การตรวจวัดระดับเสียงรบกวนจากช่วงแรกของการก่อสร้างในสภาพแวดล้อมของสถานศึกษา: กรณีศึกษาเสียงจากเครื่องตอกเสาเข็ม

Measurement of Construction Noise under Site Preparation in Academic Environment: A Case Study of Noise from The Pile Driver

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์ในการตรวจวัดระดับเสียงจากกิจกรรมการก่อสร้างของเครื่องตอกเสาเข็มเพื่อพิจารณาความเสี่ยงต่อสุขภาพของคนภายในมหาวิทยาลัย โดยใช้โปรแกรมสำเร็จรูปในโทรศัพท์มือถือระบบปฏิบัติการ iOS และ Android เป็นเครื่องมืออย่างง่ายในการตรวจวัดระดับเสียง โดยปฏิบัติตามแนวทางมาตรฐานในการตรวจวัดระดับเสียง ที่ระยะห่างแหล่งกำเนิดเสียง 50, 80, 120, 160, และ 240 เมตร และเปรียบเทียบค่าการตรวจวัดระหว่างการใช้โทรศัพท์มือถือกับเครื่องวัดระดับเสียงมาตรฐาน (SLM) ผลการตรวจวัดพบระดับเสียงสูงสุดที่ตำแหน่ง 80 เมตร ทางทิศตะวันตก โดยระบบ iOS ตรวจวัดได้ 77.70±0.39 dB (A) และระบบ Android ตรวจวัดได้ 29.67 ± 53.0dB (A) เมื่อเปรียบเทียบกับ SLM พบว่า iOS มีค่าสูงกว่า 69.20± 55.2dB (A) และ Android มีค่าต่ำกว่า - 15.9± 15.5dB (A) ผู้คนที่อยู่ห่างออกไป 80 เมตร ทางทิศตะวันตกของเขตก่อสร้างมีความเสี่ยงต่อการได้รับเสียงดังจากกิจกรรมการก่อสร้าง ซึ่งปัจจัยที่มีผลต่อความดังของเสียง คือ ระยะทางและการสะท้อนของเสียง โดยระดับเสียงลดลงตามระยะทาง 80 เมตร 160 เมตร และ 240 เมตร ตามลำดับ การสะท้อนของเสียงจากอาคารทำให้ตำแหน่งที่ห่างออกไป 80 เมตร ทางทิศตะวันตกที่ระยะไกลกว่าได้รับเสียงดังกว่าที่ตำแหน่ง A ซึ่งห่างออกไป 50 เมตร ทางทิศตะวันออก จากผลการเปรียบเทียบกับ SLM มีค่ามากกว่าค่าที่ยอมรับได้จึงควรใช้สำหรับการตรวจวัดเบื้องต้นเท่านั้น

คำสำคัญ: เสียงจากการก่อสร้างอาคาร, ความเสี่ยงต่อสุขภาพ, สมาร์ทโฟน, แอปพลิเคชั่นตรวจวัดระดับเสียง

Abstract

The purpose of this study was to measure the sound level from construction activities by using mobile applications to consider health risk of people in the university. The mobile phone applications on both iOS and Android based were applied as screening tools for measuring sound level by following the national standard sound level measurement guideline at 50, 80, 120, 160, and 240 m from the source. Comparison between applications and standard sound level meter (SLM) was conducted. The results indicated that the maximum hourly average sound level without background noise under construction preparation by pile-driving machine was found at 80 m in the west 77.70±0.39 dB(A) by iOS platform and 67.29±0.53 dB(A) by Android based application. The difference between the SLM and iOS application was 20.69±2.55 dB(A) and Android application was -9.15±5.15 dB(A). It was found that the people at 80 m away in west direction could be at risk of loud noise from construction. The factors influenced on sound level were distance and noise reflection. The sound level was decreased by distance from 80 m to 160 m and 240 m, respectively. Reflection of building enhanced noise level at 80 m in the west so it was louder than at 50 m away in the east. The results were over the acceptable value when compare with the SLM so they could be applied as screening tool.

Keywords: Building construction noise, Health risk, Smart phone, Sound level application

Introduction

Noise pollution has been reported by Thai Pollution Control Department as the second most serious public complaint (PCD, 2018). In China, noise from construction activities has become the second most serious acoustic polluting element (Xiao, Li and Chang, 2016). Construction activities generate noise pollution that depends on construction activities and stage of work. Construction activities consist of demolition, site preparation, building, extension and structural alternations, repair and maintenance of existing buildings. The noisier period is site clearing and preparation, especially concrete breaking, while the quiet activities are electrical works, internal-fit out, and painting. High noise level construction activities include earthmoving machinery, such as bulldozers, loaders, excavators; compactors; vibratory rolling – machinery rolled over a surface to make it compact; pile driving – boring steel and concrete into the ground; rock breaking – machines used to break up rock and concrete; diesel generators; power tools and other machinery; site radios; heavy vehicle movement to, from and at the site; loud voices. The impact of noise from construction can disturb daily activities requiring mental concentration, e.g., reading or studying (EPA Victoria, 2020). In the Czech Republic, the protection of noise from construction was considered using modelling software (HLUK+) by studying the influence of noise barrier. The noise barrier could reduce noise affect but high cost of installing raised construction costs (Kantova, 2017).

Health impact from noise induced by building construction has been increasingly prominent so plenty of health concerns research in many countries. In China, the noise on the 31-storey residential building residents in Guangzhou was surveyed and measured by EMM-6 Electret microphones (Dayton Audio, Springboro, OH, USA) and found that the day-time noise level was 64.9 dB(A)-86.2 dB(A) and the night-time noise level was 57.3 dB(A)-64.5 dB(A). The vertical noise along the height of the building was determined and found that noise levels within the building were slightly amplified from lower floors to middle floors and then gradually attenuated with increasing height. The noise levels in the lower floors were relatively smaller than those on the middle floors because there are noise barriers around lower floors, such as trees and walls (Zou et al. 2020). The quantitative model to assess the health impact assessment (HIA) associated with construction noise for individuals living adjacent to construction sites was developed to consider health impairments in four categories: cardiovascular disease, cognitive impairment, sleep disturbance, and annoyance (Xiao et al., 2016). In India, the study of noise from the construction site was conducted by literature review and detailed questionnaire survey in supervisors, workers, and engineers. The major noise was originated from 55% of noise from equipment and 15% of noise from heavy machineries, which affected 30% of labors and workers at the construction site in hearing loss, stress and headache, and elevated blood pressure (Geetha and Ambika, 2015). In Iran, noise annoyance from 20 construction worksites and 140 residents were surveyed and found the main sources of noise were diesel power generators, cutting and welding processes, heavy machinery, and transport of materials at average 74.57±7.12 dBA. The nearby residents affected disturbance in sleep, difficulty in reading, and distraction (Golmohammadi et al., 2013).

The important of smartphone applications is available in every smartphone for noise detection. The most common device used for measuring sound is the sound level meter (SLM). However, the device has limitation in general people that they cannot provide because of financial issues, which is the advantage of the free applications (apps). The research has been conducted to validate the accuracy by comparing it with SLM. They found that iOS platform could provide the results ±2 dBA different from SLM (Kardous and Shaw, 2014) and the result could be improved by using the external microphone with ±1 dBA difference from SLM (Kardous and Shaw, 2016). The overall accuracy depended on the age and the condition of the smartphones and the quality of the internal microphone (Murphy and King, 2016). The advantage of the apps was it could simply identify the source of loud noise i.e. measuring of noise pollution at Valaya Alongkorn Rajabhat University under the Royal Patronage by using 10 apps were conducted at various activities in the university to observe activities that generated loud noise, which were the sports activity and the activities that used amplifier in a limited area (Hinsui and Pamonpol, 2017). Two apps (Decibel x and Sound Meter) were selected to test with various smart phones in both iOS and Android platform at low level and high level of sound. The disadvantage was the results present over values when compare with SLM for 25.95±6.29% at low sound level and 21.69±7.22% at high sound level in iOS platform in some apps (Puang-ngern and Pamonpol, 2019).

During the studied period of this research, the site preparation activities generated impulsive noise from pile driving. This matter could probably have health effects on people in the university consisting of 9,942 university students, 2,145 school students, 1,042 staff, and nearby areas (VRU, 2019).

Objective

The purpose of this study was to explore the sound level from construction activities by using smartphone applications to consider the health risk of people in the university.

Methodology

1. Monitoring Sites

The sound level of building construction was monitored by four mobile phones at five sites around the acoustic source at sites A, B, C, D, and E as presented in Table 1 and Figure 1.

Table 1 Location of monitoring sites and distance from construction site

Monitoring Sites	Place	Location (Latitude, Longitude)	Distance from construction site (m)
Construction site			
Building no. 5	Construction site	14.13348, 100.61692	0
Monitoring sites			
A	East	14.13342, 100.61767	50
B	North	14.13441, 100.61648	120
C	West	14.13339, 100.61585	80
D	West	14.13328, 100.61513	160
E	West	14.13333, 100.61439	240

Location of the construction site was at the building number 5 in front of the university. Five monitoring sites (A, B, C, D, and E) were presented on the map in Figure 1.

Figure 1 Monitoring sites at A, B, C, D, and E on the university map.

Source: Applied from VRU map, 2016

The criteria of the site selection were surrounding the construction site in the university at the community area that the receptor could have risk from the noise disturbance.

2. Sound Level Measurement

Four smartphones with different models were applied in this research. Two of them were on the iOS platform (iPhone 11 Pro and iPhone 6 Plus) and another two were Android-based applications (Samsung J2 and OPPO A83). Each iOS smartphone was installed “Sound Meter-Decibel Meter” application developed by Ying Chen (China). Each Android-based phone was installed “Sound Meter” developed by Abc Apps Team. These applications were free of charge.

The sound level measurement was carried out by following the outdoor guideline measurement (DOH, NA; PCD, 2018). The construction noise was mainly from the pile-driving, which was the impulsive noise. The measurement was conducted outdoor at the height of 1.2 m above ground level, 3.5 m away from walls or any establishment. Measurements were carried out during construction site preparation in January 2020. The sampling interval of construction noise (L_{eq}) was fifteen minutes for three replicates during pile-driving operation. The working period of construction workers was 8:30 to 17:00. The pile-driving noise happened around 8:30 to 9:00 and 16:30 to 17:00. Residual noise level (L_{Aeq}) and background noise level (L_{90}) were measured at 5 minutes time intervals for three replicates. The residual noise level was measured during work hours that included the sounds from activities of people as usual (10:00-16:00). The background noise was measured after office hours and avoid during traffic congestion (19:00-20:00).

Validation between the SLM and smartphone applications was conducted indoor by installing device at 1.2 m above ground floor and 1.5 m away from wall. The test was performed at 40 dB(A), 50 dB(A), and 60 dB(A). The SLM was certified IEC 61672-1 Class 2.

3. Harmful Noise Determination

The measured sound level was determined for harmful level by following diagram (Figure 2).

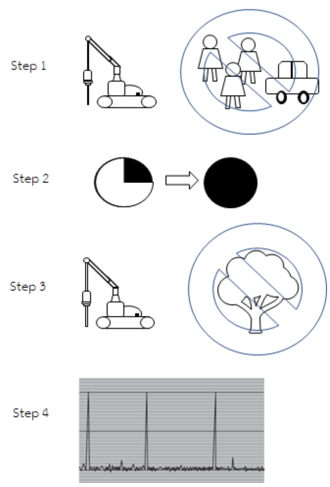

Figure 2 Diagram of calculation.

Step 1: Remove surrounding noise by

$$D = L_{Aeq,\ Ts} - L_{Aeq} \qquad (1)$$

where $L_{Aeq,Ts}$ is the average specific noise level, L_{Aeq} is residual noise level; and D is difference value of sound level between construction activities and surrounded activities. Compare the D result with the PCD reference table to obtain $L_{Aeq,\ Tm}$ (PCD, 2018).

Step 2: Calculate hourly average specific noise level

$$L_{Aeq,\ Tr} = L_{Aeq,\ Tm} + 10log_{10}(T_m/T_r) \qquad (3)$$

where T_m is the measurement period (15 minutes) and T_r is the reference period (60 minutes)

Step 3: Consider the only sound level of the construction noise without surrounding background noise by

$$L_{Aeq\ net} = L_{Aeq,\ Tr} - L_{90} \qquad (4)$$

where $L_{Aeq\ net}$ is the sound level of the construction noise without background noise; and L_{90} is background noise level at 90 percentile, and; $L_{Aeq\ net}$ is level of disturbance.

Step 4: Adjust impulsive noise level

$$L_D = L_{Aeq\ net} + 5 \qquad (5)$$

where L_D is the level of disturbance. It was used for determining whether the monitored sound is a potential noise problem by comparing with 10 dB(A) (PCD, 2018)

Results and Discussion

Results of sound level measurement at sites A, B, C, D, and E by the applications in iOS and Android smartphones are presented in Table 2.

Table 2 Sound level measurement by smart phone application results

Measurement site	$L_{Aeq,Ts}$ (dBA)	L_{Aeq} (dBA)	$L_{Aeq,Tr}$ (dBA)	L_{90} (dBA)	L_D(dBA)
Site A					
iOS1	88.61	85.72	79.59	85.40	(0.81)
iOS2	82.36	81.68	69.34	76.86	(2.53)
Android1	64.39	60.49	56.37	59.07	2.30
Android2	68.51	55.19	62.49	51.65	15.84
Site B					
iOS1	87.38	78.51	80.86	75.20	10.66
iOS2	82.88	78.51	74.86	75.37	4.49
Android1	64.97	58.73	57.45	51.36	11.10
Android2	62.85	57.64	55.33	54.67	5.66
Site C					
iOS1	84.61	76.38	78.09	70.61	12.48
iOS2	83.83	76.38	77.31	69.06	13.25
Android1	73.84	59.81	67.82	48.18	24.64
Android2	72.78	52.78	66.76	44.90	26.86
Site D					
iOS1	91.09	84.83	83.57	72.57	16.00
iOS2	80.59	77.95	71.57	72.57	4.00
Android1	62.38	60.96	49.36	46.44	7.92
Android2	58.99	47.85	52.47	41.83	15.64
Site E					
iOS1	78.43	74.55	70.41	70.61	4.81
iOS2	81.01	70.61	74.49	69.06	10.43
Android1	54.02	47.95	46.50	41.47	10.03
Android2	47.81	43.05	40.29	41.20	4.09

Note: $L_{Aeq,Ts}$ is the average specific noise level, L_{Aeq} is residual noise level, $L_{Aeq,Tr}$ is hourly average specific noise level, L_{90} is background noise level at 90 percentile, L_D is the level of disturbance (compare with standard at 10 dBA)

The data from Table 2 were analyzed by removing the surrounding sound to obtain real noise from the construction ($L_{Aeq,Tr}$) and presented in Figure 3.

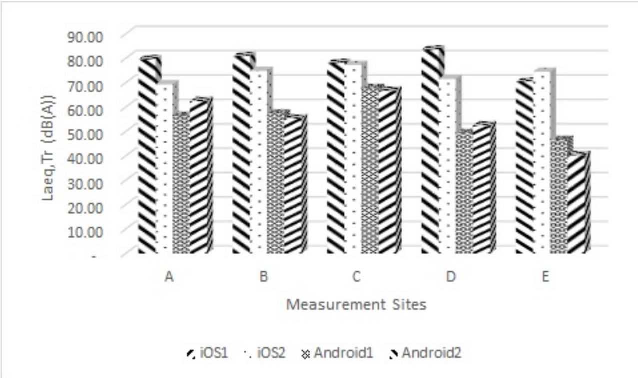

Figure 3 Sound level of construction without surrounding noise at site A, B, C, D, and E measured by sound level applications based on iOS (iOS1 and iOS2) and Android (Android1 and Android2) platform.

From Figure 3, the results were in the same range as the day-time noise level construction in China 64.9 dB(A)-86.2 dB(A) (Zou et al. 2020). The results of iOS-based application were higher than Android-based application. Therefore, the validation between the smartphone applications and standard sound level meter was conducted and presented the results in Table 3. The distance from the construction source was one of the factors that could decrease sound by 80 m at C, 160 m at D, and 240 m at E. Moreover, the obstacle such as buildings, constructions, trees, walls, and others between the source and the receptor could reduce noise (Zou et al. 2020). The 15-storey building was located before D so the noise was sharply decreased. Reflection was another factor that probably enhanced noise by 80 m at C was louder 50 m at A because of the reflection of noise at point C by the 15-storey building.

Table 3 presents the results of validation at 40, 50, and 60 dB(A) compared the applications on mobile phones with the standard sound level meter. It was found that iOS platform results detect over the standard sound level device at the low sound level. This could be because of the iOS smartphone system that expanded the signal at the speaker at quiet sound to perceive the clearly voice in iOS-based. On the contrary, the Android-based smartphone detected lower than the standard sound level meter. The same system presented the results in the same trend that the iOS smart phone was overestimated and the Android smart phone was underestimated.

Table 3 Validation of smartphone applications and sound level meter

dB(A)	Mean difference from reference			
	iOS(1)	iOS(2)	Android(1)	Android(2)
40	27.85	21.05	(4.03)	(9.81)
50	22.63	18.43	(2.58)	(18.64)
60	19.23	14.95	(5.39)	(14.47)

Note: () means minus values

From Table 3, the results were different from other study that found iOS platform could provide the results ±2 dBA different from SLM (Kardous and Shaw, 2014). All results were over the acceptable value at ±2 dBA when compare with the SLM so the apps can be used as a simple tool for warning to protect themselves but for the accuracy measurement, the SLM is needed.

The main noise sources in front of the university include building construction, road traffic, and people activities. The east of the university was located the main road "Paholyothin" so road traffic was the second loud noise during rush hour when the university and the school were started at 8:00-9:00 and when the school and the university were finished at 16:00-18:00. The traffic on the main road was busy in the morning (7:00-8:00) and in the afternoon (16:00-18:00) by buses and trucks. People activities were mainly located in the west where academics activities and services were provided. The serious health effect was found at 80 m away in the west direction from the construction site, which was at site C, which was observed from the L_D value over 10 dBA. The sound levels at site D and site E were decreased by distance at 160 and 240 m away from the construction site. The reason for high risk at C because there was no building or any installment between the construction site and site C. However, there was 15-storey building as a barrier at site D so the sound was low, which was consistent with Zou et al. (2020) that the noise levels in the lower floors were relatively small because there were noise barriers around lower floors, such as trees and walls. From site D to site E, the sound level was decreased because there were buildings that performed barrier in the distance.

Conclusion

This research measured construction noise at the initial phase that main noisy activity was pile-driving by iOS and Android-based smartphone applications. The results found that the serious health problem was at site C, which was located away from the construction site for 80 m in the west because of reflection of the 15-storey building at that site. The noise was decreased by distance from 80 m at site C, 160 m at site D, and 240 m at site E. The noise was sharply decreased at D because the noise was blocked by the 15-storey building. Therefore, the effect of noise could be from distance, reflection, and blocking objects. The validation was conducted by comparing with standard sound level meter and found that the iOS platform was over detection and the Android-based was under detection. Therefore, the smartphone could be a screening tool to detect noise to protect people but the results could not compare with the standard directly. They should be calculated by following the guideline to remove background noise then compare with the standard, because the detected noise includes surrounding noise and background noise that over noise detection in iOS system or under noise detection in Android system.

Recommendation for future research, the National Institute for Occupational Safety & Health (NIOSH) has provided the application in iOS platform so this app could be the best choice for noise measurement in the next study.

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