SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING
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DEVELOPMENT AND VERIFICATION OF TRAFFIC NOISE ESTIMATION USING QUARRY ENVIRONMENTAL MODELING (QEM)

By

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DECLARATION

I hereby declare that I have conducted, completed the research work and written the dissertation entitled **"Development and Verification of Traffic Noise Estimation using QEMs"**. I also declare that it has not been previously submitted for the award of any degree or diploma or other similar title of this for any other examining body or university.

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LIST OF ABBREVIATIONS

DOE	Department of Environment Malaysia
PCA	Principal Component Analysis
MRA	Multiple Regression Analysis
QEMs	Quarry Environmental Modelling Software
ANOVA	Analysis of Variance
JMG	Jabatan Mineral & Geosains
PPM	Pusat Penyelidikan Mineral Malaysia

PEMBANGUNAN DAN PENGESAHAN BAGI ANGGARAN BUNYI LORI DI KAWASAN KUARI DENGAN QEMS (DKLS QUARRY, LUMUT, PERAK)

ABSTRAK

Antara isu utama yang dihadapi oleh kuari-kuari di seluruh dunia ialah penyebaran bunyi daripada kuari yang berpotensi mengakibatkan kesan-kesan negatif terhadap keadaan persekitaran masyarakat setempat. Penyebaran bunyi yang datang daripada kuari-kuari adalah dihasilkan oleh lori. Pengeluaran bunyi yang tidak mengikut piawai yang ditetapkan akan mengakibatkan kesan buruk terhadap manusia terutamanya sekali. Ini mungkin akan mengakibatkan gangguan emosi dan juga pendengaran yang tidak jelas. Namun,bagi mencegah hal ini berlarutan, pihak yang bertanggungjawab telah membuat pemantauan bunyi yang kini dipraktikkan di seluruh kuari di Malaysia. Kaedah ini mampu untuk mengawal penyebaran bunyi yang berlebihan. Berdasarkan kajian ini di Lumut, Perak, tesis ini adalah untuk mencipta satu model algoritma yang mampu meramal tahap penyebaran bunyi dan disahkan oleh satu perisian yang dikenali sebagai QEMs. Data untuk tujuh parameter meterologi telah diukur menggunakan stesen cuaca dan bunyi pula diukur dengan menggunakan alat pengukur bunyi iaitu KIMO DB 200 SLM. Kemudian data yang telah dikumpul dianalisa dengan menggunakan pakej perisian IBM SPSS 13.0. Hasil daripada analisis yang telah dibuat nilai R^2 yang terhasil daripada perisian SPSS adalah sebanyak 0.044 dimana menunjukkan bahawa parameter meterologi tidak memberi kesan yang kuat terhadap bunyi. Manakala nilai R^2 yang terhasil daripada QEMs iaitu sebanyak 0.790. Ia menunjukkan bahawa perisian QEMs adalah lebih sesuai digunakan untuk mengukur bunyi kerana ia menggunakan parameter fizikal seperti jarak, kadar pantulan, gegaran dan lain-lain.

DEVELOPMENT AND VERIFICATION OF TRAFFIC NOISE EATIMATION WITH QEMS (DKLS QUARRY, LUMUT, PERAK)

ABSTRACT

Among the issues that are faced by quarries throughout the world is the emission of noise from the quarry that are potentially give the negative effects on the environmental society. The emission of the sound that come from the quarries is produced by lorries which is traffic noise. Sound emission that does not follow the standards level of noise will result in adverse effects on humans especially. This may result in emotional disturbances and also hearing loss. However, to prevent this phenomena, the responsible has made noise monitoring that is now been practiced around the quarry in Malaysia. This method is able to control the emission of excessive noise. Based on this study in Lumut, Perak, this thesis was to create a new prediction model of an algorithm that can predict the sound transmission and will be verified by a software called QEMs. Data for seven meteorological parameters were measured using the weather stations and noise was measured by using a noise measuring device which is KIMO DB 200 SLM. The data collected was analyzed using IBM SPSS 13.0 software package. The results of the analysis has been made by showed that R^2 value resulting from the statistical analysis was 0.044 which indicates that meteorological parameters do not have a strong correlation effects on the noise. While the R^2 resulting from QEMs is 0.790. It shows that the software QEMs is more efficient to use because it uses geological parameters such as distance, reflectance rate, vibration and others.

CHAPTER 1

INTRODUCTION

1.1 Background

Noise has always been with us all the time. In an environmental context, it is defined as an unwanted product that been produced from our technological civilization and it is become dangerous and give an impact towards environmental society. Surprisingly, it became the most pervasive occupational health hazard in today's industry. Noise has been produced from our daily activity. There are many sources of noise generated in our environment. Noise has been produced from the industries that used an equipment or technology that produce noise. For example, in mining and quarrying work scope. They produced sound from the transportation, blasting operation and also from the equipment used such as crusher, grinder, spiral and others. In this cases the higher the rate of production, the higher the pollution (noise) occurs.

Nowadays, in mining and quarrying field, they have generated a lot of noise from their operations. This noise has generated from the transportation of materials, process operation, mobile equipment or technology and others. Mostly, the quarry site are located near the residential area. Transport movement may include traffic truck in loading and unloading materials will be used in every operation at site. This activity may cause a disturbance of noise at the work place. This might be problem towards the environmental society if they expose to excessive level of noise in a long period of time.

In a way to reduce noise pollutions, it has the standardization for noise level while running any operations especially in produce noise. The reading of noise level will be taken by using the suitable equipment such as sound level meter (SLM), noise dosimeter, octave band analyzer, tape recorder and others. Commonly, the equipment used to measure the level of noise is sound level meter (SLM). This equipment will detect any kind of noise that been produced. Sound level meter (SLM) are often used in the site or workplace which evaluate the level of unwanted noise. After that, the reading from the sound level meter (SLM) will be transferred to the Quarry Environmental Modeling Software (QEMs). This software are used to calculate the level of noise that taken from the site. It used their specific formulae and calculation to estimate the noise level in specific form. From this software, we can know the level of noise that generated from our work place.

Noise pollutions gives a huge impact towards an environmental society. For example is hearing loss, unconditional working environment, stress, discomfort emotional, unconditional health and others. So to prevent or reduce it, action or mitigation should be taken. It is also a strategy in noise control to eliminated unwanted noise that been produced.

1.2 Problem Statement

The problem related to this research is how to estimate the level of traffic noise by using QEMs. The estimation of noise were calculated , then it would be compared to the QEMs which is Quarry Environmental Modeling Software. While the verification with this software, the result of the noise level might be different. So the development must be done properly. It might result an error on the reading of noise level. So, new formula would be created for traffic noise activity to be compared to the QEMs.

1.3 Objectives

The objectives of the research are :

i) to study the existing models for traffic noise calculation using Quarry Environmental Modeling.

ii) to monitor the sound levels from traffic and meteorological factors at selected quarry site

iii) to develop a new model for noise from traffic activities at quarry site

iv) to validate the new model and compared with QEMs formula for traffic noise at quarry site

1.4 Scope of Work

This research involved a research study at DKLS Quarry & Premix Sdn. Bhd., Lumut, Perak. The data collection has been carried out in one quarry. Multivariate statistical analysis were used to be identified the relationship between the DKLS Quarry noise level data and the effect of meteorological factors on traffic noise levels around the quarry areas. Empirical equations were developed for this analysis also known as estimated peak sound level. The statistical techniques employed were mainly principal component analysis (PCA) couple with multiple regression analysis (MRA)

The data of noise level was collected by using the KIMO DB 200 Sound Level Meter at DKLS Quarry. This process also known as noise monitoring. In this research the meteorological data was used as independent variables to estimate the peak sound level. The meteorological factors included a temperature, humidity, solar radiation, wind speed, wind direction ,pressure and rain volume. Statistical analysis was conducted by using a software which is IBM SPSS Statistics 13.0 software package.

The verification of this model estimation will be compared with the QEMs software. Which, this software were only used by Pusat Penyelidikan Minearal (PPM) , Perak, Malaysia. This software were estimate the peak sound level with the variables of geological factors. That is geometrical diversion, atmospheric absorption, ground effect, screening, reflection, reflection distance, distance and atmospheric attenuation.

1.5 Thesis Outline

This thesis contains into five main chapters:

Chapter 1 is a chapter to introduce the research project including the overview of research background, problem statement, objectives and also scope of this research work.

Chapter 2 cover on the literature review on the noise relate to its classification, standardization, problems and also effects. Besides, the technique used and suitable equipment that been used while the monitoring and data collection of noise level.

Chapter 3 explain about the overall experimental work at the site. The methodology work has been summarized in the chart with the process taken. Next, also included the information of the site location, equipment used and methodology of work.

Chapter 4 present the result that taken at the site. This include the development and verification of the new formula for traffic noise estimation. The formula will be compared to the QEM software for the traffic noise estimation.

Chapter 5 is the conclusion or summarization for this study. Recommendation or suggestion for future research are also been proposed.

CHAPTER 2

LITERATURE REVIEW

2.1 Noise

2.1.1 Noise Control Criteria

The design of engineering controls for noise is the establishment of acoustical criteria. Criteria must be established for occupational areas, employee exposure, interior spaces at the office or room and also communities near the plant. While the OSHA regulations establish a maximum noise level of 90 dBA for continuous 8- hours exposure during a working day, higher sound level are allowed for shorter exposure time. For example, in the transportation of rocks from the quarrying site. The transportation process will be done by stage according to their schedule. The employees and people are not exposed to continuous noise level. The allowable exposure time from the OSHA regulation is given in Table 2.1. Thus, there are some calculation for noise dose.

$$\boldsymbol{D = \frac{C}{T}}$$

Where :

D = noise dose

C = actual duration of exposure in hours

T = noise exposure limit in hours

When the daily exposure is due to two or more noise levels, the ratio for each level is added to compute the total noise dose :

$$\boldsymbol{D = \frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots \frac{Cn}{Tn}}$$

Table 2.1 : Permissible Noise Exposure Times

Sound Level (dBA)	**Time (hours)**
85	16.00
86	13.93
87	12.13
88	10.57
89	9.18
90	8.00
91	6.97
92	6.07
93	5.28
94	4.60
95	4.00
96	3.48
97	3.03
98	2.83
99	2.25
100	2.00

101	1.73
102	1.52
103	1.32
104	1.15
105	1.00
106	0.87
107	0.77
108	0.67
109	0.57
110	0.50
111	0.43
112	0.38
113	0.33
114	0.28
115	0.25

2.1.2 Noise Measurement

Usually, in the industrial noise situation, there will be two types of measurement which is compliance measurements and diagnostic measurements. Compliance measurements, which are made in accordance with some relatively precise set of instructions, usually based on laws and regulations. Example of equipment used is noise dosimeter. The purpose is to determine the extent of compliance with the limits set forth in the laws or regulations. While, for diagnostic measurements are made to aid in engineering control of noise by locating specific noise sources and determining their magnitudes and by indicating the types of controls needed, their locations and the amount of reduction sought. There are not always straightforward, and their success depends mostly on the experience of the person making the measurements and example of the instrument is sound level meter.

The type of noise measurement made will depend upon the type of noise source. Steady state and impulsive noises require different types of measurement. These measurement and appropriate instrumentation are summarized in Table 2.2 for various sources of noise.

Table 2.2 : Noise types and their measurement

Characteristics	**Type of Source**	**Type of Measurement**	**Type of Instrument**	**Remarks**
Constant continuous noise	Pumps, electric motors, conveyers	Direct reading of A-weighted value	Sound level meter	Octave or 1/3 octave analysis if noise excessive
Constant but intermittent noise	Air compressor, automatic machinery during a work cycle	dB value and exposure time or LAeq	Sound level meter Integrating sound level meter	Octave or 1/3 octave analysis if noise excessive
Periodically fluctuating noise	Mass production, surface grinding	dB value, LAeq or noise dose	Sound level meter Integrating sound level meter	Octave or 1/3 octave analysis if noise excessive
Fluctuating non-periodic noise	Manual work, grinding,	LAeq or noise dose	Noise dosimeter Integrating	Long term measurement

	welding	Statistical analysis	sound level meter	usually required
Repeated impulses	Automatic press, pneumatic drill	LAeq or noise dose and "Impulse" noise level Check "Peak" value	Impulse sound level meter or SLM with 'Peak' hold	Difficult to assess More harmful to hearing than it sounds
Single impulse	Hammer blow, punch press	LAeq and "Peak" value	Impulse sound level meter or SLM with 'Peak' hold	Difficult to assess Very harmful to hearing

2.1.3 Instrumentation for Noise Measurement

a) Sound Level Meters (SLM)

Sound level meter consist of a microphone, electronic amplifier, filters and readout meter. These instruments is to measure A-, B- and C-Weighted sound level and are portable. Some are equipped with octave band filters. Figure 2.1 shown an elements of sound level meter. The American National Standard Specification for sound level meter sets the levels of accuracy for sound level meters. These accuracy levels are:

Type 1 – Precision

Type 2 – General Purpose

Type 3 – Survey

The U.S. Department of Labor has recommended that a Type 1 or 2 be used for OSHA noise surveys. A Type 1 should be used for measurement where precise result required.

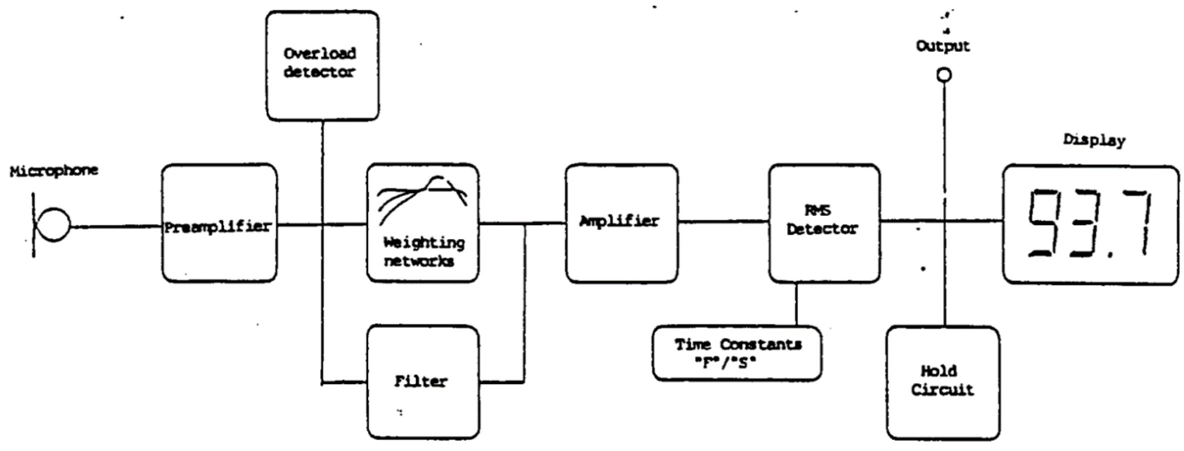


Figure 2.1 : A schematic representation of the elements of a sound level meter

b) Noise Dosimeter

Dosimeters are used in the workplace, mainly to measure noise levels in order to comply with OSHA's regulations. In doing this, the dosimeter can estimated an individual's exposure to the noise, and is then able to report the calculations related to any needed noise adjustments. A noise dosimeter is a small, light device that clips to a person's belt with a small microphone that fastens to the person's collar, close to an ear as shown in Figure 2.2. The dosimeter stores the noise level information and carries out an averaging process. It is useful in industry where noise usually varies in duration and intensity, and where the person changes locations.

Figure 2.2 : A personal noise dosimeter

c) Octave Band Analyzer

Octave band was defined as a frequency range with ratio of 2:1 between its high and low frequencies. Octave band analyzers as shown in Figure 2.3 are used for detailed measurements of sound. They are useful when the frequency of the noise needs to be determined. The instrument use filters to separate the noise frequencies, and from there, the components can be analyzed. The analysis of the sound yields information with regard to the effectiveness of set noise control protectors. Octave band filters are generally used for basic engineering design.

Figure 2.3 : Octave Band Analyzer

2.2 Transportation Noise

2.2.1 Traffic Noise

Road traffic has become an important factor in society development, specifically in terms of living and economic growth. With increasing number of vehicles in Malaysia, traffic noise represents the most pervasive source of community noise. Exposure to noise can cause health problems, disturbance, and annoyance to individual, under a certain conditions, it can also affect work efficiency and quality of life. For example, sleep disturbance is generally associated with lower noise levels, and the levels 70 dBA can cause hearing loss and also heart diseases. Lorries constitute more than 40% of the total number of vehicles and are regarded as a major source of noise pollution in Malaysia. The source of noise in Malaysia are usually vehicles, construction activities, and industry activities.

Traffic noise is produced by vehicles on the roads. Many factors influence noise emission from vehicles, including vehicle density, road type and road surfaces, vehicle speed, gradient, junctions, ratio of lorries on the road, climate, and building deflection. Table 2.3 has shown the limiting sound level from road traffic. Sound level measurements were performed using a sound level meter. Traffic noise was measured using the sound pressure level (SPL) index with an A-weighted scale expressed in decibel units, which convert the SPL value into Leq. The SPL was calculated using the following equation (Davis and Cornwell, 2008):

$$\boldsymbol{SPL = 10 \log (Pres^2 / refpres^2)}$$

Where :

pres = sound pressure , *refpres* = reference sound pressure

The following equation was used to analyze the average Leq (Davis and Cornwell 2008):

$$\boldsymbol{Leq = 10 \log \sum_{i=1}^{i=n} 10^{Li/10}\, ti}$$

Where:

n = total number of sample taken, *Li* = noise level in dB(A) of *i* sample, *i* = fraction of the total sample

Table 2.3 : Limiting Sound Level (leq) From Road Traffic

Receiving Land Use Category	Day Time (dBA) 7.00 am – 10.00 pm	Night Time (dBA) 10.00 pm – 7.00 am
Noise sensitivity area Low density residential area	55	50
Suburban residential (Medium Density)	60	55
Urban residential (High Density)	65	60
Commercial, Business	70	60
Industrial	75	65

2.2.2 Effect of Noise towards Human Ear

It is estimated that many people in Malaysia had suffered a permanent disability. The quality of life will be decreased in ability to carry out communications in business and personal life. It is because exposure to the excessive noise levels will result in permanent hearing loss. An industry is responsible for hearing loss incurred by employees which is expose to the excessive noise with their jobs. The human ear are respond to any disturbance variation in pressure. Human ear as shown in Figure 2.4 has three basic part which is outer ear, middle ear and inner ear. Outer ear which is pinna will concentrates sound waves into ear canal. While in the middle ear, the eardrum will transform pressure variations into mechanical displacements. Lastly in the inner ear, cochlea will convert pressure signals into neural signals and send them to various centers in brain for processing the noise.

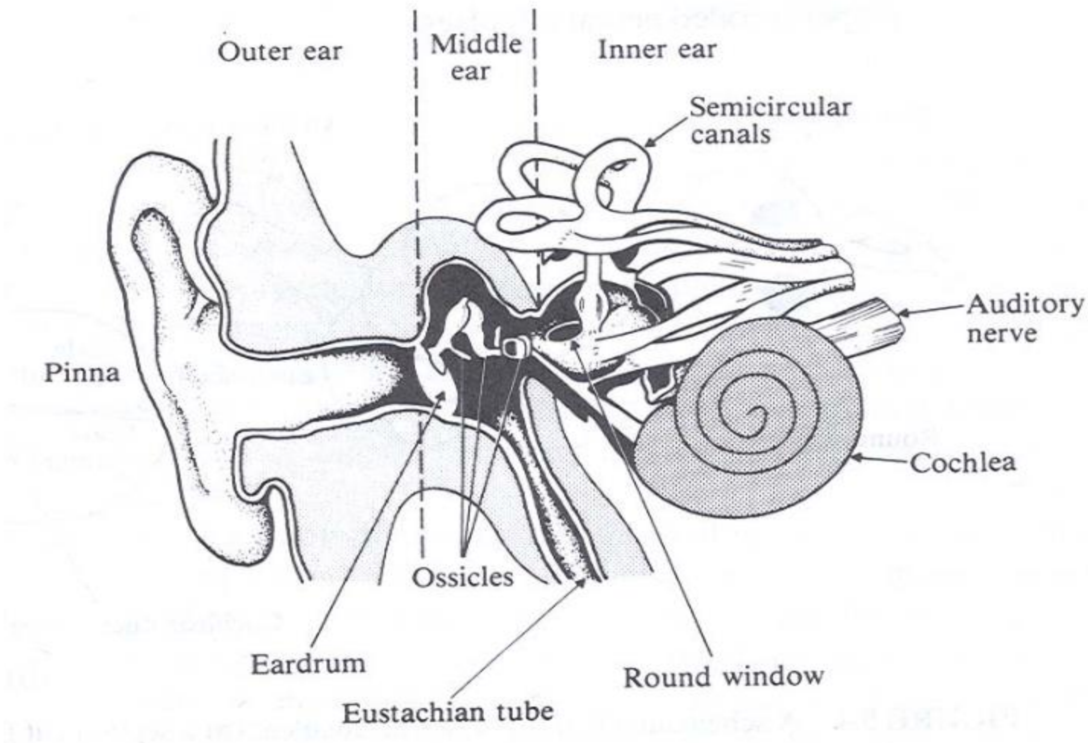


Figure 2.4 : The Basic Part of Human Ear

Other health effects within the exposure of excessive noise level is people living or working in unconditional or noisy environments. It will develop the habit of shouting, some of them are stress and become irritable. Besides , noisy environment can lead to psychiatric disorders. When human being are exposed to high noise levels, the blood vessels constrict and muscles tense. So noise pollution are very hazardous towards the environmental society if any action or mitigation are not be taken.

2.3 Environmental Noise Modeling

Environmental noise modeling defined as the process where a region of interest under a certain set of conditions. That specific set of conditions which is the noise level are being estimated for of a physical environmental of interest. Besides , in the practice of the physical environment will be not be stick, but will be evaluate by constantly varying specific conditions. These variations in nowadays world conditions could be cause the actual sound source to vary in time and space. Thus it is importance to identifies that the output of an environmental noise model will only appear an estimate for a 'snapshot' of the range of real environmental noise levels that could occur in time and space.

2.3.1 Model in general used and their limitations and risks

i) Practical engineering methods:

The method adopted by these models calculated the estimation of noise levels by add the separated contributions that each sound attenuation factor has on noise propagation. The common factor in all these models is that they are based on empirical results of analysis. They are really simple and easy to be use.

ii) Approximate semi-analytical methods:

These methods are same practical structure as an engineering techniques, but according to the simplified analytical solutions of the acoustic wave equation rather than empirical results. While the practical engineering methods its only take a meteorological effects.

These techniques allowed a better estimation of the effect of meteorological variables on noise level. This is the most commonly methods that been used.

iii) Numerical methods:

This method are based on the numerical calculation of the wave propagation equation. This groups also include the Fast Field Program (FFP), the Boundary Element method(BEM) and also the Parabolic Equation (PE).

2.4 Multivariate Statistical Software Packages

Many multivariate statistical software packages are available in the market for research and data analysis. Some commonly used packages are SPSS, CRAN SAS, R and S-Plus, Minitab and MATLAB. Each of these packages have their own strengths and benefit and also weakness and limitations. These multivariate software packages and tools allow researchers to analyze, visualize and understand large and complex data swiftly and easily. The statistical packages utilized for the treatment of data in this research is IBM SPSS Statistical Package.

2.4.1 IBM SPSS Statistics

SPSS is one of the most popular of the many statistical packages currently available for statistical analysis because of its easy to use graphical user interface. SPSS was initially an integrated system of computer programs designed for the analysis of social sciences data. Formally known as 'Statistical Package for the Social Sciences', SPSS has moved beyond its initial market and is now widely used in many other fields. It is presently simply known as 'SPSS' or 'IBM SPSS Statistics' in full. In Table 2.4 shows the range of tools for analysis that are available in the base software.

Table 2.4 : Statistical tools available in SPSS

Statistic	Tools for analysis
Descriptive	Cross tabulation, Frequencies, Descriptive, Explore, Descriptive Ratio Statistics
Bivariate	Means, t-test, ANOVA, Correlation (bivariate, partial, distances), Non-parametric tests
Predictive	Linear Regression, Factor analysis, Cluster analysis (two- step, K means, Hierarchical), Discriminant

2.4.2 CRAN-R

CRAN is the acronym for the Comprehensive R Archive Network. The R language on the other hand is programming language and software environment for statistical computing and graphics which has gained wide acceptance amongst researchers, statisticians and data miners for developing statistical software and conducting data analysis (Vance,2009). R is supported by the R Foundation for Statistical Computing. R and its libraries implement a wide variety of statistical and graphical techniques, including but not limited to linear and nonlinear modeling, classical statistical tests, times series analysis, classification, and clustering (CRAN, 2016).

A core set of packages is included with the installation of R, with about 8,300 additional packages (as of 12th April 2016) available for download at the Comprehensive R Achieve Network (CRAN) depending on the needs of the researchers. Researchers may browse package by topics, and tools are available on the website to automatically install all packages for special areas of interest (Hornik, 2016).

2.5 Quarry Environmental Modeling Software (QEMs)

A new software by JMG called Quarry Environmental Modeling Software (QEMs) Version 1.0, which was developed solely based on the Principal Component Analysis (PCA) claims to be the simple and faster model to estimate the dust deposition, traffic noise and ground vibration from quarry activities. Validation study of QEMs in this study has produced promising results. High value of correlation coefficient (R^2=0.95) for noise and also acceptable adequate coefficient value R^2 =0.57 for ground vibration, indicates good relationship between dependent and independent variables and high predictive capability of QEMs. There are still some areas of improvement. The underestimation of traffic noise of approximately 5.4% by QEMs could be caused either by uncertainties in the quarry or other background activities.

As model, QEMs cannot reflect perfectly a real situation, but this study shows that it can be used as a feasibility tool before embarking into higher investment for monitoring and risk assessment. This new software designed by MRC in order to identify the cause and control of dust pollution, noise and blasting vibration in quarries. The software has been successfully registered the copyright with the Intellectual Property Corporation of Malaysia (MyIPO) on 17 November 2016 with Registration Number: LY2016003082).

2.5.1 Quarry Environmental Modeling Software (QEMs) Version 1

QEMs was developed to estimate the dust concentration, traffic noise and ground vibration level based solely on the principle component analysis (PCA) results, followed by stepwise multiple regression analysis (MRA) of reliability analysis (RA) findings from data sampled at selected quarry sites. This software will calculate the dust concentration and Quarry Particulate Pollution Index (QPPI), noise measurement in dB(A) for traffic sound and ground vibration (PPV) using prediction model based on generic algorithms.

2.5.2 QEMs Algorithm

QEMs was created using Microsoft Visual Basic.NET. Visual Basic.NET was released by Microsoft in 2002 as a successor to the original Visual Basic computer programming language. It was implemented on the .NET_Framework_1.0.

Once the QEMs program is started, information is requested via interactive menus. The first input is the quarry information and production followed by meteorological, source and receptor coordinate which is requested through a series of window displays. Figure 2.5 shows a simplified flow chart for the QEMs algorithm, and Figure 2.6 shows startup window and series of window display interfaces.

The procedure for calculating dust deposition concentration, noise level and PPV by QEMs starts by reading the monthly production data entered into the program. These data are used together with monthly meteorological data. Each meteorological data point will be used at X and Y coordinates of the source and modeling exercise are calculated for each receptor location. The coordinates of the source and receptor locations (X, Y, and Z) are used to calculate the distance with respect to the terrain complexity options chosen by a user.

The QEMs end result will be a list of receptor dust deposition concentrations sequenced by receptor locations, emissions report for each sources and source-receptor distance, Air Pollution Index (API), Quarry Particulate Pollution Index (QPPI), traffic noise level and Peak Particle Velocity in mm/s.

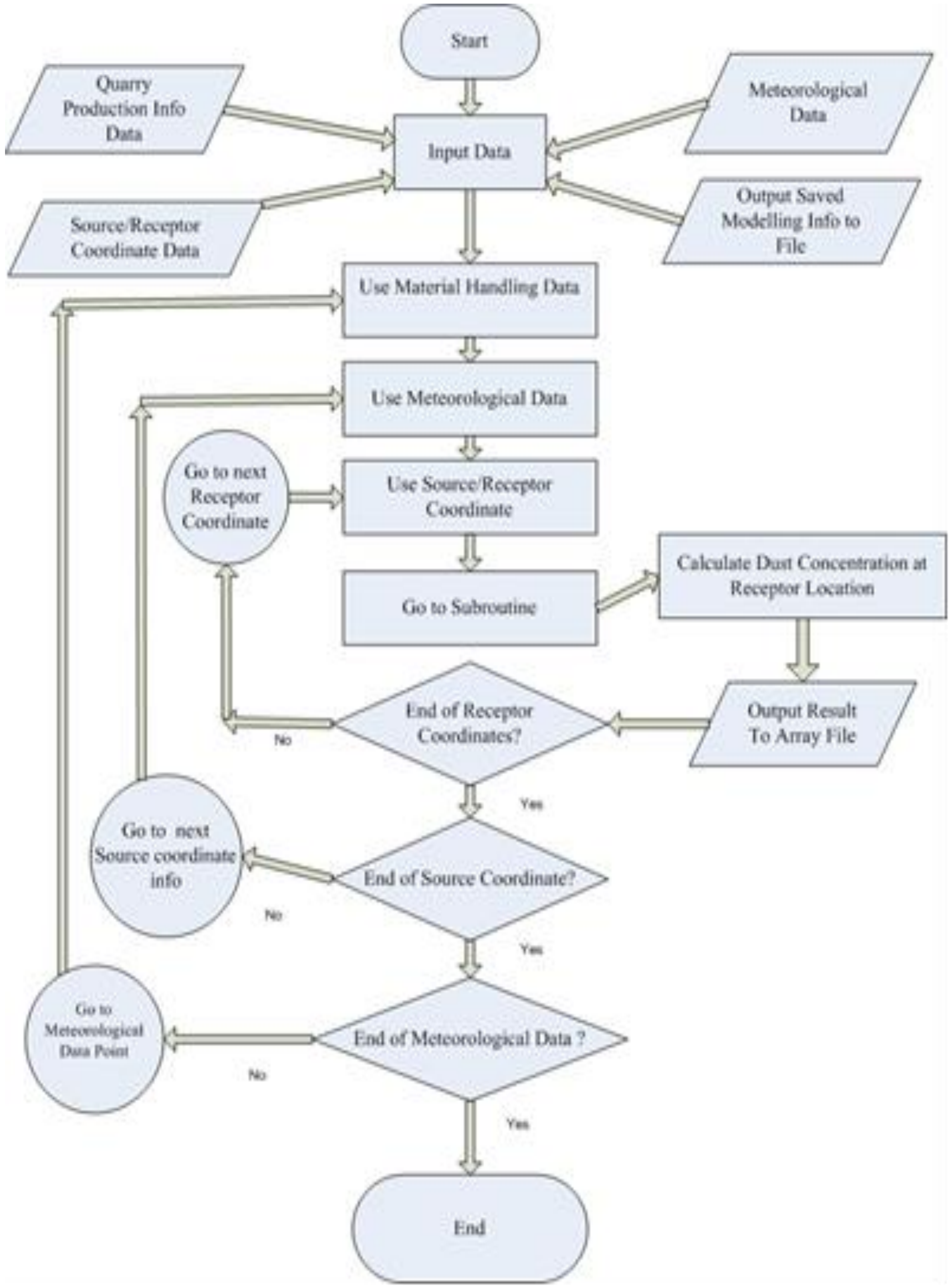
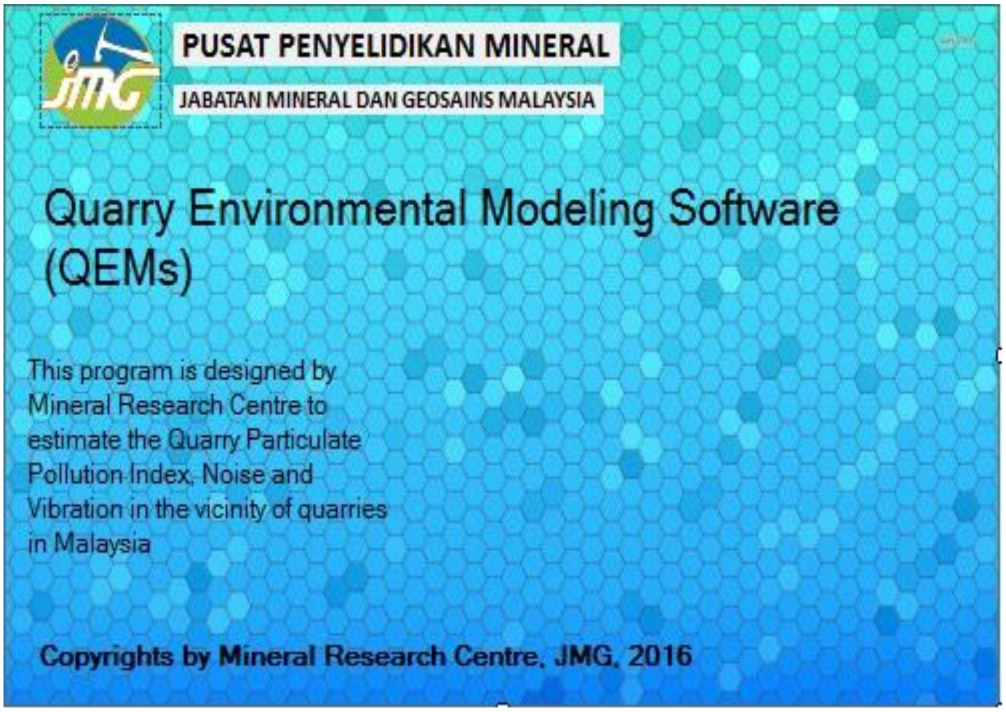


Figure 2.5 : Flow chart of simplified algorithm for QEMs.exe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Quarry Environmental Modeling Software (QEMs)
This program is designed by Mineral Research Centre to estimate the Quarry Particulate Pollution Index, Noise and Vibration in the vicinity of quarries in Malaysia
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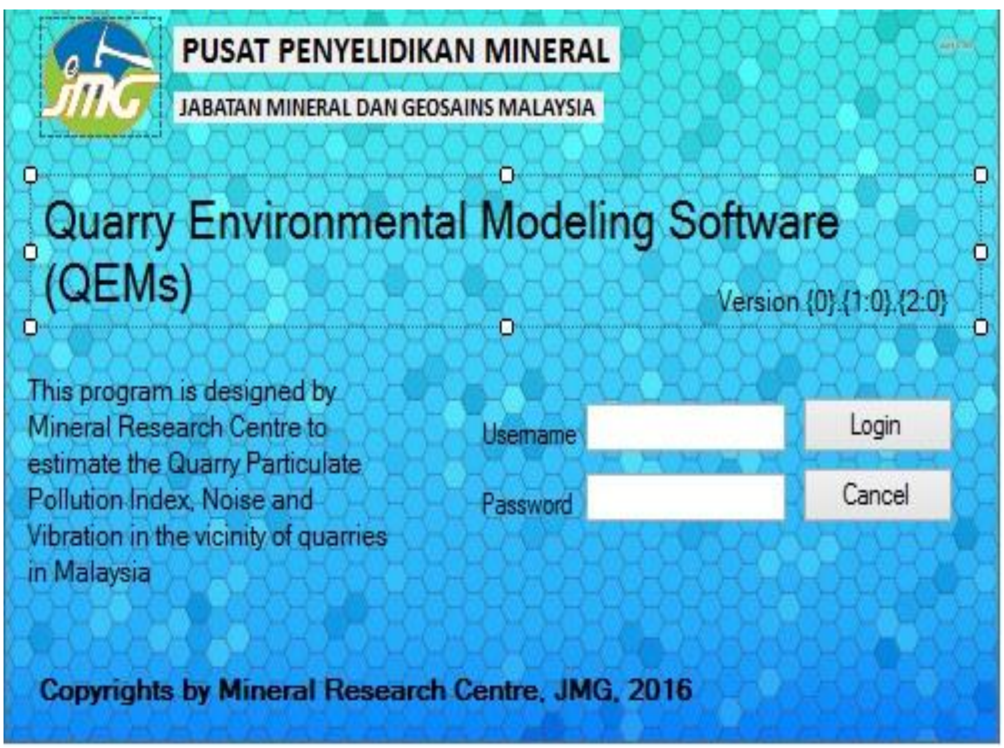
PUSAT PENYELIDIKAN MINERAL
JABATAN MINERAL DAN GEOSAINS MALAYSIA
Quarry Environmental Modeling Software (QEMs)
Version {0}.{1:0}.{2:0}
This program is designed by Mineral Research Centre to estimate the Quarry Particulate Pollution Index, Noise and Vibration in the vicinity of quarries in Malaysia
Username
Password
Login
Cancel
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