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USABILITY METRICS AND METHODS FOR PUBLIC TRANSPORTATION APPLICATIONS: A SYSTEMATIC REVIEW

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Abstract

The existence of information systems and applications has changed the lifestyle of people around the world. The applications developed to serve specific purposes in the area of public transportation have made peoples' lives much easier. The usability aspects of the applications have enabled users to use computers or mobile devices to find information about the services offered such as in the booking and ticket purchasing system. In this paper, a systematic review on the metrics and methods used to evaluate the usability of the applications related to public transportation systems are presented. The objective of this paper is to identify the metrics and methods employed by researchers and developers in conducting the usability tests and evaluation on applications related to public transportations. In total, 144 research papers were reviewed and out of the number, 22 most related research papers were selected. The results indicate that satisfaction, effectiveness and efficiency are the most frequently employed usability metrics. Meanwhile, survey seems to be the most popular usability method amongst researchers, followed by field testing and interview. The paper provides insights for professionals and researchers.

Keywords: Usability metrics, Methods, Public transportation, Mobile apps.

1. Introduction

Public transportation systems offer an alternative way of mobility to reach to a destination for a certain portion of people in a community. By utilizing public transportations, the problem of traffic congestion and air pollution can be diminished. Also, public transportation utilization promotes sustainable societies [1]. The proliferation of the Internet and mobile technologies contributes to the

application of virtual-mobile application to the public transportation sector. A number of mobile and web applications associated with public transportation available in the market include: InfoBus [2], OneBusAway [1] NavMetro [3], SubwayPS [4], StopFinder [5] and web application for Alynysse Bus [6]. These applications were developed as tools to assist travellers in planning their journey within the most convenient way by providing accurate real-time information and fast mobile ticketing services.

Numerous studies have been conducted in order to perform the usability tests on applications specifically focused on services offered by the public transportation systems. The challenge of developing usable applications encourage researchers and application developers to rigorously test the usability of any application via different sort of methodologies and based on various dimensions or metrics. Nielsen's model, Shackel's model and ISO standard are some of the most well-known models for usability tests and evaluation. Nielsen outlined five usability metrics in his model – Efficiency, Learnability, Memorability, Satisfaction and Error [7]. ISO standard provides three metrics to be measured – Effectiveness, Efficiency and Satisfaction [7]. Four metrics have been defined in Shackel's model - Effectiveness, Learnability, Flexibility and Attitude, (also see, [4,7-11, 18, 33-38]). A number of methods are available in conducting usability tests. Some of the methods are: Usability Test, Interview, Focus Group, Survey and Heuristics Evaluation.

The remaining part of this paper is organized as follows: In section 2, the systematic review approach is presented. Section 3 discusses the findings from the study. The discussion section is presented in section 4. Lastly, the conclusion is presented in section 5.

2. Systematic Review

A systematic review is a type of literature review that collects and critically analyses multiple research studies or papers. This section describes the methodology used to conduct this study in order to achieve its objectives. Systematic literature review is the selected methodology in conducting this study. This section encompasses the research questions, search strategy, and selection of related studies. A systematic review aims to provide a complete, exhaustive summary of current literature relevant to a research question. The first step in conducting a systematic review is to perform a thorough search of the literature for relevant papers. The Methodology section of a systematic review will list all of the databases and citation indexes that were searched. The titles and abstracts of identified articles are checked against pre-determined criteria for eligibility and relevance to form an inclusion set. This set will relate back to the research problem.

2.1. Research questions

In this paper, we provide two research questions to be answered in order to identify the metrics and methods used in previous usability tests related to public transportations applications.

RQ1: What are the metrics used in the usability evaluation of public transportation applications?

RQ2: What are the methods used in the usability evaluation of public transportation applications?

2.2. Search strategy

The first criterion for the searching of potentially related articles to be reviewed in this paper is the publication year. All articles are selected from year 2010 and above which includes journal articles, conference proceedings and thesis. The main databases that were used are Google Scholar, ACM Digital Library and IEEE Xplore. Furthermore, searching also has been done based on citations and references found in the reviewed articles. Phrases used for articles' search are constructed based on the combinations of keywords; "metric/criterion/element/variance/variable" and "usability" and "evaluation/testing/test/study" and "application/software/system" and "public transportation/public transport. For example; (i) "usability metrics for software testing in public transportation"; (ii) "criterion for usability evaluation of software in public transportation"; (iii) "methods for usability testing of application in public transportation". The results of the searching and paper selection process are summarized in Table 1.

Table 1. Papers downloaded for review and final review papers.

Databases	Papers downloaded for review	Final review papers
ACM Digital Library	34	4
IEEE Xplore	26	1
Google Scholar	84	17
Total	144	22

2.3. Study selection

From the 144 papers that were reviewed, a total of 22 most relevant papers were selected for this study as shown in Table 1. These papers were selected as they discussed the metrics and/or methods used in usability evaluation for public transportation application.

3. Findings

This section presents the outcomes of the study and are classified based on the research questions. We divided the findings into two sections which are usability metrics and usability method.

3.1. Usability metrics for public transportation mobile applications

This section provides answer to research question one (RQ1). Usability models such as Nielsen's, Shackel and ISO ascertain various usability metrics or attributes as dimensions to be measured in usability tests. Based on the literature review, there are 11 usability methods that have been recognized in this paper with the occurrences of 64 in total – (1) effectiveness [2-6,12,16,27-28], (2) efficiency [3-4,6,12,19,25,27-28], (3) satisfaction [1-4,6,12,16,20-21,23-25,28], (4) easy to use [3,6,12,19,21,23-25], (5) learnability [1,3,6,12,23-24], (6) error [2,3,23], (7) usefulness [1,15,21,24], (8) consistency [23,25], (9) accuracy [5,24], (10) reliability [3,5], and (11) flexibility [1,19]. The result of usability metrics occurrences in the literature is depicted in Fig. 1, with the top four including:

satisfaction (topping the list), followed by ease of use and efficiency, and then learnability. Satisfaction plays a very important role in usability metric for public transport application. Many previous articles mentioned about satisfaction for mobile application and it should be the priorities to ensure the application fulfil user need. Efficiency and easy to use are also important in the field of evaluation to ensure the application are acceptable and usable.

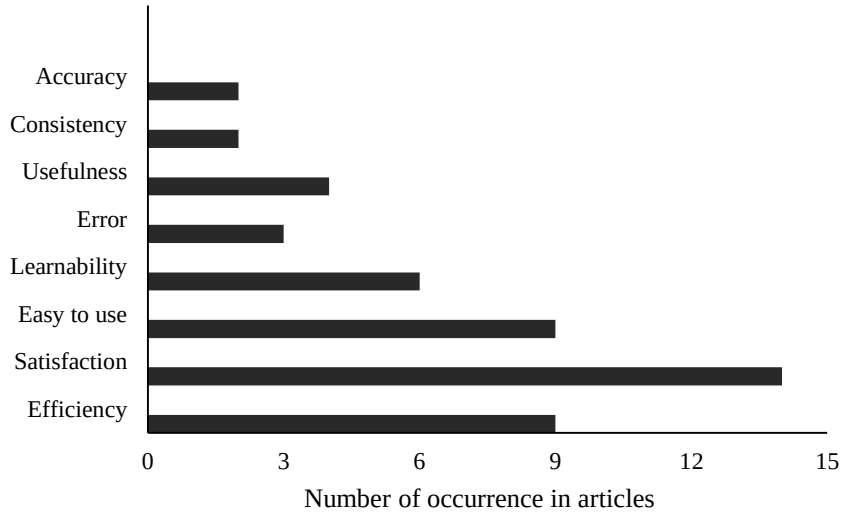

Fig. 1. Number of occurrence of usability metrics.

3.2 Usability methods for public transportation mobile applications

In this section, answer to research question two (RQ2) is provided. In applications' usability evaluation, a number of methods are usually used by researchers, namely: heuristic evaluation, cognitive walkthroughs, laboratory testing, field testing and conventional user test [32]. The selection of appropriate method depends on the purpose of the study. For example, to test the effectiveness of mobile application related to public transportation, the researcher may choose field test where the participants will be assigned tasks which need them to travel using public transport such as buses or trains. This approach will be more real compare to lab test. Based on the literature review of the usability methods used in public transportation mobile application research, 11 usability methods were identified in this paper with the occurrences of 41 in total – (1) field testing [1,3-4,12,15,27], (2) laboratory testing [4,24], (3) remote usability test [5,6,22,], (4) observation [6,13,21,24], (5) self-reporting logs [6], (6) survey [1,3,6,16,23-25,28], (7) questionnaire [4], (8) interview [2-4, 6,15,24,30], (9) user testing [1,16,23,25,29], (10) focus group [2,15], and (11) informal usability session [6]. The result of usability methods occurrences in the literature is depicted in Fig. 2 with the top four methods as: survey, field testing, interview, and user testing in the order of occurrence beginning from the highest. Survey has been use by many researchers to obtain accurate result during usability testing particularly for mobile application. The approach is very popular because it is easy to implement compare to experiment. Moreover, the existing online survey

made the approach become more popular. The significant method in usability method is field testing. Currently, many testers or experimenters select field testing compare to lab test to ensure the testing become more real.

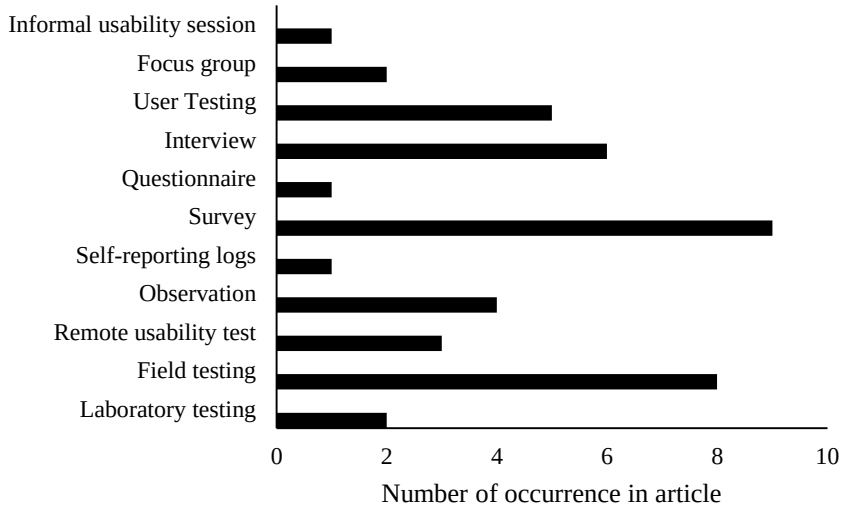

Fig. 2. Number of occurrence of usability methods.

4. Discussion

Based on the literature review, there are numerous various usability metrics and methods used by researchers in conducting usability evaluation for applications related to public transportation systems. The most employed usability metrics are satisfaction, effectiveness, and efficiency. While for the usability methods, survey was found to be the most employed method, followed by field testing and interview. However, some data have been fused into a single type of data according to the context of the researches that have been conducted previously. For example, the term 'ease to use' for usability metric is used in this paper to represent ease of use [6] and [3], simplicity [12], and simple interactivity [24]. While the terms 'comprehensibility' [12] and 'easy to learn' [3] are represented by metric learnability. The term 'user control and freedom' [19] is used to refer to the metric flexibility based on the same context used. There are some metrics used in the literature review that reflected more on human behaviour rather than the usability of the application itself. For example, amount of time they spent waiting for transit, likelihood of walking [1] and experience [15]. These metrics are omitted in this paper. For the usability methods, the metric, observation, has been utilized, which represents the term 'field observation' conducted by Ferreira & Freitas [3] based on the same context of use where users are free to voice out their opinions, feelings or frustrations while using the application.

5. Conclusions

Based on the result depicted in Fig. 1, it seems that most of the authors conducted usability tests on application for public transportation to examine the satisfaction of users, the effectiveness of the application as well as the efficiency of use of the

application. Satisfaction yields the highest percentage of 21.88% followed by effectiveness (17.19%) and efficiency as well as easy to use at 14.06% respectively. Meanwhile, survey has been identified as the most widely used usability methods (21.43%). Field testing comes second with 19.05% and the third higher result is interview (14.29%). In this paper, we can conclude that most researchers conducted usability test on applications related to public transportation systems to investigate the satisfaction, effectiveness, efficiency and ease of use of the application to assist users in their daily lives. Survey is carried out to reach a wider range of real users to obtain their feedback on the applications. In order to measure the test results in real-time, user testing in field setting were conducted. An in depth and rich information can be acquired by conducting interviews. Furthermore, the results obtained from this review will help practitioners (designers, usability experts, developers and testers) and researchers in further research and in the developing of usable public transport systems. However, this paper still lacks the reviewed papers related to public transportation applications and therefore, a more in-depth review should be conducted in future to investigate the metrics and methods used in usability test or evaluation for application related to public transportations.

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References

1. Ferris, B.; and Borning, A. (2011). *One bus away: improving the usability of public transit.* University of Washington.
2. Levita, A.; Pereira, R.L.; and Leal, A.B. (2012). *Info BUS anywhere - Mobile application for public transport use*. Technical University of Lisbon.
3. Ferreira, E.; and Freitas, D. (2012). Navmetro ®: Preliminary study applications of usability assessment methods. *Human Factors in Design*, 1(2).
4. Stockx, T.; Hecht, B.; and Schöning, J. (2014). *Subway PS: towards smartphone positioning in underground public transportation systems*. *SIGSPATIAL '14* (93–102). USA: ACM Press.
5. Prasain, S. (2011). Stop finder: improving the experience of blind public transit riders with crowdsourcing. *13th International ACM SIGACCESS Conference on Computers and Accessibility*. Dundee, Scotland, UK, 323–324.
6. Shalaik, B. (2012a). *Software for the control and analysis of public transport systems*. National University of Ireland, Maynooth.
7. Hussain, A., and Mkpojiogu, E.O.C. (2016b). A systematic review of usability test metrics for mobile video streaming apps. *Proceeding of the International Conference on Applied Science and Technology* (*ICAST'16*), Kedah, Malaysia, 1761 (1).

8. Anderson, S.M.; Riehle, T.H.; Lichter, P.A.; Brown, A.W.; and Panescu, D. (2015a). Smartphone-based system to improve transportation access for the cognitively impaired. *37th Annual Conference of the IEEE Engineering in Medicine and Biology Society*. Milan.
9. Apostolopoulos, I.; Fallah, N.; Folmer, E.; and Bekris, K. E. (2014). Integrated online localization and navigation for people with visual impairments using smart phones. *ACM Transaction on Interactive Intelligent System*, 3(4), 1–28.
10. Beul-leusmann, S.; Samsel, C.; Wiederhold, M.; Jakobs, E.; and Ziefle, M. (2014). Usability evaluation of mobile passenger information systems. *16th International Conference on Human-Computer Interaction.*, 8, 217–228.
11. Carta, T.; Paternò, F.; and Santana, V. (2011). Support for remote usability evaluation of web mobile applications. *SIGDOC*. USA, 129-136.
12. Chowdhury, S.; and Giacaman, N. (2015). En-route planning of multi-destination public-transport trips uing smartphones. *Journal of Public Transportation*, 18(4), 31–45.
13. Hussain, A.; Mkpojiogu, E.O.C.; and Hussain, Z. (2015). Usability evaluation of a web-based health awareness portal on smartphone devices using ISO 9241-11 model. *Jurnal Teknologi*, 77 (4), 1-5.
14. Hussain, A.; and Mkpojiogu, E.O.C. (2015a). An application of ISO/IEC 25010 standard in the quality-in-use assessment of an online health awareness system. *Jurnal Teknologi*, 77 (5), 9-13.
15. Hussain, A.; and Mkpojiogu, E.O.C. (2015b). The effect of responsive web design on the user experience with laptop and smartphone devices. *Jurnal Teknologi*, 77(4), 41-47.
16. Hussain, A.; and Mkpojiogu, E.O.C. (2016a). Usability evaluation techniques in mobile commerce applications: a systematic review. *Proceeding of the International Conference on Applied Science and Technology*, Kedah, Malaysia, 1761 (1).
17. Dauner, S.; Ascaniis, S.D.; and Cantoni, L. (2014). *Applications for public transport in swiss cities a state of the art of current local apps*.
18. Foth, M.; Qld, K. G.; and Schroeter, R. (2010). Enhancing the experience of public transport users with urban screens and mobile applications. *Proceedings of the 14th International Academic MindTrek Conference: Envisioning Future Media Environments, Association for Computing Machinery (ACM)*. *Tampere, Findland*, 33–40.
19. Gross, A.; and Silvennoinen, J. (2014). Surprise as a design strategy in goal-oriented mobile applications. *5th International Conference on Applied Human Factors and Ergonomics AHFE*. Kraków, Poland, 4716–4726.
20. Harrison, R.; Flood, D.; and Duce, D. (2013). Usability of mobile applications: literature review and rationale for a new usability model. *Journal of Interdisplinary Science*, 1–16.
21. Koohang, A.; and Paliszkiewicz, J. (2014). Empirical validation of an learning courseware usability model. *Issues in Information Systems* 15, 270–275).
22. Mkpojiogu, E.O.C.; Hashim, N.L.; and Adamu, R. (2016). Observed demographic differentials in user perceived satisfaction on the usability of

mobile banking applications. *8th Knowledge Management International* Conference. Chiang Mai, Thailand, 29-30.

23. Kulkarni, P.; Kalbande, D.R.; Warrier,S.; and Gulrajani, N. (2012). Smartcard based android application for public transport ticketing system. *International Journal of Computer Application*, 60(11), 29–32.
24. Li, Y. (2015). *Design of mobile technologies for traveling with public transport*. Master thesis. University of Oslo Library.
25. Lizano, F.; and Stage, J. (2014). Remote synchronous usability testing as a strategy to integrate usability evaluations in the software development process: A field study. *International Journal On Advances in Life Sciences*, 6(3,4), 184–194.
26. Mintmire, E.; Ling, C.; and Shehab, R. (2013). Usability evaluation of a paratransit management system. *Annual Conference and Expo 2013*, 57(1), 2000–2009.
27. Nagel, T.; Maitan, M.; Duval, E.; Moere, A.V.; Klerkx, J.; Kloeckl, K.; and Ratti, C. (2014). Touching transport - a case study on visualizing metropolitan public transit on interactive tabletops. Proceeding of the 2014 I*nternational Working Conference on Advanced Visual Interfaces*. USA: 281-288.
28. Peischl, B.; Ziefle, M.; and Holzinger, A. (2012). A mobile information system for improved navigation in public transport-user centered design, development, evaluation and e-business scenarios of a mobile roadmap application. *Proceeding of the International Conference on Data Communication Networking, e-Business and Opticle Communication Systems.* Rome, Italy, 217-221.
29. Salcedo, J.S.; and Battistuti, O.C. (2014). Unscheduled public transport intelligent navigation system. *Procedia Computer Science*, 35, 614–623.
30. Shalaik, B. (2012b). *Software for the control and analysis of public transport systems*. PhD thesis. National University of Ireland, Maynooth.
31. Yahya, A. (2015). *Visuäly : Visualizing the Condition of Älynysse Bus*. Tampereen Yliopisto.
32. Zaid, B.; Jamaludin, R.; and Wafaa, B. (2012). A comparative study of usability methods for mobile applications. *International Journal of Scientific & Engineering Research*, 3(8), 1–4.
33. Hussain, A.; and Mkpojiogu, E.O.C. (In press). The perceived usability of automated testing tools for mobile applications. *Journal of Engineering, Science and Technology*.
34. Hussain, A.; Abdullah, A.; Husni, H.; and Mkpojiogu, E.O.C. (2016). Interaction design principles for edutainment systems: Enhancing the communication skills of children with autism spectrum disorders. *Revista. Tecnica. Ingenieria. Univ. Zulia*. 39(8), 45-50.
35. Hussain, A.; Mkpojiogu, E.O.; and Kamal, F.M. (2016*).* A systematic review on usability evaluation methods for m-commerce apps. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, 8(10), 29-34.

36. Hussain, A.; Mkpojiogu, E.O.; and Kamal, F.M. (2016). Antecedents to user adoption of interactive mobile maps. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, 8(10), 41-45.
37. Hussain, A.; Mkpojiogu, E.O.; and Kamal, F.M. (2016). Mobile video streaming applications: a systematic review of test metrics in usability evaluation. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, 8(10), 35-39.
38. Hussain, A.; Mkpojiogu, E.O.C.; and Hassan, F. (2016). Systematic review of mobile learning applications for children. *Proceedings of the 2nd International Conference on Information and Communication Technology for Transformation (IC-ICT4T'16)*. Kota Kinabalu, Sabah, Malaysia.