MODELLING FRAMEWORK FOR BETTER ESTIMATES OF TRANSPORT-RELATED EMISSIONS IN URBAN AREAS

- A MODEL BASED ON VEHICLE OPERATING MODES -

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Transport-related air pollution is a problem of many large urban areas around the world. Its study and control constitute omplicated ssue, ecause any argely ncontrollable factors intervene between the available control policies and the harmful effects perceived by society. Traditionally, the amount of air pollutant emissions from motor vehicles (carbon monoxide, hydrocarbons, and oxides of nitrogen) is estimated from emission factors based on trip and vehicle kilometres travelled and appropriate measures of vehicle activity (including average vehicle speed). The kilometres travelled and average speeds are obtained from the output of the typical four-step travel demand model (trip generation, distribution, modal split, and traffic assignment). The emission factors used are based on data collected from road vehicles operators or from test procedures. A modeling framework has been developed to produce detailed emission nventories or arge rban reas. elationships ere eveloped between the time spent in each vehicle operating mode (cruise, acceleration, deceleration, nd queuing) and basic link characteristics based on simulations of selected real-world surface street networks and freeway sections using the VISSIM microscopic simulation model, supplemented by field data. These relationships were then incorporated into an Urban Transportation lanning ystem ype f our-step ravel emand odels. he ntegrated odel was applied to a part of Alexandria road network to generate vehicle activity estimates and atmospheric concentrations of polluting gases (CO, VOC, NO_X).

فى هذا البحث تم إقتراح طريقة لإستنتاج مقدار تلوث الهواء بالمناطق الحضرية الكبرى بأسلوب دقيق يأخذ فى الإعتبار العلاقات الرياضية بين العوامل المؤثرة (الفترة الزمنية التي تقطعها المركبات فى حالات السير المختلفة: السير المنتظم، التسارع، التناقص، الوقوف) وكذلك خصائص مكونات شبكة النقل والتي يتم الحصول عليها باستخدام أساليب المحاكاة (برنامج VISSIM). يلى ذلك إدخال هذه العلاقات الى نموذج تخطيط النقل بالمناطق الحضرية للحصول على النتائج النهائية. وقد تمت تجربة هذه الطريقة على جزء من شبكة الطرق بالأسكندرية للحصول على مقدار تركيز ملوثات الهواء (أول أكسيد الكربون، الهيدروكربونات، أكاسيد النيتروجين). هذا وقد أثبتت النتائج إمكانية الإعتماد على هذه الطريقة فى تقدير تركيز ملوثات الهواء بالمناطق الحضرية ويمكن تطبيقها بالمناطق المماثلة.

Keywords: Transportation Planning, Air Pollution, Road networks, Emissions, Traffic Simulation

INTRODUCTION

The atmospheric pollution caused by the vehicular traffic constitutes one of the most serious problems for the urban environment. Its study and control is a complicated issue, because many largely uncontrollable actors ntervene etween he available control policies and the negative effects perceived by society. Such factors include pollutant and atmospheric chemistry, topography and social and political issues. Of all the different kinds of air pollution we are interested in that produced by road traffic in urban networks and especially when it is at its worst (at saturated conditions), where vehicles flow interrupted and delays and start-stops occur frequently near the junctions.

To control this pollution, strict emission standards ave een mposed n ew ars in many countries (e.g. the United States, most Western European countries, Japan, etc.), but it is widely felt that this is not enough since the increase of vehicle use in the future will counterbalance tthe good effects of present technologies [1, 2]. What is therefore needed is on the one hand the use of regulation and incentive in order to reduce car use (modal shift) and on the other hand the application of traffic management measures in order to smooth traffic flow and reduce delays and start-stops in city road networks. The latter has been shown by many (e.g.[3,4,5,6, 7]) to have an ameliorative effect on air pollution generated by traffic.

MODELLING TRANSPORT-RELATED EMISSIONS

Air quality models are important tools for transportation planners to evaluate air quality impacts from vehicles. These tools are used to make critical decisions on land development projects and to verify conformity with air quality standards.

It is clear that a full understanding of the mobile source emissions burden will require a better representation of the vehicle operating modes that produce extraordinary levels of emissions, particularly accelerations. In part because of the success of current controls in reducing steady-state emissions, the acceleration phase has assumed much greater importance. It is feared that analyses based on the average travel speeds may lead to large differences from the actual values, especially in places in the system where acceleration profiles deviate significantly from test assumptions.

In light of these developments and the recent requirements for reducing air pollutant emissions set forth by Clean Air Acts. There is a need to investigate ways to simulate the driving patterns of vehicles in a region and to predict vehicle activity by mode of operation to obtain improved emission estimates.

Some models have been developed for the simulation of the emissions and of the atmospheric pollutants concentrations, which are inserted afterwards the traffic models and from these fed, and which allow to estimate the variation of the polluting gases concentrations present in air for the variable conditions of traffic, the type of vehicles, the network and regulations in act characteristics.

The study of these models can base itself on two different approaches: the static approach, and the dynamic approach. The static approach is sufficiently approximate and of immediate use during the planning for the evaluation of infrastructural or normative interventions, as it considers the average emissions as a function of the average speed of the vehicles on a road arc (link). The dynamic approach considers the instantaneous emissions as a function of the instantaneous kinematic parameters of the motion and it results necessary to the junctions nd heir egulation tudy, particularly for the evaluation of interventions on the typology and on the signal control planning. The dynamic approach engages a notable interest considering that in the analysis of the air quality in urban reas he ntersections re pointed out as critical points, in proximity of which the from traffic greater pollutants concentrations are found.

APPROACHES FOR IMPROVRED MODELLING FRAMEWORK

Traditionally, roads have been considered as straight line sources of air pollution. This is reflected in some early emission models, which are still in use nowadays [e.g. 8, 9]. The most common approach to emission calculation has been to assume a constant rate of emission over the length of a road, calculated mainly as a function of traffic flow and speed. Another standard mobile emission sources model [e.g. 10] includes an array of other factors in addition to speed: year of analysis, percentage of cold starts, ambient temperature, vehicle mix, and inspection and maintenance of vehicle engines, but it does not take account of the junction-imposed spatial variability of emissions. However, other models [e.g. 11] "break" the line sources into many smaller "segments" in order to accommodate road bends and/or differing emission rates for different segments, but the most common modelling practice still remains the “constant emission rate” approach.

This approach has been criticised by many researchers [7, 12, 5, 6, 13] argues that this approach as a erious shortcoming ... Although it is a fairly good assumption for uninterrupted flow conditions, it is totally inadequate in interrupted flow conditions, such as those caused by traffic signalisation" or indeed by any form of junction. It has been shown that emissions are many times higher near junctions than at mid-link (mid. block) locations [7,5] There are two basic reasons for this:

1. Vehicles spend a longer time near junctions due to queuing; and
2. The acceleration/deceleration phases they go through are more polluting than the steady speed cruising that tends to occur at mid-block.

Alternative approaches have been put forward "Automobile Exhaust Emission Modal Analysis Model" [14] and by using "Positive Kinetic Energy" and "Power Demand" Models [see 15] These are more detailed models, using instantaneous speed and acceleration data in polynomial forms to produce a vehicle's emission rates as it goes through cruise, deceleration, queuing, and acceleration.

Improved estimates of emissions from motor vehicles can be obtained from the time spent and the emission rate per unit time for each driving mode (cruise, acceleration, deceleration, and queuing). Such capability is currently available on a limited scale in existing network microscopic simulation models. For example, the VISSIM model [16] for urban road and transit networks. This model is a microscopic traffic flow simulation model including car following and lane change logic. The result of the simulation is the generation of output files gathering statistical data about each vehicle as it travels in the network.

Microscopic simulation models so far have been applied to small area studies because they require more data and computer resources than the other techniques. They also require as inputs the total volume nd urning ovements or each network link. Such data are normally estimated from a four-step travel demand model. especially for assessing the impacts of traffic growth, network improvements, or traffic management in large urban areas.

Linking Planning and Simulation Models

One possible approach for developing an improved modelling framework for estimating emissions consists of sequentially linking an Urban Transportation Planning System (four-step travel demand model, "planning model") and the network simulation models (Figure 1). The forecasted traffic volumes by the planning model would be input to the simulation models. The simulation models would then run to produce estimates of the total time spent by vehicles in each driving mode. The major issues that arise from this modelling formulation include the accuracy of the estimates, computational resources, and input data and coding requirements.

This approach has been implemented in a number of studies. and the traffic volumes assigned by the planning model are often unrealistically high especially for turning movements on the surface streets [17], The planning models do not consider queuing and other factors in the traffic assignment. Consequently, the predicted volumes are inaccurate for detailed operational analyses through simulation and would result in inaccurate estimates of vehicle activity.

The accuracy of the volume estimates can be improved by using the simulation models' predictions in the traffic assignment. The travel speeds predicted by the simulation model would be fed back to the assignment algorithm of the regional model to refine the link volumes until a user-specified convergence criterion is achieved. The simulation models would then run with the final link volumes to estimate the time spent in each driving mode. However, this model formulation requires multiple microscopic simulations of large-scale networks, which may be computationally infeasible within the computer resources typically employed by regional model users.

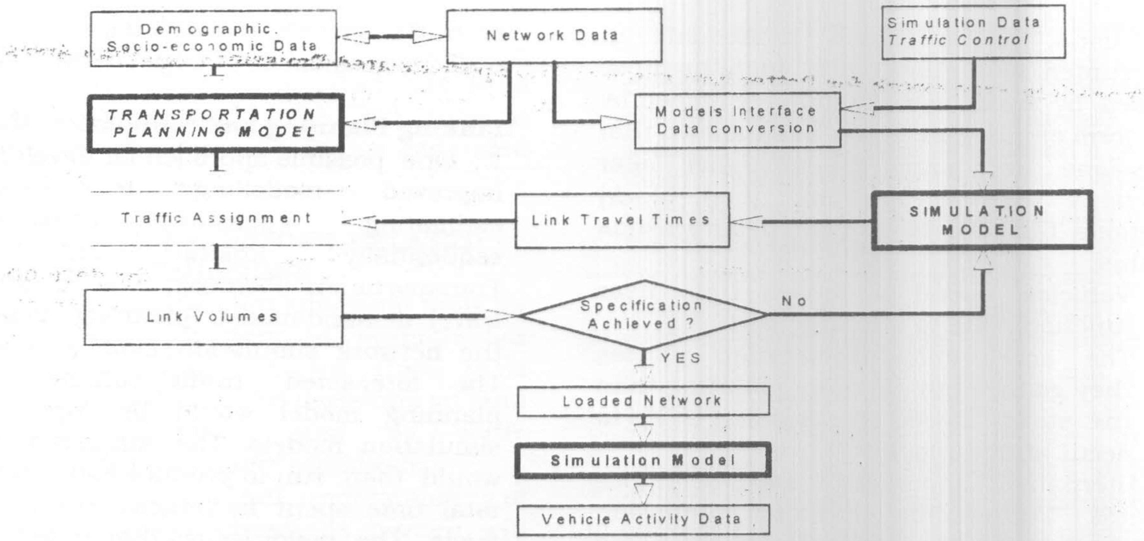


Figure 1 Sequential linking urban transportation planning models and traffic simulation models

The computer memory requirements and run times of microscopic simulators depend on the network size (number of links and nodes), number of vehicles to be processed, duration of the simulation run, and output options. Networks of up to 100 nodes have been successfully modelled with office workstations (personal computer). Larger networks have been simulated using supercomputers [18].

The regional implementations of planning models provide for a simplified representation of the road network. Simulation models, however, require detailed network coding at the intersection/approach level. Therefore, the network should be refined through zone splitting and coding of additional links and nodes. Also, additional data (lane channalization usage, traffic control data) have to be gathered and coded into the models. Such data are not readily available to most metropolitan planning organisations.

Postprocessor to Planning Models

An alternative modelling approach involves the development of a postprocessor to the planning model. The postprocessor would consist of relationships between link characteristics and the portion of the total time spent per driving mode. These relationships would then be used to calculate vehicle activity from the planning model outputs.

The network links would be stratified into distinct link types depending on facility type, design, traffic, and control characteristics. For each designated link type, vehicle activity data will be generated for different combinations of link characteristics and demand patterns through microscopic simulation on road networks with the selected link types. The analysis of the simulation outputs would produce a set of relationships that would determine the proportion of the time spent T_{ij} on a network link i in driving mode j as a function of the link's type

$$T_{ij} = F\,(link\ type,\ v/c) \qquad (1)$$

where *link type* is the link classification based on the design, traffic, and control characteristics and v/c is the volume-to-capacity ratio.

These relationships would then be incorporated into a specially written postprocessor to the planning model. The veh.km, travel time, volume, and v/c for each link predicted by the planning model would be input into the postprocessor to obtain the time spent in each driving mode based on the relationships between the link types and vehicle activity.

It is important to select a sufficient number of link types to capture the variation in the characteristics of highway facilities commonly found in the field. At the same time, it is practically impossible to develop relationships for link types representing all the combinations of link characteristics. This is illustrated through the following example: Consider the case of urban streets. Typical parameters to be considered and their range of values to determine link types for urban streets are provided in Table 1.

Table 1 Typical parameters and range of values (example)

Parameter	*Range of Values*
Location	urban, suburban
No. of through lanes	2, 3 or more
Turning lanes	yes. No
Free Flow speed (km/h)	40,56,72
Turning traffic	10%, 20%
No. of signals/km (link spacing)	2, 4, 6
Traffic Signal phasing	protected left turn, perm. left turn
Traffic Signal progression	good, uncoordinated, poor

The combination of all these parameters would result in 864 separate classifications (link types) for urban streets, for which it would be impossible to develop vehicle activity estimates. Therefore, the selection of link types would need to consider only a subset of key representative characteristics. In this example, the urban streets may be classified into 3 categories:

Category 1: Main Roads high design facilities with multilane approaches, exclusive left-turn lanes, protected phasing, and free-flow speed of 60 km/h.

Category 2: Secondary Roads, 2-3 lanes per approach, some intersections with no turning lanes, and speed of 40-55 km/h

Category ٣: Urban settings (shared lanes, permitted phasing, short spacing) and speed of ٣٠-٤٥ km/h.

The quality of signal progression may be used as a surrogate for control characteristics, that is (a) good progression (less than 40 percent f ehicles topping t the intersection approach), (b) uncoordinated operation (about 40-80 percent of vehicles stopping), and (c) poor progression (about 80 percent of vehicles stopping). This approach would result in only nine separate link types for main roads.

The final selection of link types was based on the following criteria: he ccuracy of the relationships, data collection/coding requirements to implement this approach in the planning model, the link characteristics typically coded in regional studies, and the time and computational resources to develop the relationships. A total of 25 link types was selected (Table 2).

Table 2 Proposed link types for determining vehicle activity relationships

Facility Type	Classification Criteria	Range Of Values	Link Types
Expressways	Section Type No of lanes/direction Design Speed (km/h)	Simple seetioril/merging,weaving 3,4,5 90,100	12
Primary (Main) Roads	Category Progression quality	1,2,3 poor, uncoordinated, good	9
Collectors	No of lanes Traffic control	1, 2 stop sign/signal	4
TOTAL			25

The postprocessor modelling approach produces region-wide estimates of vehicle activity data without recoding the network, except the designation of link types, and can be readily implemented with the current state of practice in regional modelling. The direct interface of planning and simulation models may provide more accurate estimates but it is best suited for subarea analyses given the input data requirements and the present computational resources of planning agencies. Therefore, the postprocessor approach was selected to develop the modelling framework for estimating vehicle activity by mode of operation.

THE PROPOSED MODELLING FRAMEWORK

Figure 2 illustrates the process for developing the proposed model. First, special software was written to obtain vehicle activity data from the outputs of simulation models. Next, simulation runs were performed on several real-world data sets. The simulation results were analyzed to determine relationships between the selected link types and vehicle activity. These relationships were then incorporated into a postprocessor to the planning model (emission model). The application of the model produces estimates of the time spent in each driving mode for each link and the total network and accurate estimates of the pollutants concentrations.

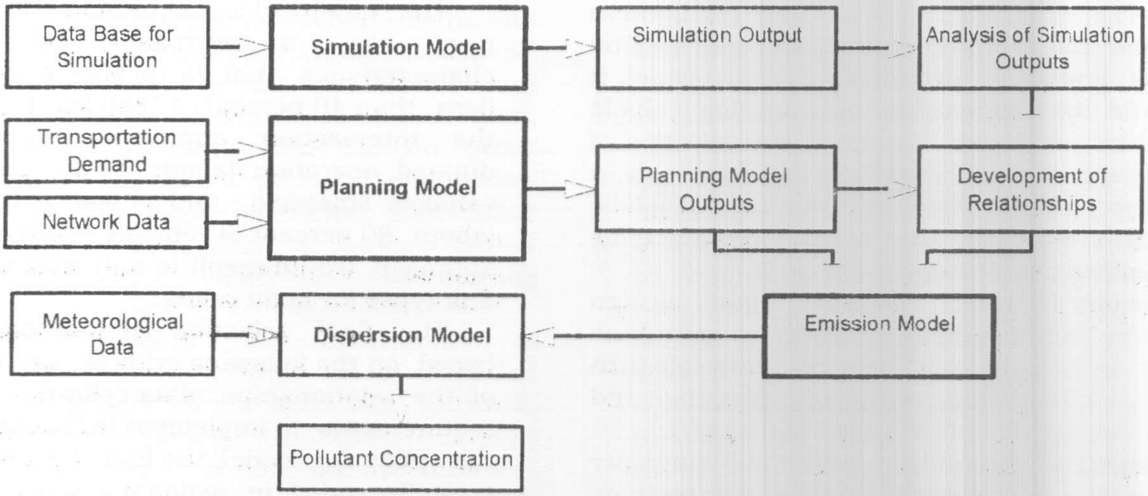


Figure 2 Structure and Information Flow Chart of the Proposed Framework

Analysis of Simulation Model Outputs

The VISSIM model stores in output files the trajectories of vehicles as they travel through the network during the simulation run. The information stored in each file record consist of the clock time, link number, vehicle type, and the vehicle's position, speed, and acceleration.

Routines were written in C++ to read the information from the output files and calculate the time spent per driving mode. The time spent (in vehicle-hour) is calculated by speed/acceleration category, speeds from 10 to 100 km/h at 10 km/h intervals, accelerations from -9 to 9 km/h/sec at 1.5 km/h/sec increments, and the queuing mode (idle mode). The routines were debugged and verified using the total distance travelled, average speed, queuing time, and moving time outputs from the simulation.

Simulation Runs

A database with real-world test sites was assembled for the simulation xperiments. t includes 12 data sets for the surface streets with a total of 171 intersections and 276 links (Table 3). The data sets were carefully chosen to provide a sufficient sample of the selected link types.

First, the selected data sets were coded into the VISSIM model and several initial runs were performed to verify the accuracy of the coding and the stability of the results. Next, baseline simulation runs were performed in each site, and the outputs were processed through the software to determine vehicle activity. The process was repeated on each site to obtain vehicle activity estimates for a range of traffic volumes. The outputs were analyzed on each site separately for each link, portion of the network (e.g.. arterial versus cross-street links) and for the total network.

The signal settings (cycle length, green times, and offsets) were optimized through VISSIG [19] and then were input into VISSIM to simulate traffic operations under good signal progression. These baseline signal timings were modified in subsequent computer runs to simulate conditions of poor progression and uncoordinated signal operation.

The following sections present some key findings from the simulations eparately for freeway facilities and surface streets.

Table 3 Selected Data Sets

Site	No. of Junctions		No. of	Peak hour	Free-Flow	No. of
	Signalised	Priority	Links	Volume	Speed	Lanes/D
Horeya Road	10	7	17	5676	60	2/3
Soliman Yoasry	10	2	11	3620	60	2/3
Cornaiche Road	5	3	9	3843	60	3
Sherif Road	2	6	7	3636	60	3
Ring Road	-	5	6	1850	90	3
Desert Road	-	9	10	2794	90	3
Coastal Road	-	10	12	3210	100	3
Raml	12	4	38	4530	60	2/3
Oraby	10	24	59	3323	60	2/3
Gomhoreya	6	9	31	3760	60	2-4
Attarin	9	11	40	1872	60	2
Shatby	6	11	36	4111	60	2/3
Total	70	101	276			

Vehicle Activity on Expressways

Table 4 gives the predicted proportion of time spent per driving mode separately for basic freeway (normal section) sections and weaving areas. Vehicle activity on normal sections remains essentially the same for traffic volumes up to capacity. The differences in the proportions of time spent in each driving mode were within 3%. When demand reaches or exceeds capacity the cruising time drops by 23%, and there is a significant increase in the time spent in acceleration-deceleration and queuing modes.

On weaving sections, the times spent in acceleration, deceleration, and queuing are higher than on normal expressway segments because of the complex vehicle interactions and intensive lane-changing manoeuvres that must be performed in a limited area. Vehicle activity strongly depends on the section configuration, the number of lanes and length of the weaving area, and the distribution of weaving and non-weaving vehicles.

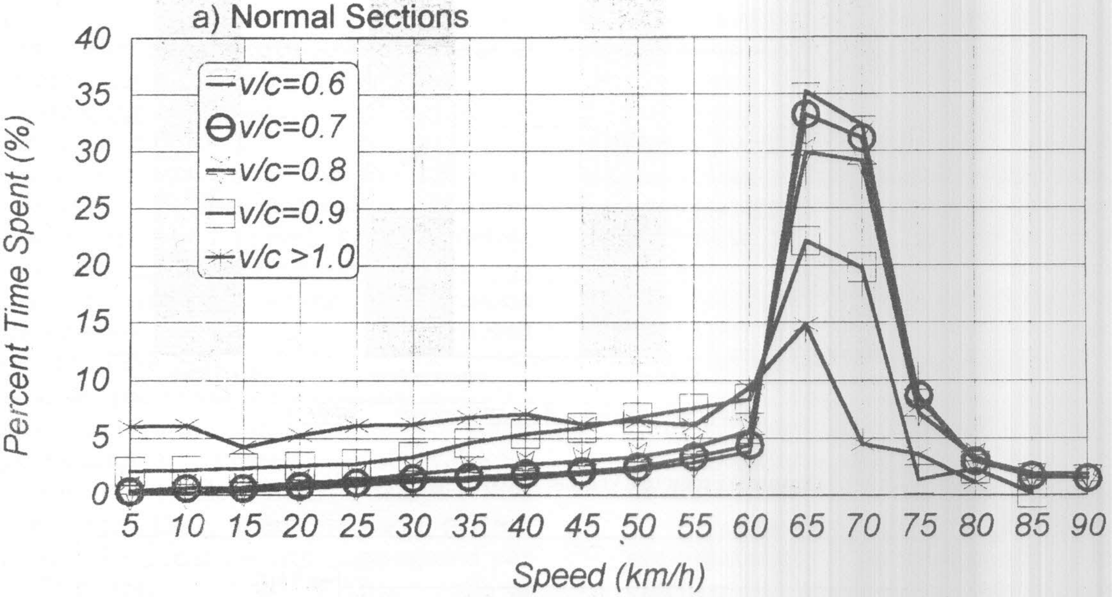
Table 4 Predicted vehicle activity on expressways

Volume/Capacity (v/c)	% Time Spent in Each Vehicle Operating Mode				Average Speed Km/h
	Cruise	Acceleration	Deceleration	Queuing	
Normal Sections					
0.6	56.30	19.80	22.50	1.40	89.6
0.7	52.40	21.80	23.90	1.90	82.2
0.8	50.80	22.80	24.10	2.30	79.4
0.9	47.60	24.40	25.20	2.80	59.4
> 1.0	33.90	30.80	28.60	6.70	48.4
Weaving Section					
0.6	53.80	21.30	24.00	0.90	83.4
0.7	48.60	24.50	25.70	1.20	76.6
0.8	42.20	27.90	28.20	1.70	61.2
0.9	36.80	30.10	30.00	3.10	50.1
> 1.0	24.90	34.80	31.00	9.30	31.2

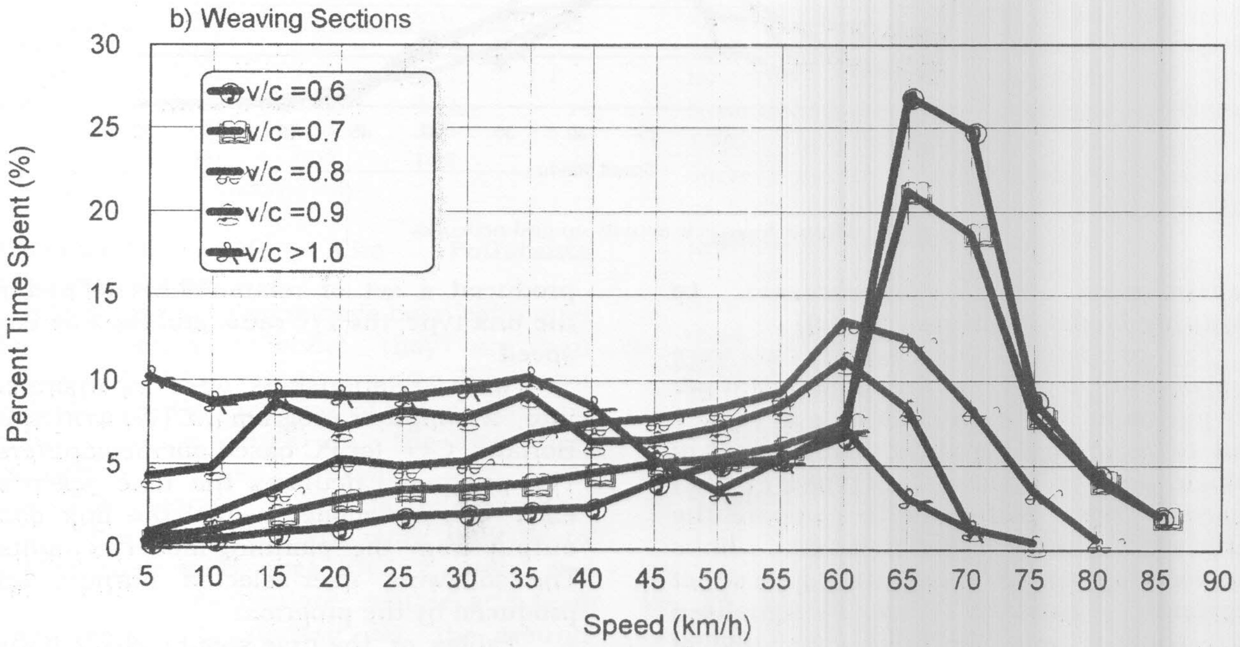
The predicted speed distributions for basic freeway sections are presented in Figure 3. For traffic volumes below capacity, about 75% of the time was spent travelling at free-flow speeds of 65 to 75 km/h, only 12% of the time was spent travelling at speeds under 60 km/h. Under oversaturated conditions, approximately 42% of the time is spent travelling at speeds of up to 50 km/h. Weaving areas have a higher proportion of time travelling at lower speeds than the basic expressway segments under all traffic levels.

Vehicle Activity on Urban Streets

Figure 4 gives the predicted vehicle activity for each main road data set. The largest variations are in the cruise and queuing times. These variations are due to their geometric characteristics, traffic patterns, and signalisation. The proportion of time spent in acceleration/deceleration was about the same in all the networks. The proportion of time in queuing mode was about 30% on closely spaced streets (Horeya Road). In contrast, Soliman Yoasry had only 12.5% of the time spent in queuing mode. The Horeya Road test site had the highest amount of time in the queuing mode because several of the traffic signals operate at or over capacity. Figure 5 gives the predicted vehicle activity on the selected grid networks. On networks typical of downtown areas, a significant amount of time is spent queuing and at low travel speeds, because of the short intersection spacing and numerous vehicle-pedestrian conflicts t raffic signals. Urban/suburban-type networks (Shatby) have lower proportions of time spent queuing and higher speeds



a) Normal Sections



b) Weaving Sections

Figure 3 Speed distribution on expressways

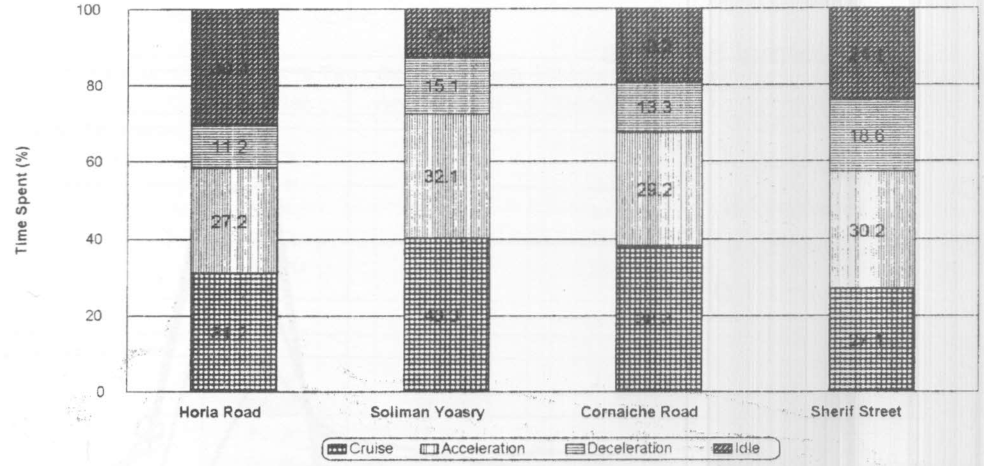


Figure 4 Predicted Vehicle Activity on test roads

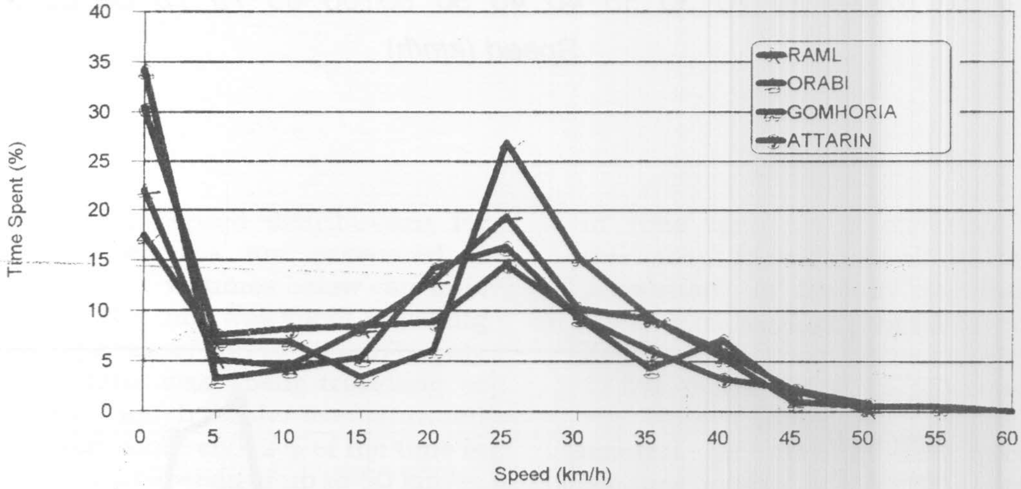


Figure 5 Vehicle activity on grid networks

Development of Postprocessor to Planning Model (Emission Model)

The predicted vehicle activity data were analysed to determine the time spent per driving mode for each link type in Table 1 and to determine significant differences in vehicle activity between link types. Further analyses were performed to compare the vehicle activity estimates for links representing single segments (e.g., a street segment between two signalised intersections) and for links consisting of several road segments. This process produced a set of relationships defined by the link type, the v/c ratio, and the free-flow speed.

These relationships were incorporated into a computer program (ACTIV) written in Borland C++ for PC based microcomputers. The program calculates the time spent in each driving mode using the link data output from the planning model as inputs. The following user-selected outputs are produced by the program:

- Tables of the time spent (vehicle-hour) for each link, facility type, and the total network by speed/acceleration category; speeds are from 10 to 100 km/h at 10-km/h intervals, accelerations from -9 to 9 km/h/sec at 1.5 km/h/sec increments, and the queuing mode. This output can be used for estimating emissions using modal emission factors.

- Summary statistics for the network, including vehicle-kilometer, vehicle-hours travelled, vehicle hours of delay, and average travel speed. The output can be used for estimating emissions using speed-based emission factors and vehicle-kilometre.
- A link performance summary includes the basic link characteristics, raffic performance (speed, v/c, vehicle-kilometre, vehicle-hour, delays), and the total time spent in each driving mode. The results are aggregated per facility/area type. This allows estimation of emissions using aggregate emission rates for each driving mode (Table 5).

Table 5 Emission Factors [4]

	Vehicle Emission Rate (gr/min)			Rate
	CO	HC	NOx	(m/sec²)
Cruise	5.08	0.95	1.71	
Deceleration	8.34	2.45	1.22	1.1
Queuing	3.00	0.50	0.03	
Acceleration	10.00	1.34	2.05	2.8
Creeping*	5.00	1.05	1.48	

* Applies to priority junctions only

Calculation of The Pollutants Concentrations

After the emissions have been estimated by the emission model, they are then "dispersed" into the air using a dispersion model. The specification of the model to be used depends much on the dispersion properties of the pollutants, with their reactivity being major factor. Reactive pollutants (O_3, NO_2) are more difficult to model than inert ones (CO). Equally, the tendency of particulate matter and lead agglomerates to deposit on the ground complicates their dispersion modelling to some degree.

There are three main approaches to dispersion modelling. The first approach uses the continuity equations of mathematical physics to develop a description of the chemical and physical processes that govern the relations between emissions and concentrations and is called the "eulerian" approach to dispersion modelling. The second approach uses a probabilistic escription of the motions of pollutant particles in the atmosphere to derive expressions of pollutant concentrations and is called the "lagragian" approach. The third approach is statistical and attempts to inter-relations between pollutant emissions and concentrations from observations of changes in concentrations that occur when emissions or meteorological conditions change.

Because of the complexity of the atmospheric phenomenon, for the calculation of the concentrations of the examined pollutants (CO, VOC and NO_x), all tractable with sufficient approximation like inert and conserved species) a single model, valid for all the situations, could not be used, but it is necessary to distinguish at least two extreme cases in which the pollutants diffusion occurs respectively in open field and in street canyons. In the former case the utilized model is proposed by the English Transport and Road Research Laboratory (Hickman and Colwill, 1982), and it introduces some empirical corrections to the classical gaussian model in order to take into account the turbulence induced by the vehicles motion.

The increment C [mg/m³] of a pollutant concentration in a downwind receptor, with road perpendicular wind, is calculated summing up the contributions from every emission interval by which the road axis is been splitted:

Where:

$$C(x,y)=\sum \frac{E(Y_1)}{\pi\sigma_y\sigma_z u^*} e^{-\frac{1}{2}\left(\frac{Y1-y}{\sigma_y}\right)^2} \qquad (2)$$

x,y [m]	are the receptor distances from the road axis and from the perpendicular axis passing through the stopline;
Y [m]	the distance from the stop-line of the source i;
E(Y$_1$)[mg/s]	the puntual emission in Y;
u*	= u/(0.59 + 0.11u) the modified value of the actual wind speed u [m/s]:

$$\sigma_z = 1.85\left\{1 + e^{\left[0.39(\ln x)^3 - 4.76(\ln x)^2 - 20.95(\ln x) - 32.67\right]}\right\} \quad ; \quad \sigma_y = 12.5\sigma_z \tag{3}$$

In the case of canyon road and equally for perpendicular wind, the increment C [mg/m^3] of concentration on the downwind side of the street canyon is calculated with the following formula (CANYON model):

$$C(x.y) = \frac{K.Q}{(u+0.5)\left(\sqrt{x^2+z^2}+l_o\right)} \tag{4}$$

where;

z [m]	is the receptor height;
Q [mg/(s.m)]	the emission for length unit;
u [m/s]	the wind speed;
l_o [m]	the average vehicle width (set to 2 m);
K	a constant set to 7.

APPLICATION OF THE MODELLING FRAMEWORK

The proposed model was applied to the Central road network of Alexandria, we tried to include both signalised and priority junctions as well as some roads with heavy traffic. A schematical representation of the network is given in Figure 6. It includes most types of highway facilities commonly occurring in the field and would allow the thorough evaluation of the capabilities and limitations of the proposed modelling framework for large urban areas. There are 13 traffic analysis zones, 144 nodes, and 312 links. The network is coded for the VISUM IT software [20] and is operational on PC-based microcomputers.

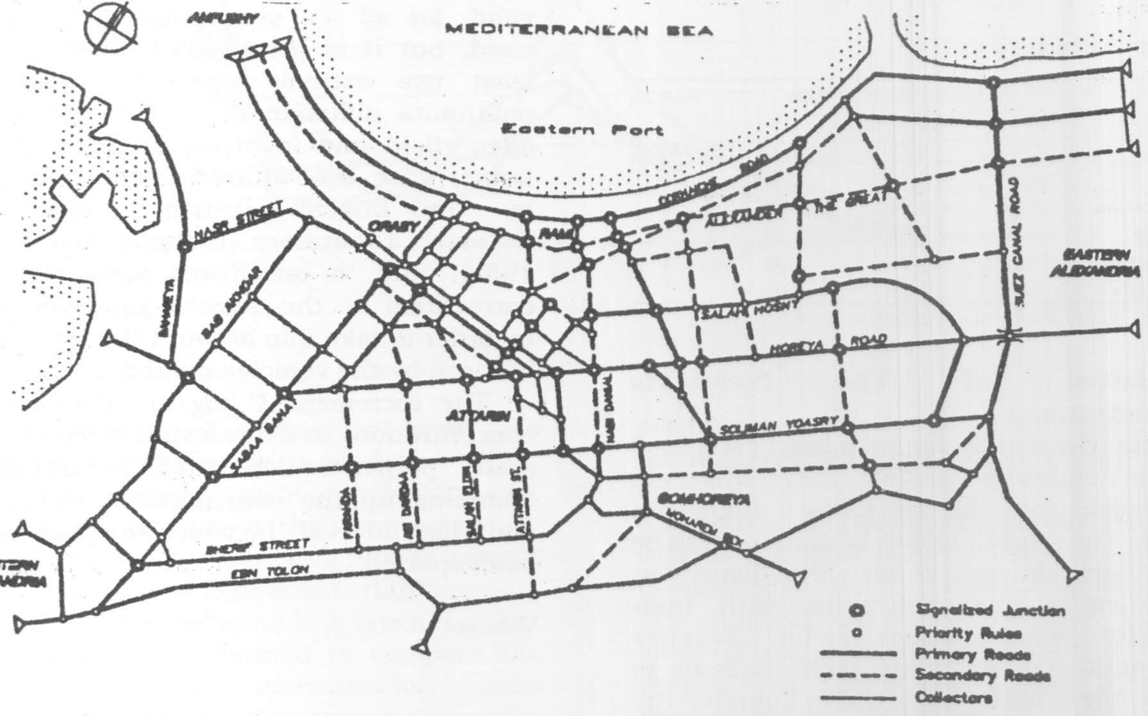


Figure 6 Schematic Representation of Alexandria City Centre Road Network

The VISUM IT model was run to obtain the link volumes and travel times using the trip table for the 1997 a.m. peak period updated from traffic counts [21]. To validate the model, the predicted volumes and speeds were compared with field data from representative network links.

A data-processing routine (EVAL) was written in C++ to process the output from the VISUM IT model run. EVAL calculates the link ID based on the process described earlier, as well as the link capacity, vehicle-kilometre travelled, and vehicle-hour travelled. It produces an ASCII data file with the following fields in each record: FromNode, ToNode, Distance, Free Speed, Capacity, Facility Type, Area Type, Volume, Average Speed, v/c, Link ID, vehicle-kilometre, and vehicle-hour. This file is then input into the ACTIV program to calculate the vehicle activity for each link, facility type, area type, and the total network.

Prediction of Vehicle Activity

The predicted values of time spent in each driving mode and the summary statistics for the Alexandria City Centre road network are given in Figure 7. About 35% of the total time was spent in cruise mode, 45% in acceleration and deceleration, and 20% queuing. The time spent accelerating/decelerating within ±3 km/h/sec represents 82% of the vehicle activity in the acceleration and deceleration mode. Delay accounted for 60% of the total travel time in the network. Most of the delay occurred on the saturated links and the average delay was 1.10 min/veh-km.

The results given in Table 6 are for the typical a.m. peak hour. The model can be applied for other time periods by first running VISUM IT model (or other urban transportation planning system) assignment to obtain the link volumes and speeds using the trip matrices for each analysis period

Table 6 Predicted vehicle activity on alexandria city-center road network

VEHICLE ACTIVITY FOR THE TOTAL NETWORK
ALEXANDRIA CITY CENTRE
A.M. PEAK HOUR

Speed	Accelerations (km/h/sec)													
Km/h	-9.0	-7.5	-6.0	-4.5	-3.0	-1.5	0.0	1.5	3.0	4.5	6.0	7.5	9.0	Total
0	0.0	0.0	0.0	0.0	0.0	0.0	8140.2	0.0	0.0	0.0	0.0	0.0	0.0	8140.2
5	0.0	0.0	57.9	14.1	338.6	365.1	1779.3	335.0	113.4	39.5	184.5	5.9	0.0	3233.1
10	0.0	0.0	21.9	94.1	1763.3	255.9	411.3	311.3	119.0	169.5	72.3	30.2	0.0	3248.6
15	0.0	0.0	28.4	91.5	216.6	257.0	389.1	287.9	103.4	146.7	34.7	40.4	0.0	1595.4
20	0.0	0.0	31.4	80.9	235.2	281.6	774.5	364.5	198.9	27.3	10.5	27.5	0.0	2032.1
25	0.0	1.8	26.0	54.8	149.3	422.7	2098.8	1660.2	325.1	0.3	2.9	2.6	0.0	4744.2
30	0.0	0.0	11.7	44.0	112.1	320.1	1561.1	1349.4	114.3	1.8	0.0	0.0	0.0	3514.4
35	0.0	0.0	4.7	14.7	54.3	256.2	900.0	738.9	65.7	0.0	0.0	0.0	0.0	2034.5
40	0.0	0.0	1.4	10.5	44.0	208.4	613.1	411.9	28.8	0.0	0.0	0.0	0.0	1317.9
45	0.0	0.0	1.1	9.6	29.4	345.0	950.4	484.5	25.5	0.0	7.2	0.0	0.0	1852.7
50	0.0	7.2	16.2	9.2	34.4	834.6	1979.3	812.9	41.6	0.0	0.0	0.0	0.0	3735.2
55	0.0	0.0	0.0	0.0	18.0	604.8	1825.5	711.6	41.6	7.2	0.0	0.0	0.0	3208.7
60	0.0	0.0	0.0	0.0	9.0	179.3	643.1	248.1	16.4	0.0	0.0	0.0	0.0	1095.8
Total	0.0	9.0	200.4	423.2	3003.9	4330.5	22065.5	7716.0	1193.4	392.3	312.0	106.4	0.0	39752.4

NETWORK STATISTICS
Total kilometers traveled: 838775.6 veh-km
Total Travel Time: 39752.4 veh-hr.
Total Delays: 15377.6 hr.
Average Network Speed: 21.1 km/

Calculation of Emissions Concentrations

In this section, the emission and concentration distributions calculated for a the Alexandria City Center road network is presented. The parameters considered here are those with a network wide effect, such as wind characteristics, emission rates and volume of transportation demand (Figure 7).

Figure 8 illustrates the emission concentration distributions of CO pollutant calculated by the model for the test network (as example). Emissions from both direction of a two-way link are taken into account. Concentrations are shown in the form of iso-concentration contours. The denser the contours are at a particular area, the faster the concentration rises there. The wind speed was set at 1.5 m/sec from the North. The tendency of the contours to gather around junctions is obvious. Comparing Figures 6 and 9 it can be seen that highest emissions and concentrations occur at highest flow junctions.

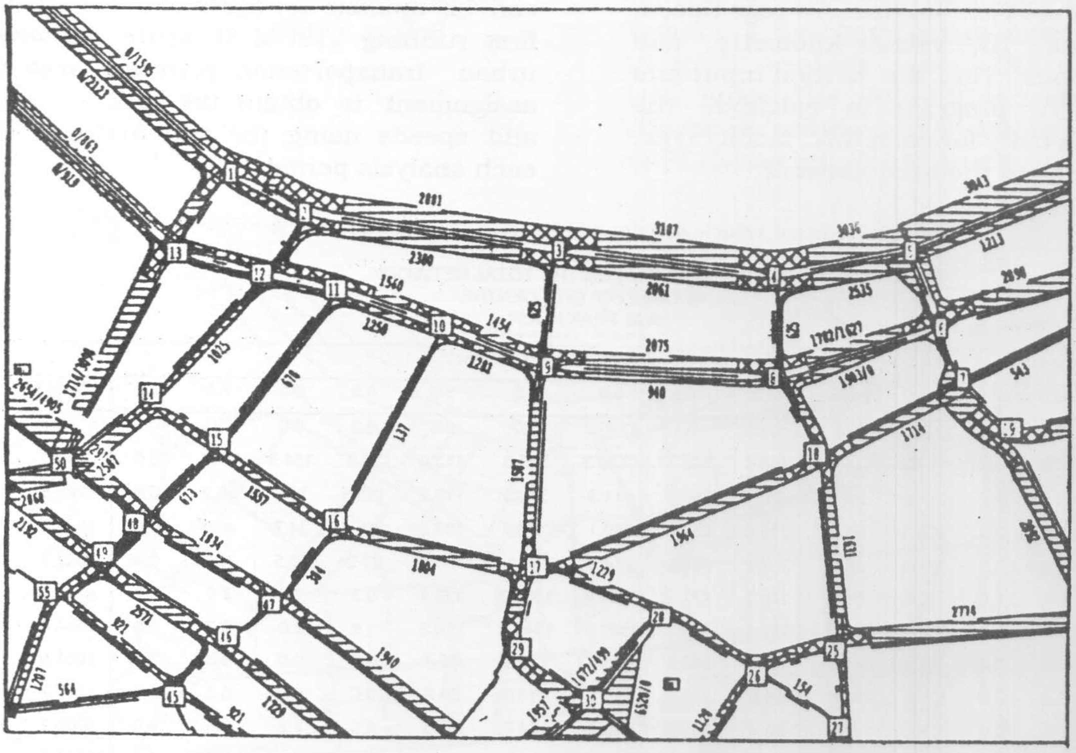
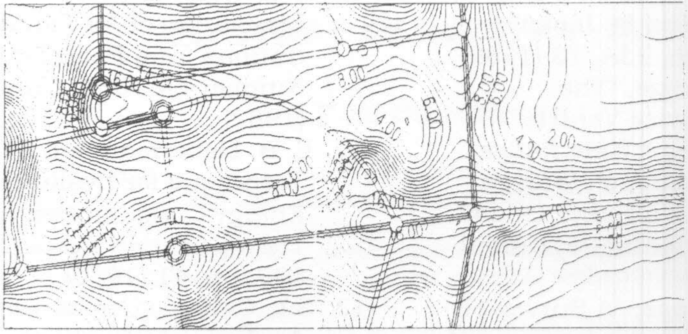


Figure 7 Alexandria City Center Road Network: Directional Flows and Node Flows

a) High Transportation Demand



b) Low Transportation Demand

Figure 8 CO Pollution concentrations over Alexandria city center road network

CONCLUSIONS

A modelling framework was developed to predict vehicle activity in regional areas to obtain improved emissions estimates and atmospheric concentrations of polluting gases (CO, VOC, NO_X). Relationships ere developed between basic link characteristics and the time spent per driving mode based on extensive simulations of representative networks with the VISSIM microscopic model. These relationships were then incorporated in a specially written emission model. The proposed model provides region-wide estimates of vehicle activity, nd t an be applied with the existing state of practice in regional modelling.

The model was applied to the Alexandria City Centre road network. The analysis of the model outputs, comparison with the VISIUM IT model estimates, and other tests indicated that the proposed model is working correctly and can be used as a tool to provide vehicle activity data, and pollutant concentrations for regional areas.

The framework is intended to be applied to practical situations and to produce useful results for practitioners. It will be of use to traffic engineers and transportation planners as a design and evaluation tool. Its integration with other software allows it to be readily applicable to real networks and produce results for a wide variety of traffic management schemes. Other uses may include testing the possible effects of lowering vehicle emission rates and producing estimates of future pollution levels, given the changes in the transportation demand. It can also very easily be adapted to produce fuel consumption estimates over the modeled network and be used in the economic evaluation of different schemes.

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