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A Prototyping Model of Intelligent Hearing Protection Device

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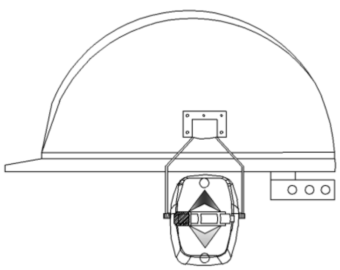
Graphical abstract



Abstract

The occupational noise exposure problem is getting serious and the workers have low self-efficacy in using the hearing protectors during the working period. In this paper, it reveals a prototyping model, namely, Intelligent Hearing Protection Device (IHPD) as a new hearing technology to cope with current problems. This device could measure the noise level in the workplace, detect the regularity of worker in the usage of IHPD and indicate the high noise area. Meanwhile, the IHPD is required to connect with the Dosiwatch and the Integrated Noise Exposure Software (INES) to improve its functionalities. The Dosiwatch is an electronic device to display the noise level and indicate the risky area, where it helps the workers to perceive the risk of noise in a workplace. The INES receives the noise data wirelessly, plots the instantaneous noise charts and supervises the regularity of workers in using the IHPD. By the way, the technical procedure development and the typical function of electronic gadgets are significant in this invention. A prototyping model was developed to ensure the technical procedure development meets the conceptual design of IHPD, dosiwatch and INES.

Keywords: Hearing protection device; occupational noise exposure; self-efficacy; prototype

1.0 INTRODUCTION

Hearing protection devices (HPD) protects the workers from excessive exposing to occupational noise. According to Occupational Safety and Health Administration (1983), HPD should be provided when the noise above 8 hour time-weighted average (TWA) of 85 dBA or 50% noise dose.[1] The earplug and earmuff are the most common types of HPD have been used in the workplaces. The utilisation of both devices is cost effective and easy to apply in the workplaces. Majority industries are preferred to use the HPD in providing the solution to cope with hazardous noise. Also, the performance of HPD depends on the noise reduction rate (NRR) in determining the level of noise attenuation. The design of HPD should be well fitted and comfortable, so it will not affect the worker's performance in their daily work.[2-3]

The function of HPD is used to protect worker's hearing system, but it cannot perform the actual attenuation if a worker do not wear this device properly and regularly during the working period.[4-5] Previous study revealed that the workers are not wearing the HPD regularly and correctly when working in a noisy area.[4] In the United State, it was estimated about 34% of the workers does not wear the HPD when exposed to the occupational noise.[6] The prevalence of hearing impairment can still be found in the workplaces, even though the employers provided the hearing protector to their workers in daily works.[7] Hence, it is important to study the reasons of workers use the HPD irregularly. Previous studies showed that several reasons for irregular use include the workers' bad attitude and beliefs, difficulty in communication, discomfort and low motivation.[5,8]

In order to increase the utilisation rate of HPD, the improvement of workers' risk recognition and self-efficacy in using the device is needed.[9] The worker's attitude and belief are main reasons influencing the self-efficacy of HPD use.[2,9,10] They are willing to wear the HPD regularly when they have high self-efficacy in HPD use. This is because the workers could recognise the impact of occupational noise, so they will take further action in the adoption of HPD. Besides, the training is necessarily providing to the workers to gain the noise knowledge. However, the previous studies proved that the training does not increase the utilisation rate of HPD, because it raises perceived susceptibility only, and cannot promise the workers will take further action.[5,11] Also, the self-report assessment determines the adoption of HPD use, but it was found that the workers overestimated the utilisation rate of HPD when reporting to this assessment.[12,13,14]

Therefore, the previous studies revealed the needs of further improvement of hearing technology. So, it could help the workers in perceiving the hazardous occupational noise and wearing the HPD regularly. This study reveals the prototyping model of new hearing protection technology, namely, Intelligent Hearing Protection Device (IHPD). The following sections discuss the conceptual design, the technical description, the prototypes and the discussions of this device.

2.0 CONCEPTUAL DESIGN

Hearing protection device (HPD) is the best solution to cope with occupational noise-induced hearing loss. However, there are several reasons had reduced the effectiveness of HPD noise attenuation, including bad attitude, poor risk perception, and low self-efficacy in HPD use. The design of IHPD is generally coping with the current problems, where it is an electronic device to be attached on a normal HPD. The design purpose is to enhance the functions of normal HPD, where it has a microphone to measure the noise levels, warning lights to indicate the noisy areas, and an infrared sensor to check the adoption of HPD. The warning lights will be automatically turned into red when the noise level exceeded 80 dBA, and turned into green when noise level below 80 dBA. Meanwhile, this device is wirelessly operating with another two components, such as the Dosiwatch and the Integrated Noise Exposure Software (INES).

The Dosiwatch is invented to change the risk perception and increase the awareness of workers towards the impact of occupational noise exposure. It is wirelessly connected to the IHPD to receive instantaneous noise data and display the results on screen. The subtle design of Dosiwatch displays the current time and the instantaneous noise levels. Thus, the workers could aware and perceive the noise exposure level in their working area. The vibratory system embedded in the Dosiwatch allows slight vibrating when exposed to high noise level. It is used to remind workers when they are exposed to a hazardous noise exposure area. So, the workers could have high risk perceived level and high self-efficacy in using the HPD.

By concerning the issue on the self-report of HPD use, many workers are overestimated their utilisation rate of HPD in the noisy workplaces. The management needs to monitor and supervise their workers to wear the HPD regularly and control their daily noise exposure limit. Thus, the INES is purposely designed to increase the awareness of management towards the workers' health, and could generate a reliable report to indicate the utilisation rate of HPD. The INES is wirelessly connected with the IHPD in order to transmit the instantaneous noise data. Multi-functional INES provides the general noise calculations, the instantaneous noise charts plotting, and the automation in generating noise monitoring documents. Interestingly, it could supervise the worker in the adoption of HPD during the working period. The INES enhances the efficiency and the effectiveness of management in monitoring and supervising their workers. It can obtain the most accurate information of HPD use, and study the behavior and response of workers regarding to occupational noise exposure.

3.0 TECHNICAL DESCRIPTION

In this section, it discusses the functions of electronic components in IHPD and Dosiwatch, as well as the INES. The Figure 1 reveals the technical procedure development of the IHPD, the Dosiwatch and the INES. The followings are the descriptions of each component in this new technology:

1. The microphone is used to measure the sound pressure from the noise sources and converting the pressure into an electrical signal. The signal will be used for the further processes.
2. The microprocessor is designed to control the measurement device, the warning zone indication, the protector-wearing status, the wireless data transmission, as well as the data logging systems. It is programmed to calculate the noise data, such as the sound pressure level, the equivalent continuous noise level, the time-weighted average (TWA) noise level for 8 hours, the dose percentage, the noise peak level, the minimum noise level, the noise level exceeded for 10% of the time, the noise level exceeded for 50% of the time, and the noise level exceeded for 90% of the time.
3. The LED represents the warning light for indicating the noisy areas. According to the Factories and Machinery (Noise Exposure) Regulations 1989 stated that the “quiet” means the “absence of exposure to sound levels exceeding 80 dBA”.[15] Thus, the warning lights on an IHPD will turn to red when the noise level exceeds 80 dBA and are green when the noise level is below 80 dBA. The warning light on an IHPD is used to increase the awareness of the workers and the officers.
4. The built-in wireless systems in the IHPD, the Dosiwatch and the INES enable the data transmission between the devices and software.
5. The infrared sensor is used to detect the usage of HPD during the working period. When the workers disuse the IHPD, a signal will be automatically sent to the INES in order to remind the officer about the current worker's status in a workplace.
6. The battery is rechargeable and the duration of battery life should be sustained more than 8 hours for the measurement.
7. The microprocessor is designed to control the warning zone indication, the data receiving, the data displaying, the data switching and the vibratory systems.
8. The buttons allow a user to switch the display data and reset the system.
9. The display screen on the Dosiwatch shows the current time and the noise data, for instance the current noise level, the equivalent continuous noise level, the TWA noise level for 8 hours, the dose percentage, the noise peak level, the minimum noise level, the noise level exceeded for 10% of the time, the noise level exceeded for 50% of the time, and the noise level exceeded for 90% of the time.
10. The vibratory device is used to vibrate for a short period of time which can remind the worker about the high noise level in a particular area, without inducing the workers feel discomfort.
11. The INES is programmed to assist the IHPD to improve its functionalities and performance. It receives the noise data wirelessly and the protector-wearing status from the IHPD. The instantaneous graphs, the histograms, and the data will be displayed in this software, including the results from the analysis of data. Lastly, it is able to generate a noise monitoring report including the result of worker in HPD use.

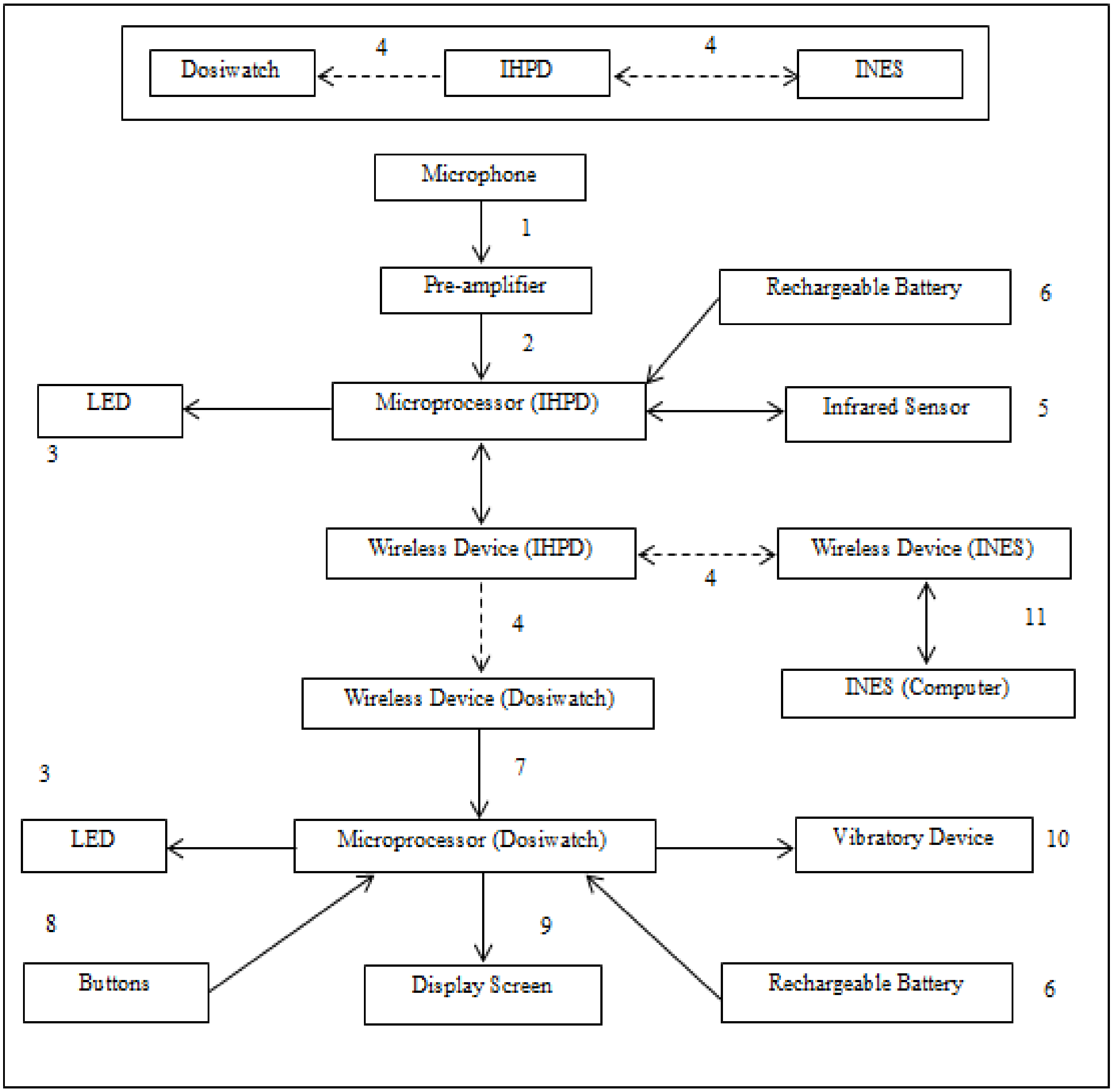


Figure 1 Technical procedure development

3.1 Application of IHPD

The application of an IHPD in efficient and effective way is shown in Figure 2. In the utilization of IHPD, a workers' representative will be chosen in a particular area to wear IHPD with a measuring device. The representative should be the person who is critically exposed to noise sources and noise data will be sent to INES for further calculations. After calculating the noise data, the results will be sent back to the representative and adjacent workers, who are wearing IHPDs without measuring devices, indicating the current noise circumstances in that particular area. For example, as shown in Figure 5, workers A, B and C are sharing the same noise levels as the representative and the safety officer is monitoring noise level in the workplace. For safety purposes, even though the adjacent workers are sharing the same noise level with the representative, they should know the critical noise level in their working area, so preliminary prevention can be taken. The intention of this application method is to minimize the cost of the IHPD and enhance the method of noise monitoring in the workplace. Also, the promotion of a caring attitude could be found in this method; co-workers are inter-reliant on each other and definitely they might remind others to use HPDs regularly in the workplace. Moreover, INES produces a personal noise exposure report, where the result represents critical noise exposure levels of the homogenous workers. The employer can assess noise exposure levels and identify how the impact of the noise source affects workers via this report.

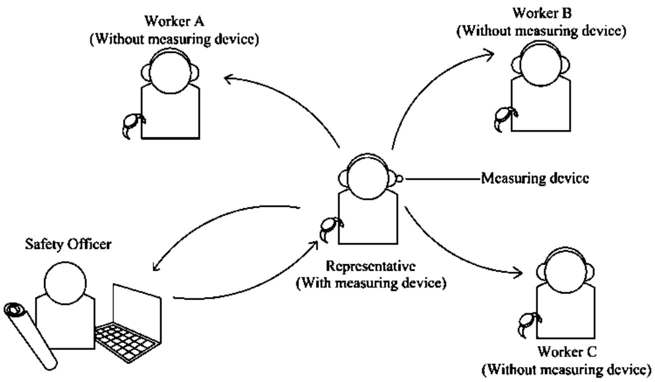
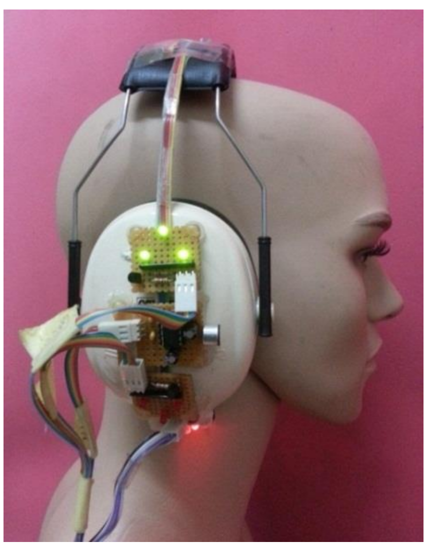


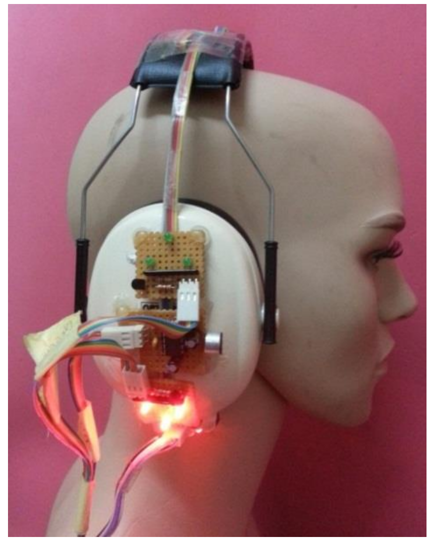
Figure 2 Application of IHPD

■4.0 PROTOTYPE TESTING

After the explanations of the conceptual design, the technical procedure development the application of IHPD, this section describes the development of the prototyping models. It tests the function of each component in order to ensure all components have met with the requirement of the design purposes. The Figure 3 shows the prototype of IHPD and the testing on the electronic components, where the Figure 3(a) and Figure 3(b) tested on the sensitivity of the warning lights when exposing to different noise levels. The IHPD design system can be effectively transmitting the noise data to the Dosiwatch and the INES wirelessly. The Figure 4 shows the infrared sensor to detect the regularity of HPD use. It transmits the instant noise data to the INES wirelessly, and so the management could receive the latest status of workers in a workplace.



(a)



(b)

Figure 3 The prototyping model of intelligent hearing protection device below 80 dBA (a) and above 80 dBA

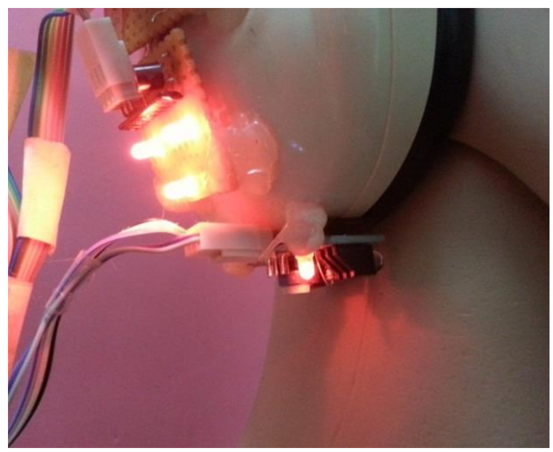


Figure 4 The infrared sensor on the IHPD

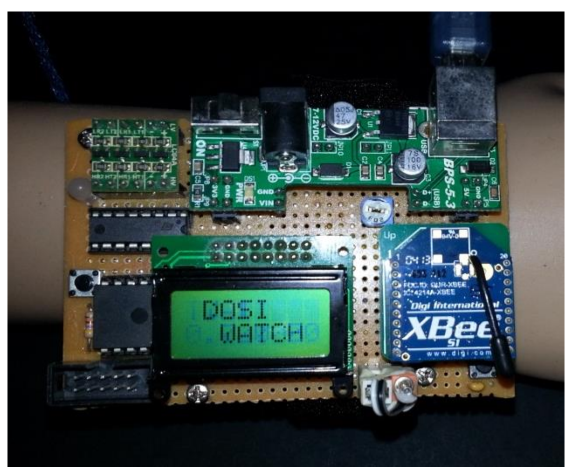


Figure 5 The prototyping model of dosiwatch

By the way, the prototyping model of Dosiwatch wirelessly connects with the IHPD and displays the latest noise information to a user as shown in Figure 5. It vibrates slightly when the noise levels above 80 dBA, which is important to remind the workers about the circumstances of the noise level in a workplace. Furthermore, the prototype of INES was developed successfully as shown in Figure 6. This software could wirelessly connect with IHPD to receive the latest noise level from the measurement. It calculates and plots the noise data, including the instantaneous sound pressure level, the equivalent continuous sound pressure level, the histogram, the TWA sound level, the noise dose percentage and the noise reduction rating charts. This software displays the latest data and includes the statistical noise levels, such as the L10, the L50 and the L90. A database was programmed to store the company and worker profiles. So, the user can select the workers through the selection function of this software and easy to conduct every new measurement. In particular, the green and red colours represent the usage of HPD by the workers as shown in Figure 6. The green colour represents the workers are wearing the hearing protector, and the red colour indicates the worker is not wearing the hearing protector. So, the management can refer the workers' status to check the regularity of HPD use. Lastly, this software could generate a report to assist the management in assessing the noise exposure problem in a workplace.

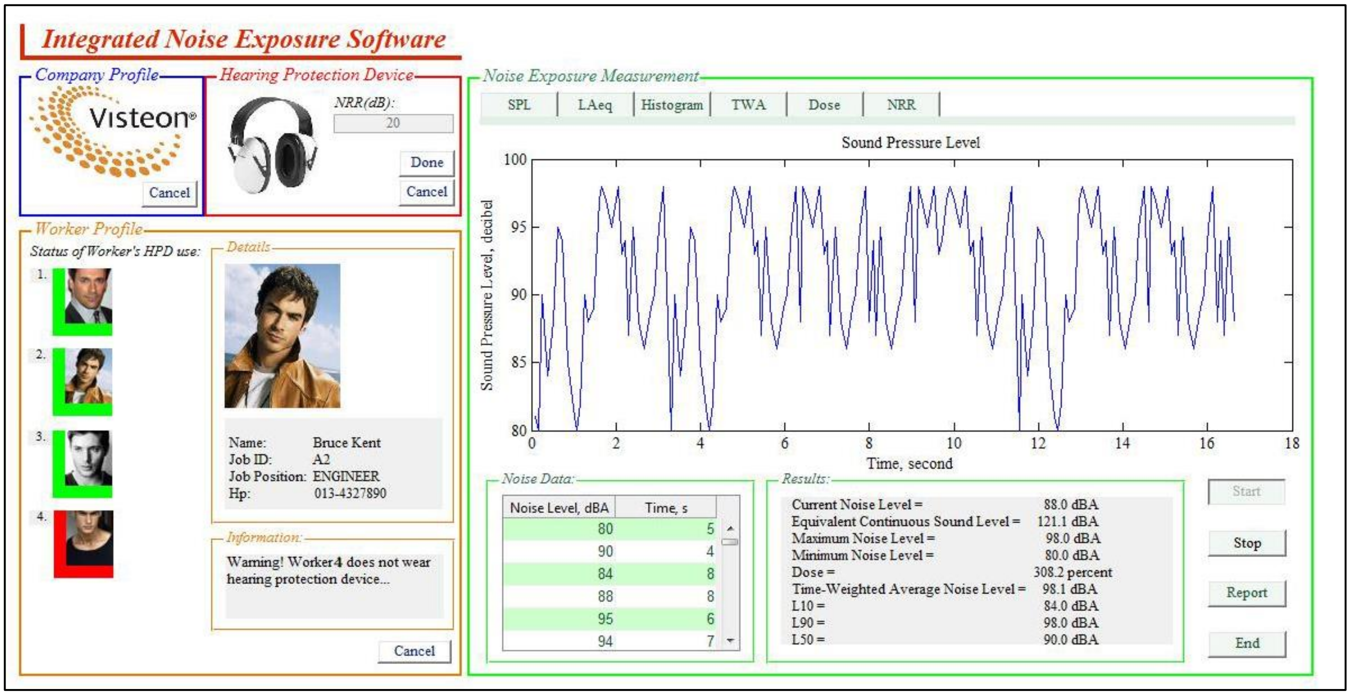


Figure 6 The prototyping model of integrated noise exposure software

■5.0 DISCUSSION

Basically, the conceptual design of IHPD is developed to solve the current noise exposure problem in the workplaces. By using the electronic components to enhance the functions of HPD, it is expected the IHPD could increase the awareness of workers towards the occupational noise. Also, it could assist the workers in identifying the potential risk when they are exposed to the noisy workplaces. This is due to the workers could recognise the noise situation through the warning lights and the vibratory system in these devices. As a return, the IHPD could increase the self-efficacy of workers in using the hearing protector. Likewise, the Dosiwatch could increase the knowledge of workers by displaying the instantaneous noise data on the display screen. It helps the workers to distinguish the hazardous noisy area and take the preventive action when working in that particular area. It is significant to gain the worker's knowledge in order to increase their self-efficacy in taking the preventive action when they are exposing to high noise area.[16] In the design of INES, it could assist the management in monitoring and supervising their worker through the latest information regarding to the noise circumstances in a workplace. The noise charts are plotted in real-time and the INES will automatically detect the worker's status in using the HPD. The INES could reduce the work burden, where the management does not need to frequently supervise their workers. The result from this software could be used as the information for noise abatement planning. It could enhance the effectiveness of strategic planning in order to maintain the noise level moderately for a sustainable development and reduce the occupational exposure problems.[17,18]

After the development of the prototyping models, the next process is conducting a site measurement and a survey for collecting the data to verify the concept of this invention. The site measurement allows the workers to use the IHPD and obtains the response from the workers after they used the device. By the same token, a survey will be conducted by obtaining the perception from the industrial officers regarding to the design of IHPD. This is important to obtain the feedbacks from the industries for verifying and improving the design concept. Indeed, there is some improvement is needed in these devices, especially the type of microphone using in the IHPD. The microphone and the measuring process should be complied with the standards as discussed in the IEC 61672-1:2002 and BS EN 61252 standards.[19,20] The devices must meet the design criteria in order to deliver the best quality and high accurate devices to the industries. In the ergonomic design, it should consider the weight and the shape of these devices, where the devices should be lighter and the shape of device must be well fitted to the workers, so they will not feel discomfort and affect their daily performance at work. Also, the clinical trials must be conducted on these devices to avoid any unexpected harm to human and safe to use in a workplace. In addition, the user interface of the INES needs further improvement on its graphic and reprogram more new features. The software must be simple and understandable without misleading the user in conducting the measurement at their workplace.

■6.0 CONCLUSION

In conclusion, the development of IHPD is important to improve the current hearing technology. The main concept of the design is to improve the workers' utilisation rate of HPD and used as a supervision tool in a workplace. It is crucial important to increase the self-efficacy of workers in using the hearing protector. The devices could assist the workers to recognize the risk of noise and noise level in their workplace. Also, it allows the management to check the noise circumstances and workers' protection status. So, the management could aware the impact of occupational noise towards the workers' safety and health. The INES allows the management to make decision for further preventive action on occupational noise, including studies the workers' behaviour in using HPD and locates the noisy area.

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