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ESTIMATION AND MODELLING OF TRAFFIC NOISE IN URBAN AND SUBURBAN ENVIRONMENTS

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INTRODUCTION

Road transport has always been and continues to be an essential ingredient of the progress of civilization. During the last few decades, the rapid increase of motor vehicle use and ownership, together with population growth and the attraction of people into urban and suburban regions for work and leisure has set in motion development that has led to a modern society in which traffic noise seems to be an inevitable problem. Thus, the importance of traffic noise as one of the design parameters for planners, building and road designers and traffic engineers has increased tremendously [1, 2 and 3].

When dealing with noise and its control, three components need to be considered: first, the source of the noise; second, the path along which the noise travels; and third, the receiver. In the case of traffic noise in urban and suburban environments the source is various kinds of vehicles travelling at different speeds and conditions through areas of various types of land use and road layout. The transmission path is the direction taken by the sound waves, while the receiver may be any subject who works or lives in the area. Of course, the best method of decreasing the effects of traffic noise is the abatement of vehicle noise at source. But this option is not one over which the planners and city engineers have control. Besides, it is now over fifteen years since traffic noise was identified as the predominant source of annoyance in Europe [4], and the markets have not yet witnessed vehicles whose noise is reduced by 10 dB(A) as recommended. Despite some successful trials, the operation of large numbers of quiet vehicles for general purposes is still a hope for the next decade [5]. The reason is that this situation is always dependent on many complex factors such as available technology, international legislation and the economic status of the country.

This paper deals with the abatement of traffic noise through planning and design. The target is a reliable model which can be implemented by planners and city engineers to forecast and evaluate noise levels arising from interrupted traffic flow in urban and suburban areas. A suite of computer programs has been evolved based on a variety of field measurements at 204 locations in Bath. It enables L_{10} dB(A) value to be determined in terms of all the essential parameters and gives results which are comprehensive, accurate and practical.

MODELLING OF TRAFFIC NOISE

Various types of forecasting methods have been utilized up until now. The main approach is to use them in the design and planning stages in place of field measurements. This has several advantages, namely, it saves time and money. Prediction methods give the decision-maker freedom to modify any variable in order to create the best system whilst avoiding unusual traffic congestion (e.g. due to maintenance or accidents) which may affect the accuracy of field measurements. Finally, it is convenient to have a prediction tool which relies on existing transportation engineering methods.

In general, prediction models fall into two areas: those for freely and those for non-freely flowing traffic. Given traffic and road parameters, models have been developed which forecast noise from freely flowing traffic and involve a number of variables including high speed traffic and steady noise levels. For non-free flowing traffic in built-up areas the models deal with several factors such as low speeds, changeable noise levels, and junctions. Traffic noise may be predicted by use of empirical, scale or theoretical models. The empirical model is usually constructed on the basis of real field investigation, using the multiple regression analysis method [6] and is widely used; most of the current prediction methods are based on such models for free flowing and non-free (with limitations) flowing traffic [7 and 8]. Scale models have been introduced as an instrument to assess the importance of specific parameters without the need for field measurements [9]. Yet the use of scale models in estimating the absolute levels of traffic noise is limited. Theoretical models are usually based on statistical distribution of noise and independent parameters or computer simulation models [10]. Apart from computer models for vehicle noise in the vicinity of traffic lights, there are no comprehensive theoretical methods in the field of non-free flowing traffic in built-up situations.

Noise from non-free flowing traffic depends on the specific driving needs of vehicles, such as accelerating and decelerating, which predominate near junctions. This complex situation has not been modelled properly. Existing methods for noise from restricted traffic flow have neglected many of the design parameters [11] and show the following limitations:

1 - <u>Speed of traffic</u>: In urban areas, speed is significant in studies connected with theory of traffic flow, road designs, traffic management schemes, signs and signals, markings and speed limit.

2 - <u>Presence of junctions</u>: Again in built-up situations, junctions are the most important single consideration in any urban road design and in land use planning.

3 - <u>Existence of surrounding building facades</u> (especially those on the farside): In built-up areas, road networks are usually surrounded on both sides by buildings of various use which have an influence on the level of propagated noise due to multiple reflections.

In addition, the studies have been based on a small number of field sites which only represent a limited number of built-up area conditions, e.g. traffic lights [10].

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BASIS OF THE COMPUTER PROGRAMS

NFNOS, UBSUB and GRUBS form a Suite of Programs designed to forecast traffic noise arising from non-free flowing traffic in urban and suburban areas for planning purposes. The programs deal with most of the parameters which characterise the structure of built-up areas, affect noise levels and are included in design standards. In designing these models the task was to permit prediction in as many cases as possible, so a wide range of field measurements were carried out. Six predominant land uses were defined at 204 sites chosen to give a representative sample of traffic conditions for each of these six types. Thirty-minute noise level recordings were made hourly at each site between 7.00 and 19.00 hours. Other variables of interest were recorded simultaneously.

The distance between kerb and receiver was one metre, with a microphone height of 1.2m. The building facades were continuous on both sides. Noise from the traffic stream was a predominant problem in all locations. The sites were selected to represent various kinds of junctions so that accelerating and decelerating traffic could be considered but only level stretches of road were taken into account. Three separate programs were designed to meet the following goals:

1. To identify those variables that affect the environment significantly.
2. To predict noise levels.

COMPONENTS OF THE PREDICTION MODELS

In built-up areas there are huge numbers of physical constraints controlling the flow and speed of traffic [12] and of these the following factors are used in the study:

1. The road system: The study was carried out along various road networks. Road width (W) ranged from 6m to 18m and 43 junctions were considered. The junctions covered were roundabouts, priority junctions and traffic lights. One and two way traffic were included. Noise levels L_x dB(A) at one metre from the traffic stream and distance (J) from various kinds of junctions have been shown to be of the form (up to 250 m):

$$L_x = a_0 - a_1 J \quad (1)$$

where a_0 and a_1 are empirical constants and J ranged from 4 to 420 m.

2. Traffic variables: The vehicles in the traffic stream were divided into three categories [13]; light (L), medium (M) and heavy (H). Again noise level with traffic flow (Q), percentage of heavy and medium vehicles (P), and mean speed (V), have been shown to be of the form:

$$L_x = a_2 + a_3 \lg Q \quad (2)$$

$$L_x = a_4 + a_5 P \quad (3)$$

$$L_x = a_6 - a_7 \lg V \quad (4)$$

where a_2-a_7 are empirical constants. Traffic flow ranged from 284 to 3000 v/h, depending on site and time. P was between 0 and 20% while speed was between 10 and 75 km/h, despite the speed restriction of 48 km/h (urban) and 64 km/h (suburban).

3. Building locations: Buildings flanked the roads on both sides. Noise levels with distance of measurement point from nearside facade (N) and distance from farside facade (F) have been shown to be of the form:

$$L_x = a_8 - a_9 \lg N \quad (5)$$

$$L_x = a_{10} - a_{11} \lg F \quad (6)$$

where a_8-a_{11} are empirical constants. N ranged from 1.5 to 24 m whilst F from 9.35 to 37.5 m.

4. Noise units: Traffic noise is generated by a number of vehicles of different specifications being driven under changing conditions through various roads surrounded by areas of different land use classifications. For studying this noise, L_{10} dB(A) was considered during the course of study, where L_{10} is the basis for government regulations and design guides dealing with traffic noise in Great Britain . It also correlates well with human reactions defined by another part of this study [14].

5. Other variables were considered such as number of lanes; condition of road surface; traffic conditions, characteristics and directions and weather conditions.

PROGRAM DEVELOPMENT

NFNOS Program: This program uses a statistical computing system [6] to establish a prediction formula, based on multiple regression analysis. The following equation summarises the finding, based on the field study data:

$$L_{10} = 58.6 - 5.99 \lg V + 11.4 \lg Q + 0.183 P - 5.94 \lg F - 0.0102 J - 2.46 \lg N \quad (7)$$

This model is expressed in terms of the most effective parameters. It gave a good correlation coefficient R=0.969, standard deviation, 0.770 and accuracy prediction with ± 1.8 dB(A). The model has the following advantages:

1. It is a practical way of saving time and money and avoids the need for field measurement.

2. It is simple and easy to understand by City Engineers who may have a

limited knowledge of acoustics but are in a position to consider traffic noise.

3. It is based on real field data which covered various situations.

4. It uses variables that are necessary for design purposes.

5. It provides rapid prediction to an accuracy appropriate to the planning process, based on the fundamental parameters.

UBSUB Program: Field investigation and the development of the above model has provided significant data necessary for assessment of road design and location for enviromental planning. Thus, in order to estimate more complex situations than can be introduced by theory alone, and because of the difficulty of including all the parameters in one formula, the presentation of UBSUB as a comprehensive computer program was required. The program is designed to compute noise levels in terms of most of the parameters which formalise the environment. Input data are required describing road, traffic and propagation features and land use classification. The program is written in the FORTRAN language and the output is in the form of a printed report containing predicted noise level values, mean and range of variables, and identification of land use, junctions and traffic circumstances (see Table 1). The advantages of the model are:

1. It predicts noise levels with regard to a large number of variables.
2. It is based on a thorough investigation of real sites.
3. Noise level and other parameters in built up areas are subject to change from time to time and this model has the flexibility to incorporate these variations.
4. The program is written in a common computer language and it could be run or transferred to any system.
5. It uses variables that are necessary for design and land use planning, and are easily obtainable.
6. It provides detailed data which cannot be covered by one method such as Equation 7. Thus it is a tool which may aid the planner in assessing the development of built-up areas involving a variety of conditions.

GRUBS Program: This is a graphic program which takes the input information from the formulae of the last program and introduces a graph, to allow for the estimation of the variables which are required to predict levels of noise. The main objective of this program is to modify any variable in order to maintain the acceptable level of noise. The computer program was developed utilizing the Gino graphic facilities at Bath University computer system.

SUMMARY

The increasing importance of noise effects in built-up areas has not been matched by the development of a comprehensive prediction model for assessing its significance. This study set out to use noise from urban and suburban

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traffic and the parameters which characterise the structure of built-up areas, influence environmental noise and are necessary for the work of designers and planners. Three models for prediction of noise levels were proposed. An empirical model which provides rapid prediction is suggested that enables the L_{10} dB(A) value to be determined in terms of principal variables. A comprehensive computer model has also been designed that enables L_{10} dB(A) value to be obtained based on a large number of variables. A graphic model has been established to assess the value of parameters related to predicted noise levels. Also, a modification has been made to the UBSUB computer model to allow a variety of design parameters and conditions to be employed [15, 16 and 17].

The techniques have been formalised to aid planners and designers in assessing and controlling the noise impact from non-steady traffic, in order to implement partial or total road network development, using easily obtainable urban and suburban parameters. These techniques will enable a reliable environmental policy to be established which includes traffic management, road and building design and land use planning.

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REFERENCES

[1] Croome, D.J.,(1977), 'Noise, Buildings and People', International Series in Heating, Ventilation & Refrigeration. Volume 11, Pergamon Press.

[2] Croome, D.J.,(1982), 'The Role of Noise Control in Building Design', Noise and the Design of Buildings & Services, edited by D.J. Croome, 47-63, Construction Press.

[3] House of Commons. Building & Buildings, (1975), 'The Noise Insulation Regulation 1975', Statutory Instrument 1975 Number 1763, HMSO, London.

[4] Road Research Laboratory (1970), 'A Review of Road Traffic Noise', Report LR 375, U.K.

[5] Taylor, J.W.,(1985), 'The UK Quiet Heavy Vehicle (QHV) 90 Programme', Proceedings Inter-noise 85, 157-160, W. Germany.

[6] Thomas, A.R. et al, (1981), 'Minitab-Reference Manual', Statistical Department, The Pennsylvania State University, USA.

[7] Powell, W. and Jraiw, K.S.,(1984) 'Urban Road Traffic - Noise Level Prediction', Proceedings FASE 84, 269-272, Norway.

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[8] Delany, M.E.,(1972), 'A Practical Scheme for Predicting Noise Levels (L10) Arising from Road Traffic', NPL, Acoustic Report AC57, UK.
[9] Delany, M.E. et al, (1972), 'Scale Model Investigations of Traffic Noise Propagation', NPL, Acoustic Report AC58, UK.
[10] Favre, B., (1978) 'Noise at the Approach to Traffic Lights: Results of a Simulation Programme'. J. Sound Vib., 58(4), 563-578.
[11] Fisk, D.J., (1974), 'Prediction of Urban Traffic Noise (BRS)', Eighth International Congress on Acoustics, 107, London.
[12] Jraiw, K.S., (1981), 'Geometric Design and Traffic Capacity', MSC Dissertation, Southampton University, UK.
[13] Nelson, P.M. et al.,(1977), 'Classifying Road Vehicles for the Prediction of Road Traffic Noise', DOE, TRRL Report LR752, UK.
[14] Jraiw, K.S., (1985), 'Social Response to Noise from Interrupted Traffic Flow', Proceedings IOA,Spring Conference, 383-390, UK.
[15] Jraiw, K.S., (1986), 'Prediction Techniques for Road Transport Noise (Leq) in Built Up Areas', Proceedings Inter-Noise 86, USA (to be published).
[16] Jraiw, K.S., 'Prediction Techniques for Road Transport Noise (Leq) in restricted flow situations', (to be published).
[17] Jraiw, K.S., (1986), 'A Computer Model to Assess and Predict Road Transport Noise in Built-Up Areas' (to be published).

Table 1. Typical Output of UBSUB Computer Model

1. Noise Values dB(A)

Total Site Nos. = 3

Site No.	Predicted L10	Actual L10
1	83.44	84.50
7	79.77	79.40
104	70.53	70.60

2. Mean Values of the Variables

V = 29.87 km/h H = 29.3 v/h

L = 1519.33 v/h Q = 1691.30 v/h

M = 142.67 v/h

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3. Mean Values of the Predicted Noise Levels

$L_{10} = 77.91$

4. Range of Variables

Parameters	max	min	Parameters	max	min
V	38.96	24.00	N	5.40	2.10
L	2277.00	260.00	J	113.40	25.00
M	213.00	10.00	Q	2526.00	284.00
H	52.00	0.00	P	11.30	3.75
W	9.90	8.00	F	16.00	13.00

5. Range of Predicted Noise Levels

Parameters	max	min
L10	83.44	70.53

6. Distribution of Measurement Locations

1. Height of measurement = 1.20 m
2. Distance between measurement point and nearside kerb = 1.00 m
3. No. of light traffic sites = 0
4. No. of medium traffic sites = 1
5. No. of heavy traffic sites = 2
6. No. of accelerating traffic sites = 3
7. No. of decelerating traffic sites = 0
8. No. of one-way traffic sites = 1
9. No. of two-way traffic sites = 2
10. No. of two lane sites = 3
11. No. of four lane sites = 0
12. No. of more lane sites = 0
13. No. of asphalt road surface sites = 3
14. No. of concrete road surface sites = 0
15. No. of traffic lights = 1
16. No. of roundabout = 0
17. No. of priority junction = 1
18. No. of residential area sites = 0
19. No. of office area sites = 0
20. No. of shopping area sites = 1
21. No. of urban main route sites = 2
22. No. of suburban principal route sites = 0
23. No. of rainy weather sites = 0
24. No. of dry weather sites = 3
25. No. of windy weather sites = 0