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TITLE The use of geographical information systems for traffic monitoring and planning

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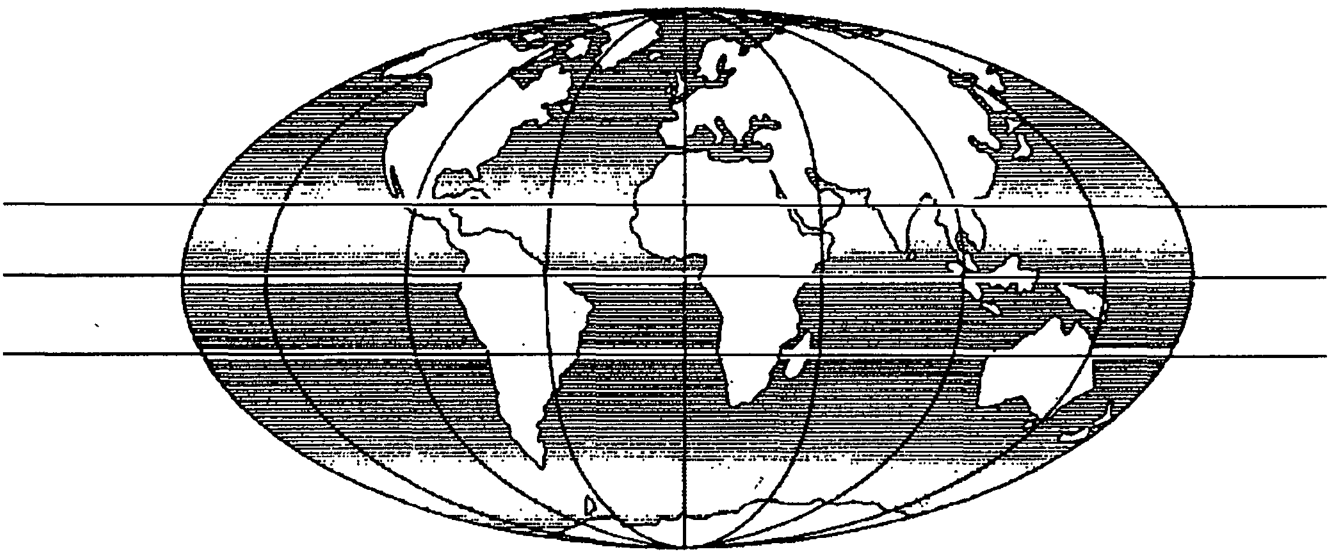

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THE USE OF GEOGRAPHICAL INFORMATION SYSTEMS FOR TRAFFIC MONITORING AND PLANNING

Paper for the United Nations Conference on Geographical Information Systems, Cairo, Egypt. December 1995

BY G Gardner, PR Fouracre and JC Rutter. Transport Research Laboratory, United Kingdom

INTRODUCTION:

This paper describes a project which aims to improve the planning of efficient urban transport. It draws upon work being undertaken in Ghana in association with the Ministry of Transport and Communications, as part of a World Bank funded Urban Transport Project and an Overseas Development Administration (ODA) Technology Development and Research Project on simplified urban planning.

The paper focuses on two aspects of the transport analysis process:

- a study of the requirements of a database for performance monitoring and evaluation.
- the development of a low-cost urban traffic and transport sketch-planning system to identify patterns of traffic and transport problems.

BACKGROUND:

Growth in the population of developing cities continues remorselessly, and with it the associated urban development problems: housing, sanitation, water supply, health-care, and transport. The general problem pervading all urban development (including transport) is a basic lack of understanding concerning the way in which cities function and grow. Very little is known, for example, of how a city populace will respond to major transport projects, and whether the project in general will contribute to city efficiency or develop sustainability.

Urban transport development makes a key contribution to the development and welfare of a city, particularly a large city which generates huge commuter flows over long distances, and focussed on small areas and corridors. As well as access and mobility, transport is also increasingly concerned with environmental issues, safety and the overall quality of city life. In addition to the requirements for informed planning, there is a need to be able to monitor how travel and transport are changing over time, and in response to what influences and with what impact, not only on congestion, but also in terms of these wider issues.

A basic requirement for understanding the urban transport development process is a source of background information which can support informed decision-making. At present, there is rarely information for tracking transport problems and trends within a city. Few developing cities have a well-established method for continual monitoring and analysis of transport; indeed many cities maintain few records of any worth. A common problem is lack of resources, coupled with a certain degree of antipathy towards the urban transport cadre. Traffic surveys are usually *ad-hoc*, perhaps undertaken in support of a particular investigation, but rarely to evaluate the impact of a project. As a result, there is no cumulative learning process which can contribute to more successful transport projects and policy development in the future.

EXISTING PRACTICE

Methods already exist for the analysis of transport problems. These include the use of multi-stage network optimisation models such as TRIPS and EMME/2. Since the first use of a transport planning model in Chicago in the 1950s, these have been used in almost every developed city. As the twenty year forecast periods have now elapsed, it is possible to look back on the achievements of these studies, and the results of many of them have been found lacking (Atkins 1986).

According to Talvitie (an experienced transport modeller) the problem almost always arises from the planners' lack of understanding of the human elements of the planning process (Talvitie,1995). Additionally, though the results from the models are a useful guide, and could help to alleviate transport problems, implementation is almost always too slow. Part of the reason for this is that the traffic planning process has become so complex that specialists with both planning and computational skills are needed. Such specialisation is rarely available in developing countries, particularly in the public sector.

Stopher (1980) and others have criticised the use of transport planning models in developing country conditions, casting doubt on one of the key assumptions, namely, that travellers in developing countries have an implicit value of time which they seek to optimize in making travel decisions.

Barrett (1984) suggests that many of the transport problems of the developing world are due to organisational incompatibilities. Gardner et al (1989) also concluded that the main problems are not technical but connected with lack of motivation towards the orderly and timely implementation of simple, low-cost measures. Other work by Gardner (1994) on the decision-making process and the choice of mass transit systems has reiterated the relative unimportance of technical details in influencing what actually gets implemented in a city. Ultimately the choice of action (rightly or wrongly) rests with the political leaders.

The aim of the present research is not to increase the amount of data collection or to develop a more accurate simulation model. Rather it is to devise methods of generating information in a form that will be usable by the decision-makers, and to guide their choice and make explicit the implications of their choices.

DATA COLLECTION

What is required is a means of data capture and storage, which is low-cost, but still robust enough to provide the basis for sound analysis of transport problems, impacts and trends. Data storage is relatively easy, but the types and scale of information to collect, together with methods of collection, require detailed investigation.

The research is in two parts; first, identification has been made of the requirements for the best possible data set for the evaluation and monitoring of transport in a city. A major data collection effort for this is now nearing completion in Ghana in the five main cities. Secondly, a pilot study of how this data might be represented graphically has been completed in Istanbul, Turkey. The work has also given consideration to the implications of the graphical representation of coarse data.

TRANSPORT INFORMATION NEEDS

While the problems of travel, congestion and pollution are tangible and quite apparent to transport operators and users alike, there is often little objective measurement of the nature and impact of these problems. The need for such a quantitative assessment is important for the following reasons: -

- to clearly establish failing performance of the transport system, and in particular where, how and why it is failing;
- furthermore, to help identify possible remedial actions and priorities for implementation;

in addition, further developments by Fouracre (1995) are investigating the data needs for the following:

- to provide a baseline against which to monitor impact of remedial actions in particular, and trends in general;
- to provide basic data for longer term strategic planning.

To furnish this information on a comprehensive basis requires major survey work which is likely to involve significant resources. These cannot be mobilised on a regular and frequent basis; periodicity of a major transport study for a city may be as low as every 10-15 years, with perhaps small ad-hoc studies addressing particular transport issues at irregular intervals between. These circumstances dictate that maximum use is made of available information. Fouracre suggests that this can be achieved through two related paths: - collating existing information, and "infilling" irregular survey material through small-scale sample surveys.

URBAN TRANSPORT PERFORMANCE INDICATORS

Table 1 shows a number of possible key performance indicators that would be of use to municipal authorities. An example of how these indicators can be used to assess performance and progress is also given in the table.

Table 1 is not exhaustive, and in some circumstances other indicators may be appropriate. In Ghanaian cities, for example, the performance of transport terminals is the subject of much controversy. Two indicators will be used for the purpose of performance evaluation: average turn-round time of vehicles and revenue generated at terminals. If measures to improve output are successful, then turn-round times will be reduced, and revenues will be raised.

Table 1: Key performance indicators

Indicator	Purpose	Description	Target
Road Accidents	*To gauge magnitude of road safety problem*	*Total injury accidents (absolute and per vehicle) and percentage change over time.*	*Accident rate no worse than peer group of similar cities, and a positive, sustained and significant downward trend.*
Passenger Service	*To determine quantity, quality and trends in use of public transport.*	*(I) Numbers of public transport vehicles & seats (absolute and per capita)* *(ii) Weighted average flow of public transport vehicles on inner/outer city roads.* *(iii) Weighted average waiting times at key sites* *(iv) Weighted average journey times on key routes.*	*(I) Numbers should be comparable with other similar cities; Trend should not be negative.* *(ii) No specific target; for monitoring only.* *(iii) Waiting times no worse than 20 min in peak on high frequency routes; trend should not be negative.* *(iv) Overall journey time should not be more than 3 hours per day.*
Roads Performance	*To determine level of congestion*	*(I) Road kilometerage. (absolute and per unit area).* *(ii) Weighted average vehicular speeds[1] on inner/outer roads during peak.* *(iii) Weighted average peak-hour flows on main corridors*	*(I) Numbers should be comparable with other similar cities; trends should not be negative.* *(ii) Inner city roads should have peak-hour speeds in excess of 10kmph; trend should not be negative* *(iii) No specific target; for monitoring only.*
Vehicular Fleet	*To indicate growth in demand*	*Numbers of vehicles (absolute and per km of road and per capita)*	*No specific target; for monitoring only.*
Transport Prices	*To indicate trends in cost of transport*	*(I) Average public transport fares for fixed distances (including taxi)* *(ii) Price of fuel* *(iii) Average price of vehicles*	*No specific target; for monitoring only*
Modal Choice	*To indicate relative importance and development of different modes*	*(I) Number of vehicles by type (absolute and per capita)* *(ii) Proportion of trips undertaken by different modes of transport*	*No specific target; for monitoring only*

[1]Door to door journey speeds are preferable - though more difficult to measure - as one way streets can cause an artificial speed increase. Delay is a better indicator than speed, though again this is difficult to survey.

Source: Fouracre 1995

FIELD SURVEYS

Table 2 lists the main types of field surveys that are recommended to collect information on urban transport performance. The Table lists the general output that each survey yields, and the particular performance indicator(s) that it serves. Each survey can yield information for more than one performance indicator and conversely, some performance indicators may be a composite from different survey types. For example, transport fares can be determined from driver interviews or passenger surveys, but it may need information from both surveys to give a complete picture of fare structures, including any informal aspects of pricing policy. (Detailed methodologies of some of these surveys are contained in TRRL ORN 4 and ORN 11).

Traffic counts and composition: These surveys can be undertaken manually or automatically with electronic counters. The importance of monitoring composition is that it can give some indication of mode choice, and the relative importance of different modes. By estimating vehicle occupancies it is possible to determine the proportion of persons travelling by mode using each road where counts are undertaken. This is important, since the aim of traffic management should be to maximise the movement of "people", not "vehicles".

Car journey times: Monitoring in-vehicle journey times over a specified route is a standard method of establishing journey speeds. The survey is expensive, but sampling methods reduce the amount of coverage that is necessary. Point speeds from electronic counters can provide a guide, especially for long term monitoring at key locations. Some indicative information may be available from bus commercial speed data where these are known.

Bus journey times and loadings: This survey is undertaken in-vehicle, with observers (the number depending on the size of the vehicle) monitoring journey times between designated timing points, and the boarding and alighting patterns of passengers. By staying with one vehicle throughout the working day it is possible to build up a complete picture of vehicle utilisation (time spent productively, idle time, etc.), average vehicle speeds, passenger carrying performance, passengers carried, revenue, trips made and average passenger travel distance.

Passenger interviews: Interviews with passengers can yield details about the quality of public transport service, as well as the characteristic of the public transport user. Quality can be measured by journey times (including its components: waiting time, access time and in-vehicle time), and stated preferences and attitudes. Information on fares paid (which may differ from driver information on fare structures) can also be established.

The extensive data collection effort in Ghana is coming to an end, with teams of survey staff under the direction of local traffic consultants having visited all of the five major cities of the country. Data will be given to the Ministry of Transport/TRL team in Lotus WK1 format and afterwards transferred to a Foxpro for preliminary analysis.

GEOGRAPHICAL INFORMATION SYSTEMS

The value of a Geographical Information System (GIS) is the ability to present database information powerfully in pictorial format. The GIS can be deployed with any database format, but does require special facilities for converting maps into digital format: it also requires that suitable maps exist. In Ghana at the present time there are no suitable street maps in the cities outside of the capital Accra and the second city Kumasi. The possibility of using satellite imagery is being investigated. Meanwhile, a suitable case study opportunity arose in Istanbul where maps are available, and this has been used for a pilot test of the methodology.

The GIS package MAPINFO was chosen because, although less powerful than the more sophisticated packages such as ARCINFO, it is capable of representing graphically the main characteristics and features of urban traffic systems. MAPINFO has the advantage of being easy to learn to use (and having links with Microsoft suggests that the format will be well supported internationally.)

Following the pilot test, the project will use trial sections of Istanbul and in the city of Monterey in Mexico. These will then be analysed using two different methods. The first is a traditional transport model package, of the type widely used and marketed internationally. The second method will use MAPINFO.

Table 2: Survey Types

Type	*Information*	*Method*	*Output*
Road inventory	*Road network characteristics*	*Observation*	*Geometry, Land-use, Road-furniture provision*
Parking inventory	*Parking supply*	*Observation*	*Available parking space, Types of parking*
Parking use	*Demand for parking space*	*Parking patrol survey*	*Occupancy times, Usage of space*
Origin-destination	*Demand forecasting*	*Registration Number method*	*Route choice, Through-traffic, Travel times*
Traffic volumes	*Demand*	*Manual counts, Automatic counts*	*Vehicle flows on links, Junction movements, Passenger flows, Traffic variability, Peak-hour factors, AADT*
Spot speeds	*Vehicle performance on links*	*Short-base method, Radar observation*	*Vehicle speeds on links, Speed flow measurements*
Network speeds and delays	*Route network performance*	*Floating car method*	*Network speeds, Link speeds, Network delay, Congestion points*
Junction delay	*Junction performance*	*Stopped vehicle count, Elevated observer method*	*Total delays, Average arm delays, Distribution of delay times by turning movement, Delay causes*
Saturation flows	*Junction capacity*	*Flow profile method, Saturated period count*	*Saturation flow, Junction capacity*
Loading surveys	*System effectiveness* *Vehicle performance*	*In-vehicle, continuous, by observation*	*Vehicle load patterns, Av. load factors, Av. passenger lead Passenger throughput, Vehicle handling capability, Fare revenues/leakage, Use of bus passes, Journey speeds/time, Boarding/alighting times.*
Journey time and penalty time surveys	*Vehicle performance*	*In and off-vehicle, continuous or ad-hoc, by observation*	*Journey speeds, Causes of delay, Penalty times.*
Waiting times and bus frequencies	*System effectiveness, Demand, Vehicle performance*	*Off-vehicle, continuous or ad-hoc, by observation*	*User waiting times, Passenger arrival patterns, Bus arrival patterns, Boarding/alighting times.*
Passenger interviews	*Demand System effectiveness*	*On or off-vehicle Ad-hoc interviews*	*Travel patterns and use of buses, Estimates wait times and travel times, Opinions of service.*
Household surveys	*Demand System effectiveness*	*Off-vehicle Ad-hoc by interview*	*Demand for transport, Modal choice criteria.*
Time and motion surveys	*Staff/vehicle performance*	*On or off-vehicle Ad-hoc by observation*	*Staff time use, Vehicle use.*
Staff interviews	*Staff performance*	*Off-vehicle Ad-hoc interviews*	*Knowledge and training needs.*
Boarding/alighting	*Vehicle effectiveness*	*On/off-vehicle by observation*	*Time boarding/alighting.*

Sources: TRRL (1987), TRL (1993)

The outputs of both methods will be assessed by independent traffic experts to advise upon what type of countermeasures or new construction would be recommended for each city. Comparison can then be made of how likely it is that a simpler planning tool could bring results of similar utility to the more expensive methods. In the third stage of the project, the findings of the experts will then be relayed back to the cities and form a public presentation of the proposed ideas. The reaction of the public will be monitored and recommendations made for further studies of this type

OPTIMISING SURVEY DATA

In association with the pilot test of the GIS system, research is taking place on the optimisation of survey data. The hypothesis here is that although inaccurate or sparse data may not give useful advice when in text format, when presented graphically it may have greater value if it serves to identify transport problem patterns

Most of the surveys described above require an experienced team of three or four observers per location; they are therefore highly expensive. A smaller set of performance indicators, using information from surveys which have a lower sample size or reduced coverage, might be used to provide a basis for updating historic transport information, for example, and for identifying the need for more detailed studies on specific issues.

These simple surveys should not, normally, be used as a replacement for more comprehensive surveys. The research is designed to test to what extent a coarse data set is better than none at all. For example, if decision makers are not using currently available information, this may be because data collection needs to be improved or extended, or reduced because some of it is not useful.

One of the advantages of GIS is that graphical representation of data does permit patterns to be identified by eye. Preliminary investigation suggests that these patterns, though less accurate, are still discernable when using coarse data. At the very minimum, this can provide some indication of the need for further investigation. Expensive data collection can then be concentrated in the areas where it will be most effective in terms of leading to direct implementation of projects.

PILOT STUDY

As a trial of the use of coarse data sets for GIS study, a section of the city of Istanbul in Turkey was selected for a pilot study. The area contains a range of features and road types, and includes a section of exclusive busway studied in previous TRL research (Gardner et al. 1991). The survey visit shared priorities (and costs) with this research.

The surveys were conducted over a two-week period by a single observer with no equipment or support staff. Table 3 lists the data types collected. Empirical data of road and junction layout and traffic flow parameters can be collected from a survey on foot. A vehicle-based survey can quickly provide a valuable supplement of overall, subjective assessments of road use and traffic flow/congestion patterns. Results from the Istanbul survey are shown in Tables 4 and 5.

Examples of the sort of patterns which can be obtained when this data is transferred to GIS are shown in Figure 1. The actual busway (not shown here) follows a north-south orientation between junctions marked as 20 to 70 and continuing beyond the latter. It is normally bi-directional for its entire length but in February and March of 1995, when the surveys were carried out, link 208 between junctions 50 and 60 was only open to northbound buses and closed to general traffic while cut-and-cover excavation was being carried out as part of the Metro extension programme.

The principal aim of the study was to test the methodology, but some limited interpretation of the results is possible. It is relatively easy to see that congestion was largely associated with links in the northern part of the corridor. The free flow of traffic is also associated with a decrease in the effective lane width by parked cars. Many of the links on which heaviest congestion occurred were those with one lane per direction blocked, usually by legal or illegal car parking. The exceptions to this were largely entry/exit links where traffic flow may have been influenced by other factors external to the network.

It is not possible to say with any form of statistical significance that obstruction by parking is causing traffic congestion. The results of this quick and easy survey have shown, however, that there is a pattern which should be looked at by the municipal engineers. Further studies should concentrate on car parking, and should be focused on the streets where this has been suggested as being a problem. This type of survey can help to identify priorities for an immediate action programme of the sort that most developing cities urgently require.

Table 3: Types of data for GIS representation of an urban highway network

Link data	*Node data*
Link No. *From Node No.* *To Node No.* *Street Name(s)* *Length (km)* *Actual width (No. of lanes)* *Effective width* *Congestion factor*[a] *Use of surrounding land*[b] *Hilliness*[c] *Traffic use (busway or general)*	*Node No.* *Junction type:* *CS - Complex Signalised* *SS - Simple Signalised* *DU - Defined Uncontrolled* *UU - Undefined Uncontrolled*

[a]*Subjective scale of 1 (freely flowing, unimpeded traffic) to 5 (flow of traffic heavily impeded)*
[b]*e.g. Commercial, residential, parks etc.*
[c]*Subjective scale of 1 (level) to 3 (very steep gradients)*

CONCLUSIONS

It should always be kept in mind that the ultimate aim of any transport project is an improvement in the quality of urban life, and not the project itself. The 'correct' level of detail of a data collection effort is then one that helps to achieve these aims in the most cost-effective and timely manner.

For the Ministry of Transport in Ghana, the requirement is for performance monitoring and evaluation. A comprehensive, but realistic, data set has been identified, and a relational database is being used for this purpose. There is still an argument for more detailed planning studies, particularly when large scale infrastructure investments are planned.

The research described here is at an early stage. Nevertheless, it suggests that a useful amount of data can be collected in a very short period, and this can be used for rapid action programmes and to plan more detailed surveys. Where suitable maps are available, a GIS display of basic urban transport information can provide a useful input to the decision-making process at a fraction of the cost of a full-scale transportation planning study.

The amount of detail that a non-specialist can assimilate is inevitably lower than that of technical specialists. It is almost always non-specialists who are responsible for decisions about what actually gets implemented. This situation is unlikely to change. The onus is on the specialists, therefore, to change the emphasis from collecting or simulating ever more accurate data, towards feeding the decision process at the right level of detail.

Table 4: Link data for Taksim-Şişli Busway Corridor, Central Istanbul

Link	*Street name*	*From node*	*To node*	*length (km)*	*Lanes per direction (actual)*	*Lanes per direction (effective)*	*Congestion factor*	*Land use*	*Hills*	*Busway (B) or General traffic (G) with Direction (1 or 2 way)*
200	*Taksim Cumhuriyet Maydani, Cumhuriyet Caddesi*	10	20	0.18	3	3	1	C	1	G2
202	*Cumhuriyet Cad.*	20	30	0.31	4	4	1	C	1	G2
204	*Cumhuriyet Cad.*	30	40	0.95	3	3	2	C,M	2	G2,B2
206	*Hâlaskârgazi Cad.*	40	50	0.44	4	3	3	C,R	2	G1,B2
208	*Hâlaskârgazi Cad.*	50	60	0.20	4	3	3	C,R	1	B1
209	*Hâlaskârgazi Cad.*	60	70	0.78	4	3	1	C,R	2	G1,B2
210	*Abide-i Hürriyet Cad.*	70	80	0.72	4	3	2	C,R	1	G1
212	*Bozkurt Cad.*	80	90	0.29	4	3	1	C,R,Cem	1	G1
214	*Ergenekon Cad.*	90	50	0.34	4	3	1	C,R	2	G1
216	*Rumeli Cad.*	60	80	0.24	3	2	4	C	2	G1
218	*Rumeli Cad.*	140	60	0.47	3	3	2	C	2	G1
220	*Valikonaği cad.*	40	13	0.32	4	4	1	C,M	1	G1
222	*Valikonaği cad.*	130	140	0.21	4	4	1	C	1	G1
224	*Taki-i Zafer Cad.*	110	10	0.23	3	3	1	C	1	G1
226	*Taki-i Zafer Cad.*	10	110	0.22	3	3	1	C	1	G1
228	*Mete Cad.*	110	120	0.45	3	3	1	C	1	G2
230	*Taşkişla Cad.*	120	130	1.46	2	2	1	C,H,P	2	G2
232	*Asker Ocaği Cad.*	30	120	0.24	3	3	1	C,H	1	G2

(continued overleaf)

Table 4: Link data for Taksim-Şişli Busway Corridor, Central Istanbul (continued)

Link	*Street name*	*From node*	*To node*	*length (km)*	*Lanes per direction (actual)*	*Lanes per direction (effective)*	*Congestion factor*	*Land use*	*Hills*	*Busway (B) or General traffic (G) with Direction (1 or 2 way)*
234	*Tarlabaşi Bulvari*	20	100	0.12	4	4	1	C	1	G2
236	*Abdülhak Hamit Cad.*	30	100	0.68	4	3	3	C	1	G1
238	*Siraselviler Cad.*	10	external	_	4	3	3	C	1	G2
240	*Tarlabaşi Bulvari*	100	external	_	3	3	1	C	1	G2
242	*Yedi kuyular Cad.*	30	external	_	1	1	3	C,R	2	G2
244	*Kurtuluş Cad.*	90	external	_	2	1	3	C	1	G2
246	*Büyükdere Cad.*	70	external	_	4	3	4	C,R,Cem	1	G1,B2
248	*Abide-i Hürriyet Cad.*	external	70	_	4	3	2	C,R,Cem	1	G1
250	*Teşvikiye Cad.*	140	external	_	2	2	1	C,H,R	3	G2
252	*Asker Ocaği Cad.*	120	external	_	2	2	3	H,P	2	G2
254	*Inönü Cad.*	110	external	_	2	2	3	C	3	G2

Notes:

For explanation of friction factor and hilliness grading see Table 3.

Land-use categories:

H - Hotels
C - Other commercial
R - Residential
P - Parks
M - Military bases & military museums
Cem - Cemeteries

Table 5: Node data for Taksim-Şişli Busway Corridor, Central Istanbul

Node No.	*Junction type (see Table 3)*
10	*SS*
20	*SS*
30	*CS*
40	*CS*
50	*SS*
60	*SS*
70	*CS*
80	*SS*
90	*SS*
100	*SS*
110	*DU*
120	*SS*
130	*UU*
140	*SS*

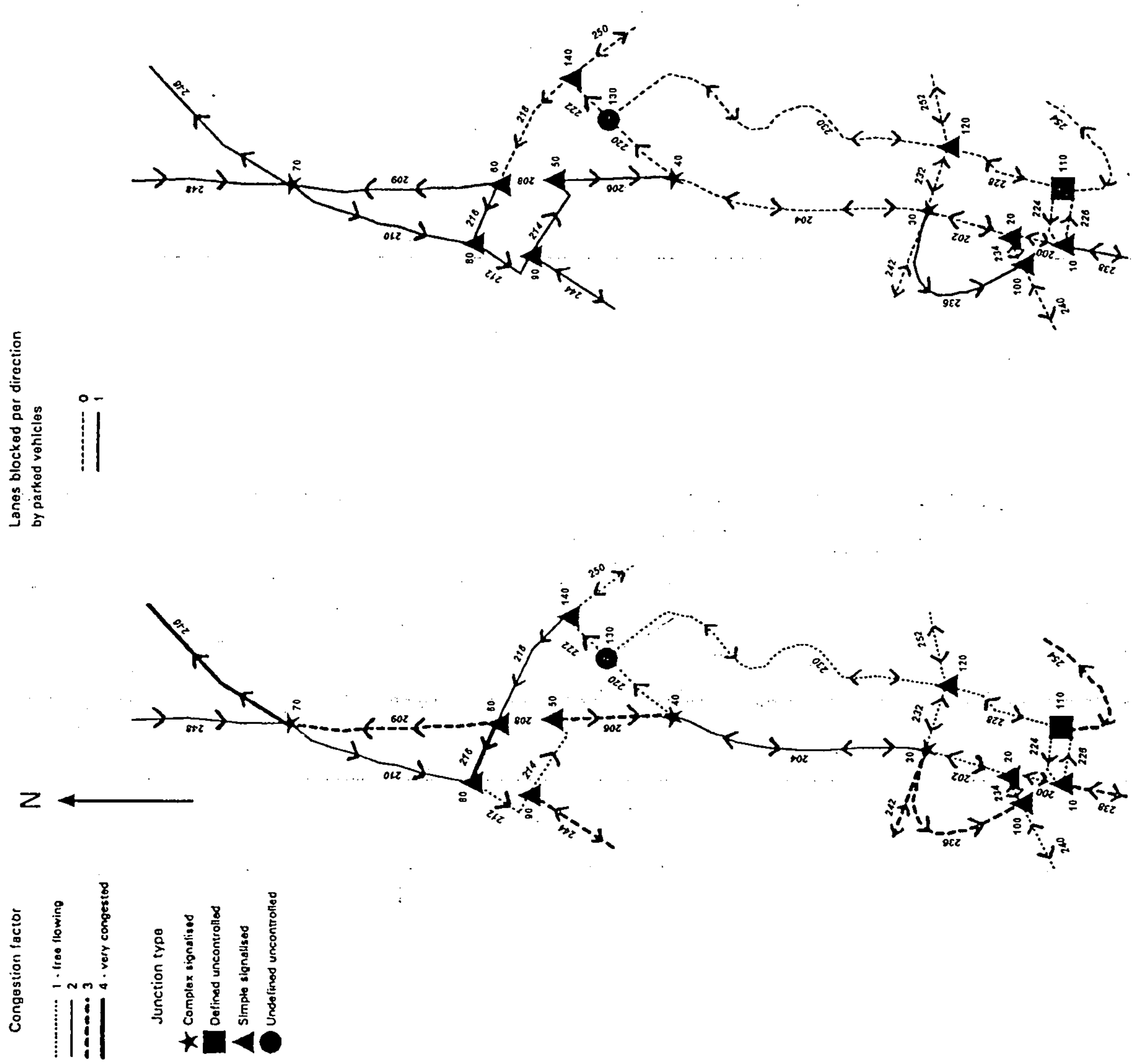

Figure 1: Some general traffic characteristics and road layout features of the Taksim-Şişli Busway Corridor, Central Istanbul

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