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The Impacts of Urban Air Pollution on Malaysian Traffic Police: A Framework for Evaluation of Real-Time Monitoring System on Its Usability

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Abstract. The respiratory health of Malaysian Traffic Police has been compromised by working in heavy traffic and congested junctions with bad air for long hours. A wireless outdoor individual exposure device is vital to track their exposure, however, the efficacy of the system remains uncertain. While existing techniques exist to examine the efficacy of such system, there is a lack of methodology for engaging multiple assessment methods to evaluate the degree of user experience. This paper aims to propose a methodological framework tool for a quantitative evaluation of the wireless outdoor individual exposure indicator system prototype. A systematic search was conducted in major electronic databases (MEDLINE, Web of Science, Google), grey literature sources and all relevant data in the field. A three-stage framework consisting of simulation real-time monitoring, in-field testing, and usability testing is assembled. The three-stage framework proposed serves as a generic approach for evaluating the prototype with the purpose of tracking individual outdoor exposure. The method is capable of describing the complete evaluation process, from the accuracy and performance of the sensor to the extent of the end-user experience. Using the three-stage approach, future researchers may be able to create a monitoring system that is relevant to their needs.

1. Introduction

Rapid urbanisation in Malaysia has influenced the growth of our population, thus increasing the number of vehicles on roads [1]. As a consequence of increasing traffic on public roads, vehicular pollution has increased. Despite the emergence of better traffic management systems such as the Intelligent Transportation System (ITS) and Advanced Traffic Management Systems (ATMS), the need for travelling back and forth to work using personal vehicles is demanding [2]. To reduce traffic congestion, the Malaysian Traffic Police plays the main role by controlling and diverting the traffic at highly congested junctions and roads [3]. In highly dense areas, especially in the city centre of Kuala Lumpur, there is a higher need for traffic police to regulate the traffic flow [4]. They are more susceptible to adverse health effects such as respiratory diseases, heart diseases, and even lung cancer as they spend more time working at congested roads and junctions. [5] (Jamil et al., 2020a).

Unable to eradicate the cause of hazards to these traffic police, which is traffic-related air pollution, they would benefit from management control, such as an exposure indicator system [6]. Thus, a continuous real-time wireless outdoor individual exposure indicator system using low-cost sensors has a great potential to enhance the working environment in terms of safety and health for the Malaysian Traffic Police [7]. Numerous studies performed globally recommend the use of such a device to control air quality [8, 9, 10]. This device is practical and can effectively detect air pollutants that can help improve the protection of the population, personal health care, and environmental monitoring [11]. In recent times, these sensors have been used to collect high-resolution spatial and temporal air pollution data in real-time in many well-developed countries [12].

The development of low-cost air monitoring technologies has also been acknowledged in Europe and recommended to be included in the next Air Quality Directive [13]. Both the United States and the European Union (EU) have sponsored projects to assess low-cost air quality monitoring systems and set up test networks [14]. It shows that sensor technologies have a bright future and their use have proven to be beneficial. Nevertheless, air quality monitoring devices that are currently equipped with sensor technology are still limited in Malaysia. Similar devices with available sensors for wireless air monitoring have received a considerable amount of research in laboratory experiments and in-field testing globally [15,16]; however, their evaluation method on the extent of its usability is rarely documented. Assessments method for evaluating the effectiveness of wireless outdoor individual exposure indicator system prototype is still sparse in Malaysia.

Therefore, this study aims to test its accuracy, in-field performance, and, design a usability testing. Specifically, the study to propose a methodological framework tool for a quantitative evaluation of the wireless outdoor individual exposure indicator system prototype for traffic policemen.

2. Methods

A systematic search was conducted in major electronic databases (MEDLINE, Web of Science, Google). The characteristics of the studies that were used to construct methodological frameworks, were retrieved. The keyword used for the search was ‘outdoor air monitoring’, ‘in-field experimentation’, ‘wireless sensors’ and 'usability testing'. The search was conducted from 2000 until 2021.

The research methods and design, should be directed by the study question [17]. Thus, the evaluation of the system requires characterization against defined criteria that are relevant to the objective of the system and the extent of the reliability and performance of the system to be measured, as covered by the questions listed in the Table 1.

Table 1. Questions for the evaluation of a wireless outdoor system

Topic Area	Number	Question
Accuracy	1 (Q1)	Does the prototype provide sufficient accuracy of the readings when compared to a reference monitor?
In-field Performance	2 (Q2)	Does the prototype able to collect and transmit exposure data during in field experimentation (mobile testing)?
Usability	3 (Q3)	What is the usability score of the prototype for traffic policemen based on end-user feedback?

When developing a research plan, the research approach, depth of existing knowledge in the subject field, accessibility to data sources, and the availability of resources that would assist the implementation of the study should all be taken into account [17]. Based on research background, this section presents a three-stages framework to propose an evaluation method to determine the usability of the monitoring system. The summary of each stage according to the objectives is shown in Fig. 1.

Figure 1. Proposed three-stage framework for evaluation of wireless outdoor individual exposure indicator system

3. Results and discussion

3.1. Stage 1: Simulate real-time monitoring (Collocation with reference monitor)

Q1 is concerned with the measurement of the sensor, its accuracy in the use of the wireless outdoor individual exposure indicator system. For an air quality monitoring system, it is essential to evaluate its effectiveness and sensitivity in collecting all the parameters desired to determine the surrounding air quality [18] (Wei et al., 2018). A simulation and comparison of real-time monitoring with a reference monitor side by side should prove the performance of the system [19]. The National Exposure Research Laboratory of United States Environmental Protection Agency has described a guideline entitled Instruction Guide and Macro Analysis Tool: Evaluating Low-Cost Air Sensors by Collocation with Federal Reference Monitors to effectively perform and evaluate any newly developed real time monitors [20]. In addition, the United Kingdom of Environmental Agency Technical Guidance Note is another available guideline widely used by developers around the globe for the evaluation method [21] (Environment Agency, 2011). By adopting the method in [20], it was proposed to compare the prototype and reference instruments by collocation and in this study, the temperature, relative humidity, $PM_{2.5}$, CO and NO_2 measurements of the prototype were compared with the measurements from DustTrak II for $PM_{2.5}$ and data from DOE for the rest of the parameters.

The collocation is a process by which a reference monitor and non-reference monitor (sensor) are operated at the same time and place under real world conditions for a defined evaluation period [20]. The regulated DOE air monitoring stations were indicated as reference instruments, with Federal Reference Method (FRM) or Federal Equivalent Method (FEM) methodologies being used. These instruments must meet the National Ambient Air Quality Standards (MAAQS). These instruments are referred to as "The Gold Standard" whereby most countries and company are using the FRM or FEM in their monitoring tools [22]. The DustTrak II Aerosol Monitor 8532, were used to measure $PM_{2.5}$ whereas the CO and NO_2 data from the prototype were compared using past year data from DOE. The data was collected and compared based on the concentration's uptake of the air pollutants. On this basis, the accuracy of the results from the prototype was observed through the variations when compared against the reference monitor [23] which is explained in detail in Table 2.

Table 2. Collocation with the reference monitor

Parameters	Reference Monitor	Performance Metrics
Particulate Matter 2.5 microns ($PM_{2.5}$)	DustTrak II Aerosol Monitor 8532	When evaluated at the same time and place, the variability in concentrations of all parameters from the system is compared to the reference monitor to assess if there is a significant difference between the two sensors. There should be less variability to reflect a good and accurate sensor.
Carbon Monoxide (CO)	DOE Air Monitoring Station	
Nitrogen Dioxide (NO_2)		

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3.2. Stage 2: In-field testing (Performance)

Q2 is focused on the performance of the system in real practice to test the overall system. The system was proposed to be tested at the chosen study location. In this stage, the system was tested for its usage during the working hours of the respondents. The mobile testing was done in suburban district (Ampang Jaya) at Ampang Traffic Police Station. Both the prototype and the reference instruments were brought using a pickup truck and assembled at the tailgate. The mobile testing involves two hours driving around the same area with regular stopping at the traffic lights and junctions. The data was collected and observed for its performance in an ambient environment. The concentration measurement was plotted against time. Each parameter's average concentration was recorded and analysed descriptively. From this, the traffic police's working condition was portrayed and the exposure to outdoor air pollutants were known at the same time. The respondents were briefed on how to monitor the readings from the system using their smartphones. As they complete their working hours, they were asked to proceed to the next stage which is the usability testing (questionnaire).

3.3. Stage 3: Usability testing (Post-Study System Usability Questionnaire

The most important stage is to test its usability among the users. First, a usability testing plan is developed to evaluate the usability of the prototype (wireless outdoor individual exposure indicator system) for website and apps from the perspective of the Malaysian Traffic Police. The specific goals are to; identify the current level of exposure; search for previous exposure information by date and time; and save and download the information searched.

In usability testing, there is no specific formula for sample size agreed among the scholars for the best practice. Conversely, there is an established thumb rule which is a 4±1 or 10±2 model being used commonly as the usability testing sample size [24]. There are some valid reasons for using the thumb rule as the best approach for detecting problems in usability testing. Based on previous research [25,26,27,28], three major conclusions can be drawn: most problems are discovered by the first three to five participants; the increase in problem discovery after five participants is minimal; and the return on investment of usability testing can be maximised by reducing the sample size.

As stated before, for estimating the sample size required in the testing of a web interface, the rule of thumbs of 4±1 or 10±2 model is widely used to obtain a proportion of at least 80% of the problem discovery [24]. Experts in user experience studies agree that a smaller sample size is critical in understanding the core problem in a user experience study and achieving reasonable levels of problem recognition [29, 30,31,32, 33]. To avoid biased results from a small sample size, this study uses 10±2 as the rule of thumb. Hence, the total respondents for this study are 12 end users.

In the usability testing plan, a few test sessions are proposed in the following order, namely:

1. Screener test

This test was administered prior to the collection of data to classify respondents who meet the study criteria. The criteria for the users were working age at 18- 56 years old [34], have internet access and regular users of the internet [35]. The respondents were asked to complete the next stage afterwards.

2. Pre-test questionnaire (Parts A, B, C, D, and E)

In usability testing, the pre-test is essential to define the profile of user who will be performing the testing. A quick pre-test questionnaire is frequently undertaken before the user begins to experience the product. It is designed to assist the developer to better understand the user's views, goals, and behaviour in relation to the product under test [36,37,38]. In this test, the respondents were required to complete the questionnaire mainly on self-information, occupational information, knowledge of air quality, health effects from exposure to bad air, and actions taken to prevent exposure to bad air. These parts of the questionnaire are adopted from [39] which has been translated to Malaysian Language.

3. Post-task questionnaire (Task scenarios)

Next, the respondents were asked to install the application of this system on their smartphones and are required to follow the instructions given by the examiner according to the scenarios. This usability testing plan is adopted from [40].

4. Post-test questionnaire (Parts F, G, and H)

These parts of the questionnaire are adopted from the revised version three of standardized Post-Study System Usability Questionnaire (PSSUQ) by [41]. The questionnaire has also been used in other recent user-centered application research proving the usefulness in problem recognition of their product [42,43,44].

Overall, the questionnaire comprises a few parts, namely; Part A: Self-information, Part B: Occupational information, Part C: Knowledge of air quality, Part D: Health effects from exposure to bad air, Part E: Actions taken, Part F: User Feedback on the Prototype, Part G: Usability Testing (Apps), and Part H: Usability Testing (Website). The overall study flowchart from the early stage to the evaluation of the prototype is illustrated in Fig. 2.

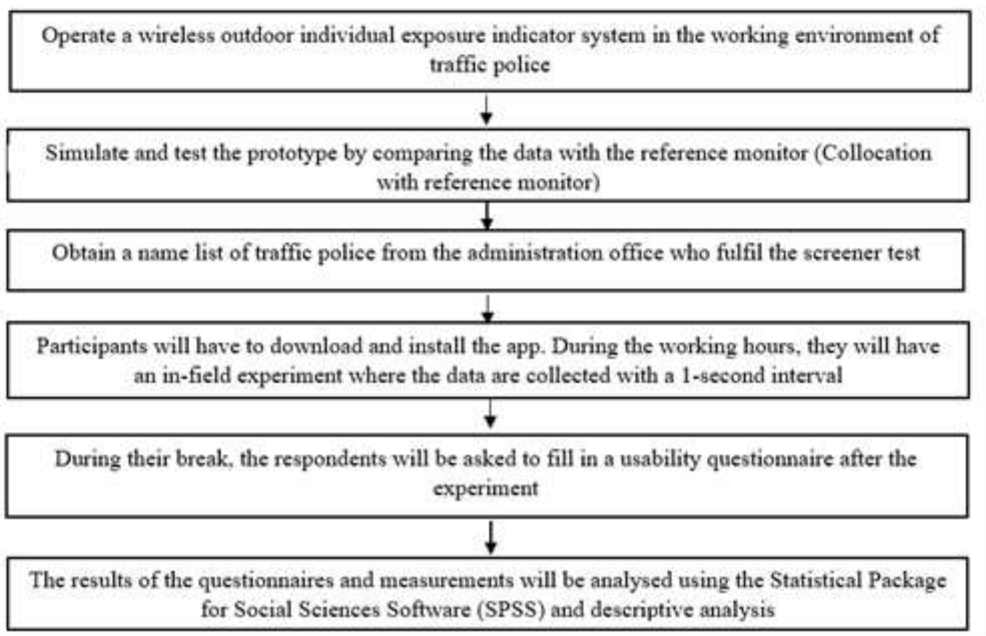

Figure 2. Flowchart of the proposed evaluation methods

4. Conclusion

This chapter has developed a generic methodology to evaluate the wireless outdoor individual exposure indicator system prototype with the aim of monitoring outdoor air quality. Furthermore, this method has laid the overall evaluation process from the sensor's accuracy and performance to the extent of end-user experience. Future researchers could seek to achieve a monitoring solution unique to their needs by following the three-stage framework.

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