health Monitoring Usability Model has five of the usability factors to improve application quality based on insights from limitations of extant studies on integrating various usability factors into the CVD applications [41]. Beside that, this model created based on needs of patients and limitations of existing applications available on iOS and Google Android apps for CVD shown in Table 4. The proposed model, adapted and updated from [41] had three key components: (i) input components have user interface elements on them consists of four elements (content, aesthetics, layout and navigation), (ii) process components have user activity for the CVD health monitoring, and (iii) output components have five usability factors (ease of use, ease of learning, efficiency, flexibility and attitude of users). The proposed Cardiovascular Health Monitoring Usability Model is shown in Fig. 3.

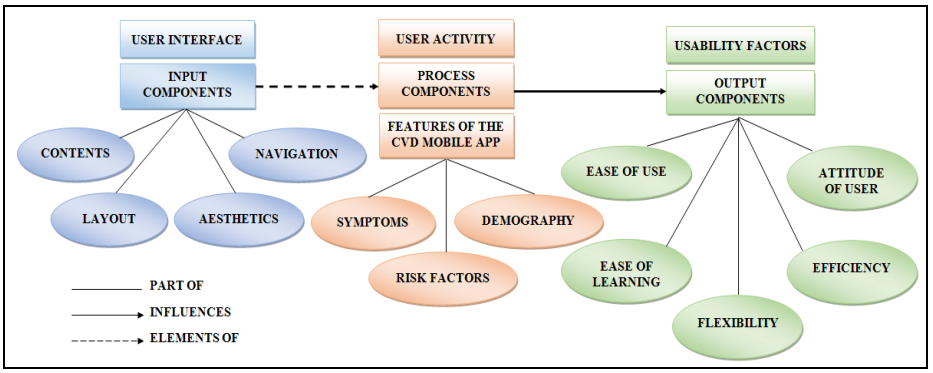

Fig. 3. The Proposed Cardiovascular Health Monitoring Usability Model

a. User Interface as Input Components

In terms of input components, the user interface of the CVD health monitoring application will consist of content, aesthetics, layout and navigation. Content refers to the mobile applications fulfilment to provide information needed by users such as the features of the said application [42]; aesthetics refer to the pleasing visual appearance of the application such as the selection of colors and shapes that are used so that the user views [42]; layout refers to how the contents are organised using hierarchy or icon shortcuts so it's easy to understand by users [42], while navigation refers to the process of navigating a network of information or resources represented in the content and information of the CVD health monitoring application [42]. The performance of input components are the elements for the process components (i.e., the CVD health monitoring features) represented by the dashed lines in Fig. 3. The model focuses on how the design of usability factors, their communication on a mobile application to given information such as age, gender, weight, heart record, blood pressure, risk factors, symptoms and other processes related to the monitoring of the heart disease [9] [43].

b. User Activity as Process Components

User activity is part of the process components and contain all the CVD health monitoring features (refer Table 4) for perusal of the heart patients and their cardiologists. The CVD health monitoring features will be available of this research include: (a) patients demography cover age, gender, weight, heart record and treatment history, (b) risk factors cover smoker, blood sugar and family history (c) symptoms cover chest pain, breathless and headache and many other future features deemed suitable to be introduced into the CVD health monitoring application. The performance of process components (i.e., the CVD health monitoring features) to output components represented by the solid arrows in Fig. 3.

c. Usability Factors as Output Components

The usability factors correspond to the CVD health monitoring application features as the output components. For example, all of the features are needed to monitor health refers to the mobile applications fulfilment such as an aesthetic design that has a

content with good appearance, organized layout using hierarchy or icon shortcuts, and navigational elements to show the information or resources, represented of the CVD health monitoring application. It will ensure and positively influence of the easiness of use, claims that a person believes the interaction with the system is easy, and need less effort to get what is required. The application can be learned by beginner-level users to interact with the system. Efficiency aims to achieve specified goals with accuracy and completeness in a specified context of use. Flexibility of the CVD health monitoring application pertains to the exchange of information that the users needed and it will impact towards the attitude of users on their satisfaction level in using the CVD health monitoring application.

Conclusion

This paper proposes to reduce errors in healthcare software design that are not suitable with users' needs and particularly requirements of healthcare professionals such as users are difficult to understand when first using application, slow to get information which needed and the application interface is not convenient to the user's eyes. These errors are related to usability factors problems that could have impact to users' interaction with the application that they are using. With integrating usability factors into the design of CVD health monitoring application, can increase the use level of such CVD health monitoring application by heart patients and their cardiologists. Theoretically, the paper contributes to usability knowledge and its integration into CVD health monitoring application in the context of developing countries where CVD is one of the major killers. The proposed model has the potential to make it easier for HCI practitioners and mobile application developers to understand on how the usability factors can be integrated into the CVD health monitoring application. From the practical contribution side, this research contributes in helping cardiologists to interact, more cost-effective and efficient manner with their patients. Further, the model empowers the patients to self-monitor their heart conditions using the CVD health monitoring application. Future research will embark on empirical data collections to verify and validate the proposed model with heart patients and cardiologists, as well as developing our own translations of the Cardiovascular Health Monitoring Usability Model into a new breed of CVD health monitoring application.

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References

[1] C. D. Mathers, A. D. Lopez, and C. J. L. Murray, "Chapter 3: The Burden of Disease and Mortality by Condition : Data , Methods , and Results for 2001," in *Global Burden of Disease and Risk Factors*, vol. 2003, 2006, pp. 45–93.

[2] F. Anwar, "Title : 10 Penyebab Kematian Terbesar di Dunia," 2017. [Online]. Available: https://health.detik.com/berita-detikhealth/3416930/10-penyebab-kematian-terbesar-di-dunia-1. [Accessed: 01-Dec-2017].

[3] A. H. Yusro, "Penyakit Jantung Koroner di indonesia Penyebab Kematian Nomor 1 Manusia," 2017. [Online]. Available: http://www.sehatalamiyah.com/2017/05/mengenal-pembunuh-nomor-1-manusia.html. [Accessed: 13-Dec-2017].

[4] Pengelola, "Angka Kematian Penyakit Jantung Di Indonesia | Obat Penyakit Jantung Herbal," 2016. [Online]. Available: http://www.ahlinyapenyakitjantung.web.id/angka-kematian-penyakit-jantung-di-indonesia/. [Accessed: 28-Aug-2018].

[5] M. Anshari and M. N. Almunawar, "Mobile Health (mHealth) Services and Online Health Educators," *Biomed. Inform. Insights*, pp. 19–28, 2016.

[6] S. Kumar *et al.*, "Mobile health technology evaluation: The mHealth evidence workshop," *Am. J. Prev. Med.*, vol. 45, no. 2, pp. 228–236, 2013.

[7] A. S. Miller, J. A. Cafazzo, and E. Seto, "A game plan: Gamification design principles in mHealth applications for chronic disease management," *Health Informatics J.*, vol. 22, no. 2, pp. 184–193, 2016.

[8] L. Feinberg, J. Menon, R. Smith, J. G. Rajeev, R. K. Kumar, and A. Banerjee, "Potential for mobile health (mHealth) prevention of cardiovascular diseases in Kerala: A population-based survey," *Indian Heart J.*, vol. 69, no. 2, pp. 182–199, 2017.

[9] J. C. Goldwater, "Human Factors and Usability in Mobile Health Design – Factors for Sustained Patient Engagement in Diabetes Care," in *International Symposium on Human Factors and Ergonomics in Health Care: Advancing the Cause*, 2016, pp. 63–70.

[10] A. Ariani, A. P. Koesoema, and S. Soegijoko, "Innovative Healthcare Systems for the 21st Century," in *Innovative Healthcare Systems for the 21st Century*, Springer International Publishing AG 2017, 2017, pp. 15–70.

[11] M. F. Collen and R. A. Miller, "The History of Medical Informatics in the United States," London: Springer, 2015, pp. 339–383.

[12] N. Menachemi and T. H. Collum, "Benefits and drawbacks of electronic health record systems," *Risk Manag. Healthc. Policy*, vol. 4, pp. 47–55, 2011.

[13] G. Yucel, S. Cebi, B. Hoege, and A. F. Ozok, "A fuzzy risk assessment model for hospital information system implementation," *Expert Syst. Appl.*, vol. 39, no. 1, pp. 1211–1218, 2012.

[14] R. Khajouei, A. Ameri, and Y. Jahani, "Evaluating the agreement of users with usability problems identified by heuristic evaluation," *Int. J. Med. Inform.*, vol. 117, pp. 13–18, 2018.

[15] J. Nielsen, *Finding usability problems through heuristic evaluation*. 1992.

[16] M. Yasini, C. Duclos, J. B. Lamy, and A. Venot, "Facilitating access to laboratory guidelines by modeling their contents and designing a computerized user interface," *Stud. Health Technol. Inform.*, vol. 169, no. June 2014, pp. 487–491, 2011.

[17] R. Khajouei, D. De Jongh, and M. W. M. Jaspers, "Usability evaluation of a computerized physician order entry for medication ordering," *Stud. Health Technol. Inform.*, vol. 150, pp. 532–536, 2009.

[18] R. Hosoya, Z. Ding, and T. Kamioka, "A Bibliographic Network Analysis of Big Data Literature," in *PACIS 2017 Proceedings*, 2017, p. 2017.

[19] A. L. Russ, R. J. Fairbanks, B.-T. Karsh, L. G. Militello, J. J. Saleem, and R. L. Wears, "The science of human factors: separating fact from fiction," *BMJ Qual. Saf.*, vol. 22, no. 10, pp. 802–808, 2013.

[20] D. R. Kaufman *et al.*, "Usability in the real world: Assessing medical information technologies in patients' homes," *J. Biomed. Inform.*, vol. 36, no. 1–2, pp. 45–60, 2003.

[21] ISO, *Ergonomic requirements for offi ce work with visual display terminals. Part 11: Guidance on usability (ISO DIS 9241-11)*, ISO DIS 92. London: International Standards Organization, 1994.

[22] F. D. Davis, "Perceived Usefulness , Perceived Ease of Use , and User Acceptance of lnformation Technology," *MIS Q.*, vol. 13, no. 3, pp. 319–340, 1989.

[23] E. M. Rogers, *Diffusion of innovations*. 1995.

[24] N. Ndubisi, “Factors of Online Learning Adoption: A Comparative Juxtaposition of the Theory of Planned Behaviour and the Technology Acceptance Model,” *Int. J. E-Learning*, vol. 5, no. 4, p. 2006, 2006.

[25] A. Triantafyllidis *et al.*, “A personalised mobile-based home monitoring system for heart failure: The SUPPORT-HF Study,” *Int. J. Med. Inform.*, vol. 84, no. 10, pp. 743–753, 2015.

[26] A. Abran, A. Khelifi, W. Suryn, and A. Seffah, “Usability meanings and interpretations in ISO standards,” *Softw. Qual. J.*, vol. 11, no. 4, pp. 325–338, 2003.

[27] P. A. Booth, *An Introduction to Human-computer Interaction*, no. september. New York: Pcychology Press, 1989.

[28] D. Hix and H. R. Hartson, *Developing user interfaces: Ensuring usability through product & process*, 1st ed. Wiley, 1993.

[29] E. Furtado, U. De Fortaleza, F. L. Mattos, and J. Vanderdonckt, “Improving Usability of an Online Learning System by Means of Multimedia, Collaboration and Adaptation Resources,” in *Usability Evaluation of Online Learning Programs*, USA: INFORMATION SCIENCE PUBLISHING, 2003, pp. 68–85.

[30] J. Jeng, “Digital Libraries : Effectiveness , Effi ciency , Satisfaction , and Learnability,” *Assessment*, vol. 55, pp. 96–121, 2005.

[31] J. Nielsen, *Usability Engineering*. San Francisco: Morgan Kaufman, 1993.

[32] J. S. Dumas, J. Redish, and J. R. Lewis, *A practical guide to usability testing*. 1999.

[33] J. R. Vest and L. D. Gamm, “Health information exchange: Persistent challenges and new strategies,” *J. Am. Med. Informatics Assoc.*, vol. 17, no. 3, pp. 288–294, 2010.

[34] B. Shackel, *Usability-Context, Framework, Definition, Design and Evaluation*. New York: Cambridge University Press, 1991.

[35] R. Kengeri, C. D. Seals, H. P. Reddy, H. D. Harley, and E. A. Fox, “Usability study of digital libraries: ACM, IEEE-CS, NCSTRL, NDLTD,” *Int. J. Digit. Libr.*, vol. 2, no. 2–3, pp. 157–169, 1998.

[36] P. Athilingam, B. A. Jenkins, H. Zumpano, and M. A. Labrador, “‘Mobile technology to improve heart failure outcomes: A proof of concept paper,’” *Appl. Nurs. Res.*, vol. 39, no. September 2016, pp. 26–33, 2018.

[37] S. Surka, S. Edirippulige, K. Steyn, T. Gaziano, T. Puoane, and N. Levitt, “Evaluating the use of mobile phone technology to enhance cardiovascular disease screening by community health workers,” *Int. J. Med. Inform.*, vol. 83, no. 9, pp. 648–654, 2014.

[38] L. Neubeck *et al.*, “Development of an integrated e-health tool for people with, or at high risk of, cardiovascular disease: The Consumer Navigation of Electronic Cardiovascular Tools (CONNECT) web application,” *Int. J. Med. Inform.*, vol. 96, pp. 24–37, 2016.

[39] B. N. Li, B. Bin Fu, and M. C. Dong, “Development of a mobile pulse waveform analyzer for cardiovascular health monitoring,” *Comput. Biol. Med.*, vol. 38, no. 4, pp. 438–445, 2008.

[40] O. Boursalie, R. Samavi, and T. E. Doyle, “M4CVD: Mobile machine learning model for monitoring cardiovascular disease,” *Procedia Comput. Sci.*, vol. 63, no. Icth, pp. 384–391, 2015.

[41] M. Sobri, M. T. Ijab, and N. M. Nayan, “Systematic Literature Review untuk Membuat Model Aplikasi Pemantauan Kesehatan Cardiovascular,” *J. Rekayasa Sist. dan Teknol. Inf.*, vol. 2, no. 2, pp. 458–464, 2018.

[42] Ahmad, Zhang, and Azam, “Measuring ‘Navigational Burden Publish,” in *the Fourth Int’l, Conf. on Software Engr. Research, Management and Applications*, 2006.

[43] A. P. Gurses *et al.*, “Using human factors engineering to improve patient safety in the cardiovascular operating room,” *Work*, vol. 41, no. SUPPL.1, pp. 1801–1804, 2012.