AUTOMATED PREDICTION OF NOISE FROM CONSTRUCTION SITE USING STOCHASTIC APPROACH

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Especially for my beloved parent, Mr Idris Husin and Ms Kholijah MdLazim, my husband, Hamidun Mohd Noh and my family.........

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ABSTRACT

The excessive of noise causes annoyance and suffering to the surrounding neighborhoods. A reliable method of noise prediction is needed to minimize this impact which can be utilized whilst the construction is still in the planning stage and tendering period. This will help the engineers to carry out the proper mitigation method. One such prediction model is stochastic modelling using Monte Carlo approach which has been identified to be able to predict the content of sound for a working day period and has been found to have a good agreement with deterministic method. However, this method is yet to be validated with measurement data and has not been presented in a way that user can utilize them with easy manner. This study investigates the accuracy of the model by comparing the result of the model with measurement of data from real construction sites. Also, this study develops the construction noise prediction tool by using Graphical User Interface, GUI which is useful for the user in noise management. In development of prediction tool, the model was designed to have two parts which are local model and global model that represent the small site and large site respectively. The model has taken into consideration of both the random movement of machines onsite and the random acoustic power of machines for samplings. The model results in the temporal distribution of noise level generated in a working period, including the equivalent noise level, L_{Aeq} and the standard deviation. The results were validated with the noise levels for a working day period measured from two different sites which represent a small construction site and a busy construction site. The prediction parameters obtained from measurements on site were applied in current prediction in BS5228 using deterministic approach, for further validation on L_{Aeq}. The accuracy of the developed construction noise prediction tool was carried out by means of t-test and mean absolute percentage error (MAPE). It was found that L_{Aeq} between measurements, stochastic approach and deterministic were not statistically significant at 0.05. MAPE of temporal distribution noise levels between measurement and modelling showed that the discrepancy was classified in range of 10-50 which was between good and acceptable condition classes. With these results, it showed that stochastic approach can be used as an alternative method of noise prediction to assist the environment engineers as early as in the planning stage in determination of noise arising that may affect the quality of life to the neighborhoods.

ABSTRAK

Bunyi bising yang melampau menyebabkan gangguan dan penderitaan terhadap masyarakat setempat. Kaedah yang boleh dipercayai dan boleh digunakan bagi meramal bunyi bising diperlukan bagi mengurangkan kesan ini ketika pembinaan masih berada dalam peringkat perancangan dan tempoh tawaran. Ini dapat membantu para jurutera melaksanakan kaedah pengurangan bunyi yang sewajarnya. Satu model ramalan stokastik menggunakan kaedah Monte Carlo telah dikenal pasti boleh meramal kandungan bunyi bagi dalam tempoh sehari bekerja dan telah dikenal pasti mempunyai hubungan yang baik dengan kaedah deterministik. Walaubagaimanapun, kaedah tersebut masih belum disahkan dengan cerapan data dan masih belum dipersembahkan dengan cara yang mudah dan dapat digunapakai oleh penguna biasa. Kajian ini menyelidik ketepatan model dengan membandingkan keputusan yang diperoleh dari model dengan cerapan data dari tapak bina sebenar. Kajian ini juga membangunkan alat meramal bunyi dari pembinaan menggunakan *Graphical User Interface*, GUI, yang sangat berguna kepada pengguna dalam pengurusan bunyi. Dalam pembangunan alat ramalan tersebut, model telah direka untuk mempunyai dua bahagian iaitu *local model* dan *global model* yang mewakili tapak pembinaan yang bersaiz kecil dan besar. Model tersebut mengambil kira pergerakan rawak jentera di tapak bina dan kuasa akustik rawak bagi persampelan. Keputusan dari model dalam *Temporal distribution* bagi aras bunyi yang terhasil dalam tempoh bekerja termasuklah aras bunyi setara, L_{Aeq} dan sisihan piawai. Keputusan disahkan dengan aras bunyi bagi tempoh satu hari bekerja yang dicerap dari dua tapak berbeza yang mewakili tapak pembinaan yang kecil dan tapak pembinaan yang sibuk. Parameter ramalan yang diperoleh daripada pengukuran di tapak bina digunakan dalam ramalan semasa dalam BS5228 menggunakan pendekatan deterministik bagi pengesahan lanjutan terhadap L_{Aeq}. Ketepatan alat ramalan bunyi pembinaan yang dibangunkan telah diuji menggunakan ujian t dan peratus kesilapan purata mutlak (MAPE). Keputusan menunjukkan L_{Aeq} hasil dari cerapan, pendekatan stokastik dan deterministik adalah tidak signifikan pada 0.05. MAPE bagi *temporal distribution* aras bunyi antara cerapan dan permodelan menunjukkan perbezaan dikelaskan dalam julat 10 hingga 50 iaitu antara kelas bagus dan boleh diterima. Dengan keputusan ini, didapati bahawa pendekatan stokastik boleh digunakan sebagai kaedah ramalan bunyi alternatif untuk membantu jurutera alam sekitar seawal pada peringkat perancangan dalam menentukan peningkatan bunyi yang boleh memberi kesan kepada kualiti hidup masyarakat setempat.

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LIST OF SYMBOLS

L_p	=	Sound pressure level
L_w	=	Sound power level
L_{Aeq}	=	Equivalent continuous sound level
L_{Aeq10m}	=	Sound level equivalent at 10 meter
L_{Aeq30s}	=	Sound level equivalent for 30 seconds
L_{max}	=	Maximum sound level
LN	=	Percentile Levels
L_{10}	=	Percentile levels with values exceeding 10% of elapsed time
L_{50}	=	Percentile levels with values exceeding 50% of elapsed time
L_{90}	=	Percentile levels with values exceeding 90% of elapsed time

LIST OF ABBREVIATION

DOE	=	Department of Environment
WHO	=	World Health Organization
SAE	=	Automotive Engineers Society
dB(A)	=	Decibel
SPL	=	Sound pressure level
CDF	=	Cumulative Distribution Function
PDF	=	Probability Distribution Function
MAPE	=	Mean Absolute Percentage Error
GUI	=	Graphical Interface User
CNPT	=	Construction Noise Prediction Tool

CHAPTER 1

INTRODUCTION

1.1 Introduction

Construction noise is a major contributor as physical contaminant in noise pollution after traffic noise in the society nowadays. Noise arising from construction activities is unwanted and undesirable not only to the workers but also to the community which effects on physical, psychic and social deterioration (Fernández *et al*., 2009). Annoyance on people is one of the most effects of noise (Large and Ludlow, 1975; Ng, 2000) and several reports in the mass media have also highlighted how people have been annoyed. In some developed countries, complaints regarding traffic noise are not as much as the complaints from construction noise (Berglund *et al.*, 1999). In Malaysia, the number of public complaints regarding construction noise has increased from year 2007 to year 2008 that is 44 percent to 56 percent respectively (Noh *et al*., 2009). The number of complaints might be increasing year by year if no action were undertaken. In 1996, DOE annual report proclaimed that a high percentage of urban dwellers are exposed to noise over 65 decibels. However, the only way to avoid health damage is to prevent the excessive noise exposure (Sensogut, 2007).

Thus, the prediction of noise level is concerned as early as in the planning stage through EIA report for approval of new development so that the annoyance can be reduced (Carpenter, 1997 and Carpenter *et.al*, 1997). Moreover, the noise is also concerned during tendering period and construction phase for not exceeding the limits specified by the authority. Therefore the appropriate method of noise prediction is required in order to give an accurate prediction of noise emission from construction activities. The trustworthy of noise prediction might reduce the effects of noise including annoyance that can minimize the public's complaint and no disruption on construction progress so that the project is not halted due to a few complaints.

1.2 Background of Study

The excessive noise arising from construction operations gives negative effects that might cause afflict to the workers and people living in the vicinity, which can lead to the public animosity or civilian's ire. One aspect of noise generated from construction sites is that in reality the noise level is non constant, fluctuates and vary with time (Ivanov *et al*., 2005; Gannoruwa and Ruwanpura, 2007; Haron and Yahya, 2008). The fluctuations of noise level are typically due to the nature of the construction activities, the types and the status of machinery being used and others. For example, many machinery will work in different phase where the machine might be in off condition, idling or fully power operated. The movement of machineries also influence the noise level experienced at the receiver (Haron and Yahya, 2008 and 2009) of which the noise levels is increased when the machinery as the noise source is near to the receiver and vice versa (Khouski *et al*., 2004). However, the current noise prediction method assumes these factors as gross simplification and laborious to apply if analysts want to examine the effect of various parameters due nature of prediction is deterministic.

In addition, the current deterministic noise prediction using BS5228 results only in single index which is equivalent noise level, L_{Aeq} without any information regarding confidence levels. A single L_{Aeq} prediction may mean that quality of the sound, which has a particular effect on people, may be ignored. Carpenter *et al.* (1997) claimed that prediction of L_{Aeq} in this way is inaccurate and annoyance to the community is not being addressed appropriately. He also suggests that prediction could be a model that is able to provide statistical distribution and as the result, stochastic model has been introduced. Other researchers also reported that the environment quality could be depending on the information in temporal distribution, also in addition to the L_{Aeq} value (Raimbault and Dubois, 2005; Yang and Kang, 2005; Wong, 2004). The noise prediction using stochastic approach was first developed by Waddington and Lewis (2000) and later by Gilchrist *et al.* (2003). However, both Waddington and Lewis (2000) and Gilchrist *et al.* (2003) do not present the results in a way that makes effective use of the stochastic modeling which provides statistical distribution such as Cumulative Distribution Function, CDF. Then, Haron and Oldham (2004), Haron and Yahya (2009) and Haron *et al.* (2009) have furthered the Waddington and Lewis model using the Monte Carlo approach and probability approach with CDF output. As a result, both Monte Carlo and probability approach were found to be in a good agreement with deterministic approach in terms of $L_{Aeq.}$ Beside L_{Aeq} value, a time history of noise levels arising from construction site or CDF for working day period also provides statistical information for L_{10}, L_{50}, L_{90}, L_{max} and L_{min}. L_{10}, L_{50}, and L_{90} are percentile levels with values exceeding 10%, 50% and 90% of the elapsed time respectively, and L_{max} and L_{min} stand for the maximum and minimum sound levels.

1.3 Problem Statement

Recently, researchers have shown an increased interest in noise prediction especially using stochastic approach (Waddington and Lewis, 2000; Gilchrist *et al.*, 2003; Haron and Oldham, 2004; Gannoruwa and Ruwanpura, 2007; Haron and Yahya, 2009; and Haron *et al.*, 2009). Stochastic model using Monte Carlo method have been used in noise prediction due to the variation of number of machines involved, different acoustical characteristic such as sound power, different mode of operations, for example idle, off mode or fully powered, and the movement of machinery which are not having fixed location during real construction process. Haron and Yahya (2009) and Haron *et al*, (2009), have reported that the mean value of equivalent continuous noise level obtained from stochastic modelling has good agreement with BS5228. However, this is yet to be verified with data from measurement. The automated computation or system should enable user which the user utilized easily is also yet to be developed.

1.4 Aim and Objectives

The aim of this study is to evaluate and validate the stochastic modelling system for the purpose of noise prediction from construction site. The comparison between result obtained from modelling and that of onsite measurement were carried out in order to verify the result acquired from the modelling based upon stochastic approach and ascertain whether it can be used as the construction noise prediction tools or vice versa.

The specific objectives of this research are as follows:

1. To develop a construction noise prediction tools based on existing stochastic modeling which produce the temporal distribution of noise levels for a working period, CDF for noise management.

2. To measure the noise levels generated from the actual construction site during working period as the real system.

3. To compare the results obtained from measurements, stochastic modelling and deterministic model in BS5228.

1.5 Research Scope

The scope of the research is restricted to the real onsite measurements whereas the measurements of noise emission levels arising from construction site are focused on substructure stages of construction and the measurements are carried out in the state of Johor. In addition, the results are obtained from real measurement, simulation modelling using stochastic approach and deterministic in BS5228 procedure in terms of L_{Aeq} only. The stochastic modelling in form of interface is designed in Graphical User Interface, GUI which is user friendly and is limited to maximum of four local models.

1.6 Significance of Research

The research is important and significant from both the theoretical and practical perspectives. The rationale and motivation for this research are :

- The prediction of noise exposure at the planning stages and during tendering process could be carried out using stochastic modeling which provide the temporal of distribution for a working day period and standard deviation in addition to the $L_{Aeq.}$

- The comparison and verifying of noise prediction from simulation model with the real system which is the real measurements and using deterministic approach in BS5228, will be strong evidence that simulation could be used as noise prediction and also to reduce the annoyance on people which facilitate the mitigation planning. It will be very useful to the environmental engineer.

1.7 Definition of Terms

- Sound power level: The total sound energy per unit time given out by an item of plant under particular conditions. Thus, it is an intrinsic characteristic of the source (DOE, 2004).

- Sound pressure level: Sound pressure level is the sound energy received at a specific location, at a given distance from a sound source and given conditions such as screening, etc. The units are dB(A) (DOE, 2004).

- L_{Aeq}: ‘A’ weighted equivalent sound level, a constant sound level which has the same sound energy as an actual varying sound over a given period. The unit used is ‘A’ weighted decibels (DOE, 2004).

- dB: Decibel, a measure of sound power or sound pressure (DOE, 2004).

- dB(A): ‘A’ weighted decibel to allow for sensitivities of the human ear at different frequencies (DOE, 2004).

1.8 Brief Methodology

This study was implemented in three main stages as demonstrated in Figure 1.1 below. Phase 1 of the research focused on the development of stochastic modelling using Monte Carlo method with applied the random of locations and acoustic power and also take into consideration of screening of each machinery. The model was divided into two parts which were local and global model and designed in GUI, Matlab software. Then the onsite measurements were conducted from real construction site and analyzed the noise level. The inputs that represent the real system that measured from construction site were applied in the modelling system as to evaluate and validate the noise prediction and lastly the statistical analysis were carried out to compare the results obtained and verify whether the modelling could be used as noise prediction tool or vice versa.

Stage 1-Development of stochastic modelling in term of Monte Carlo approach

- Randomly sampling locations and acoustic power of each machine in simulations of noise prediction
- Divided into two models : local model and global model
- Noise simulations interface designed in Graphical User Interface, GUI in Matlab software.

↓

Stage 2- Validation with on site measurement and deterministic approach, BS5228

- 2 different site locations selected:
  - Small site- 1 local model
  - Bigger site- multiple local models

↓

Stage 3- Comparison results between Monte Carlo simulations and real measurement and deterministic, BS5228

- Simulations were made using the actual probability and acoustic power from measurement
- The values of equivalent continuous sound levels, L_{Aeq} from simulation, measurement and BS5228 were compared using statistical analysis which is t-test and box plot
- The discrepancy between cumulative distribution levels, CDF from simulations and measurement were compared using mean absolute percentage error, MAPE

Figure 1.1: Framework of the research

1.9 Organization of the Thesis

The approach in this study is based on a number of stages which are reflected in the titles of the chapters of the thesis. The introductory chapter summarizes the problems related with the excessive noise from construction site and the effects on workers and neighborhoods. The limitations of current noise prediction using deterministic approach as it only provides the value of L_{Aeq} without any confidence levels of noise and leads to a particular sound level that might affect people is ignored.

In chapter 2, the overview of construction noise characteristic, differentiation between sound and noise, effects of noise towards workers and the communities, the measurement of noise emission levels, permissible noise emission levels and the current available noise prediction method that have been employed in this research are reviewed and analyzed.

Chapter 3 describes the methodology to conduct the research regarding the development of stochastic modelling and measurements of noise emission levels from construction site. The chapter also includes the methods of analysis of the statistical techniques that are performed to evaluate the noise emission levels and the noise prediction using stochastic and also deterministic.

In chapter 4, the analysis of results from the onsite measurement is presented. Instead of L_{Aeq}, the results also included the cumulative distribution function, CDF which provides the important percentile level such as L_{10}, L_{50}, L_{90} and L_{max}. The prediction using deterministic in BS5228 procedure are conducted using the condition as onsite measurement and are compared together in terms of L_{Aeq} only.

Then, the prediction of noise using stochastic modelling is presented in Chapter 5. In this chapter, the input data are based on the real system as measured such as noise emission level for a machine, distance and working probability. The modelling is designed in the form of interface and the example of noise prediction using the modelling tool is also included in this chapter.

In chapter 6, the comparisons of results obtained from measurement, stochastic simulation and deterministic are conducted. The statistical analysis is used to compare the results and determine whether the prediction using stochastic modelling is valid to be used or vice versa. Finally, the summary and conclusions derived from this study are presented in Chapter 7 together with recommendations for future research.

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