TRAFFIC NOISE AS A GUIDE FOR TOWN PLANNING
"AN OPTIMIZATION STUDY"

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INTRODUCTION

A mathematical model developed by the authors, in [1], relating the equivalent noise level to the traffic composition. The validity of this model has been verified using field measurements taken in Alexandria (Egypt). Moreover, it has been shown that this model can be used in town planning [2]. A method was explained so that a town planner who is planning a quieter city may be able to suggest a relevant traffic plan. Also, we have announced a rigorous way of handling the problem using optimization techniques. The present work explains and develops this method theoretically. Moreover, an application will be given at a local point in Alexandria (Egypt).

GEOMETRY

The city plan from traffic noise viewpoint is considered as a certain configuration [3]. This configuration may be considered as lines (straight or curved) representing main main streets crossed by other lines representing side streets, this is the global view. Each one is considered as a collection of what we shall call local points (sites). There are two types of local points; main streets local points and side street local points. We shall be concerned here with the first type differing the second to another work.

OPTIMIZATION

The problem, facing a town planner, of minimizing traffic noise will be put in a linear programming setting. To do so, we have:

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Consider a local point of the first type. At this point, traffic noise level \( \text{Leq} \) is given from the following formula:

\[
\text{Leq}/10 = \sum_{i=1}^{n} \frac{t_i}{T} a_i 10(L_i/10) + R \tag{1}
\]

Where:

- \( \text{Leq} \) = Equivalent noise level in dB(A)
- \( t_i/T \) = Percentage of the total observation time, \( T \), during which the noise is attributed to the traffic component \( i \)
- \( a_i \) = Passenger car equivalent factor for the traffic component \( i \)
- \( n \) = Number of vehicle types under consideration e.g. private cars, taxis, buses, ...
- \( R \) = Residual equivalent energy due to sources not included among the above \( n \) types.

For the purpose of this work \( R \) will be considered as the equivalent sound energy corresponding to the background noise.

Let

\[
\mathcal{M} = \sum_{i=1}^{n} a_i \frac{t_i}{T} 10(L_i/10) \tag{2}
\]

Writing

\[
M_i = a_i 10(L_i/10) \quad \text{we have}
\]

\[
T \cdot \mathcal{M} = \sum_{i=1}^{n} t_i \cdot M_i \tag{3}
\]

It is known that a linear programming problem is the one of minimizing an objective function subject to certain constraints \[4\]. The function defined in (3) will be taken as the objective function. As for constraints, we have many choices. We may choose total number of passengers, total transported tonnage passing by a local point in one hour. Also cost of transportation may be considered as well as lane capacity. In fact, these are the constraints chosen here and formulated to solve the linear programming problem. However, we must point out that other constraints may be added such as types of travelling passengers and types of transported goods. Such refinements as well as the global analysis need an area not provided here so that it will be treated elsewhere.

The following constraints will be superimposed on the objective function:

1. Total number of passengers constraint

\[
\sum_{i=1}^{m} t_i \cdot p_i = P
\]
Where $p_i$ = average number of passengers transported by type $i$ vehicle, $n$ = number of vehicle types, $m$ = number of the passenger vehicles, and $P$ = total number of passengers travelling by a local point in one hour.

ii- Cost of transporting passengers constraint

$$c' \leq \sum_{i=1}^{n} t_i c_i \leq c^*$$

Where $c'$ and $c^*$ are minimum and maximum cost of transporting $P$ passengers, and $c_i$ = vehicle $i$ operating cost.

iii- Transporting goods constraint

$$\sum_{i=1}^{k} t_i b_i = B$$

Where $B$ = total transported tonage passing by a local point, $b_i$ = tonnage capacity of type $i$ vehicle, and $k$ = types of goods transport fleet.

iv- Cost of transporting goods constraint

$$T' \leq \sum_{i=1}^{k} t_i g_i \leq T^*$$

Where, $T'$ and $T^*$ are minimum and maximum goods transport cost, and $g_i$ = vehicle $i$ operation cost

v- Lane capacity constraint

$$\sum_{i=1}^{a_i} t_i < T$$

**RESULTS**

As an application of the mentioned method we have chosen a local point in one of the main roads in Alexandria. The values $a_i$, $b_i$, $c_i$, $g_i$, $p_i$, $P$, and $B$ are taken from [5] and [6].

Hence, $C'$, $C^*$, $T'$, and $T^*$ can be estimated. As for $L_i$, it is taken from [7].

Accordingly, the problem is written as follows:

Minimize

$$M = 3.9 t_1 + 3.9 t_2 + 79 t_3 + 18.8 t_4 + 23.8 t_5 + 119 t_6 + 476 t_7$$

Subject to

$$2 t_1 + 4.9 t_2 + 85 t_3 + 11 t_4 = 9650$$
$$6.15 \leq 0.025 t_1 + 0.032 t_2 + 0.063 t_3 + 0.035 t_4 \leq 61.04$$
$$3 t_5 + 6 t_6 + 24 t_7 = 600$$

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Solving this linear programming problem using the Primal-Dual Simplex method yields the following results
\[ L_{eq}(\text{min}) = 6 \text{ dB(A)} \] for \( t_1 = t_3 = t_5 = t_7 = 0 \), and \( t_2 = 1657 \), \( t_4 = 16 \), \( t_6 = 200 \). Thus \( L_{eq}(\text{min}) = 74 \text{ dB(A)} \) for \( L(BG) \) equals to 66 dB(A), where all passengers are transported by 1667 taxis and 16 buses while all goods are transported on 200 semi-trucks.

**CONCLUSIONS AND COMMENTS**

A town planner goals in designing a traffic plan are transporting all passengers and all goods. We have proved using the above described method that these goals could be achieved with a minimum traffic noise. In obtaining the above results we have not used all possible constraints. In fact more constraints must be added to refine these results which we shall put in another work. Moreover this method could be carried out to all local points i.e. the whole traffic network.

**REFERENCES**

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