TRANSPLAN V2: A REGIONAL TRAFFIC ESTIMATION MODEL

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ABSTRACT

Traffic estimation is necessary in order to understand future scenarios of transport demand. Most regional traffic models that are presently available are those that have been calibrated in developed countries. They are not suitable for use in third world countries due to a number of limitations in transferability.

The TransPlan V2 model is a regional traffic model calibrated using data from the Colombo Metropolitan Region. It is based on two sets of data and a set of transport demand models. The data sets, which cover the socioeconomic, and road network data are simplified and can be collected without much difficulty. The estimation algorithms in the model maybe used, depending on the forecasting requirements and the availability of data. The model provides flexibility to specify different algorithms if the data requirement for the default model is not available. Its GIS interface provides a valuable tool in presenting model outputs.

INTRODUCTION

In modern physical land use planning, geographically and economically integrated regions are increasingly used as the unit of planning. In Sri Lanka too, the Southern Development Area (JICA, 1996) and the Colombo Metropolitan Region (Urban Development Authority, 1998) are two of the most recent examples, wherein regional land use planning has been undertaken.

Regional planning is concerned with the allocation of resources of a region. In particular, it focuses on physical, social, economic and environmental features of a region, with a view to allocating land among different uses in order to achieve an economically progressive, socially equitable and environmental sustainable region.

A planning region maybe defined as an area that has a high degree of functional interdependence between activities, and together form a cohesive unit. Such an area may also relate to administrative boundaries for the purpose of jurisdiction and investment planning. The Southern Development Area, which covers all of the Southern Province and small parts of Sabaragamuwa and Uva Provinces and the Colombo Metropolitan Region (CMR) which coincides with the Western Province are two such examples. The Greater Mekong Region (ADB, 1998) is an example of a much larger land area which is defined on the same basis, but includes several different countries.

A region would then include diverse land use activities distributed across its physical area. These include commercial centers, residential areas, industrial zones, agricultural areas, forests, wetlands, water bodies and other environmentally sensitive areas.

Transport is an important functional aspect that determines the potential for different land use activities within a region to be effectively linked together. Together with other infrastructure facilities, the features of access and mobility that a transport network provides leads to the efficient and productive interaction between the different land uses within the region, in order to achieve the multiple objectives of economic, social and environmental balance.

The overall transport function of a region would be defined by one or more transport networks such as roads, railways, waterways etc. In most instances, and particularly when the region is geographically smaller, such as the case in Sri Lanka, the road network predominates over others. A road network is composed of a set of nodes and links representing intersections and sections of important roads within a region. A regional traffic model would relate the traffic carrying potential of such a network to the demand for road traffic in the region.

Land use–transport models were first developed by Lowry (1964). These have since then been developed into commercial planning tools in the form of computer packages such as TRIPS (MVA, 1993), EMME2 (Florian et al, 1994), TransCAD (BCC, 1998) etc. Most of these are regional traffic models, wherein only the road network is considered.

The need for another regional traffic model stems from the absence of such a package specifically calibrated to suit the conditions of third world countries. These conditions vary with respect to developed countries in the areas of:

(i) Differences in vehicle categories, which in typically third world countries would include several distinct types such as motor cycles, cars, utility vehicles, three wheelers, vans and many other forms particular to each country;

(ii) The nature of mobility on the roads which in most cases have different forms of intense roadside development and activity with little or no control.

MODEL STRUCTURE

A traffic model is formulated to incorporate the relationships of regional interaction as shown in Figure 1.

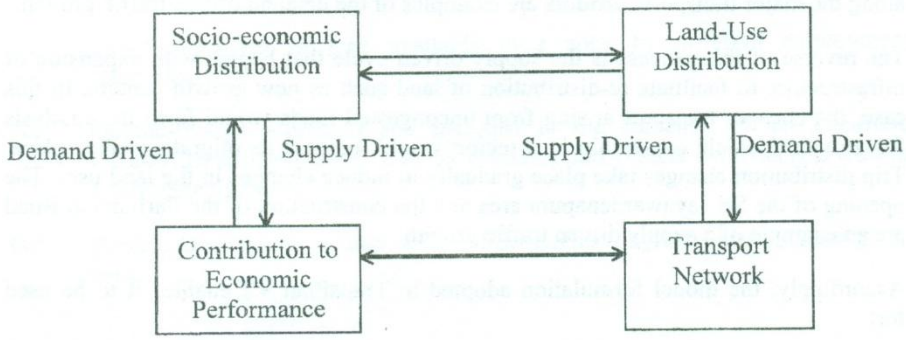

Figure 1: Structure of a Regional Traffic Model

In this structure, land use is identified as trip generating and trip attracting land uses. The former refers to mostly residential land use and the latter to locations of employment, industries, schools and other locations to which heavy traffic volumes are attracted. The distribution of the vehicle stock determines the traffic potential in the region. For example, a high level of private vehicle ownership will translate to high traffic levels within a region. These features should be adequately represented in a socioeconomic database for the region.

The road network has two distinct but inter-related features that determine the distribution of these trips between traffic generators and attractors. On the one hand, it has a transport supply feature that is represented by capacity, frequency and speed. On the other hand, it has a cost feature that is represented by vehicle operating costs, fares and tolls. These features should be represented in a road network database.

The traffic model is based on the hypothesis that there exists a relationship between land use distribution, vehicle stock and transport costs which would determine the intensity of traffic generation and its distribution.

This relationship is shown in Figure 1 to begin with the socioeconomic and land use distribution of the region. Any changes in income and land uses in a region are generally translated to changes in mobility and vehicle ownership. The nature of the transport network determines the available supply of transport capacity. Where transport capacity is less than the demand, congestion occurs and the cost of travel increase. Therefore, travel distances tend to be shorter. If transport supply is greater than the demand and if taxes and tolls affecting vehicle operation are also low, travel distances would increase. The efficiency of the overall transport network eventually contributes to the productivity of the region and its economic growth. These would in turn have a bearing on the socioeconomic conditions of its people and the further development of land use, thus continuing the cycle of demand-driven traffic growth. For example, with inexpensive transport, the commuting distances between residential areas and employment areas would increase. This would lead to the re-distribution of land to complete the demand driven cycle. In the CMR, the urban sprawl extending along the major transport corridors are examples of the demand driven traffic growth.

The reverse of this process is the supply driven cycle that begins with expansion of infrastructure to facilitate re-distribution of land such as new growth centers. In this case, the cheaper transport arising from uncongested roads would form the catalysis for growth. Vehicle ownership in a region would increase as migration takes place. Trip distribution changes take place gradually to induce changes in the land use. The opening of the Sri Jayawardenapura area and the construction of the Parliament Road are an example of a supply driven traffic growth.

Accordingly, the model formulation adopted in TransPlan V2 enables it to be used for:

(i) Estimation of increases in demand for traffic when land use developments are proposed

(ii) Assessment of impending long-term changes to land use when transport networks are changed.

A CASE STUDY: THE COLOMBO METROPOLITAN REGION

The TransPlan V2 is a regional traffic model calibrated with data from the Colombo Metropolitan Region (CMR) that covers the Western Province of Sri Lanka. This model can be used for any given region, provided that data pertaining to the region is available.

MODEL DATABASES

There are two databases used by this traffic model. These are referred to as the socioeconomic and road network databases respectively.

Socioeconomic Database

The socioeconomic database includes the following which is described in detail by Wijeratne, (1999).

(i) Zoning -the zoning of the land area of the region into smaller sub regions or zones. In the case of the CMR, the 33 Divisional Secretariat Divisions are considered as zones.

(ii) Population- the resident population forms the basic socioeconomic variable for each zone.

(iii) Households-the number of households in each zone, though correlated to the population is an important attribute when considering vehicle ownership rates.

(iv) Jobs-the number of jobs available in a zone by different employment categories.

(v) Income-though identified and included in the database, as an important variable. In the Case Study it is not available and vehicle ownership is used as a surrogate variable.

(vi) Vehicle Ownership-the total vehicle fleet licensed by category within a given zone.

Road Network Database

The road network database includes the following and is described in detail by Bandara et al, (1998).

(i) Nodes-all intersections of A and B class roads within the region and other important intersections have been coded.

(ii) Links-all sections of roads falling between two adjoining nodes have been coded and included.

(iii) Geometry of Links-A number of physical properties pertaining to each link, such as link length, road width..........etc.

MODEL ALGORITHMS

A set of algorithms has to be used in a regional traffic model. In TransPlan V2, the algorithms are based on the following three-way classification.

- By trip type
- By trip purpose
- By vehicle type

Trip Types

A regional traffic model requires identifying at least four different trip types. They generally refer to the two ends of a given trip. This is illustrated in Figure 2. They are:

(i) Intra-zonal trips: -Trips that have both ends within the same zone.

(ii) Inter-zonal trips: -Trips that have the two ends in two different zones within the region.

(iii) External trips: Trips that have one end within the region and the other end outside the region.

(iv) Outside trips: Trips that have both trip ends outside the region, but are found to use the road network within the region.

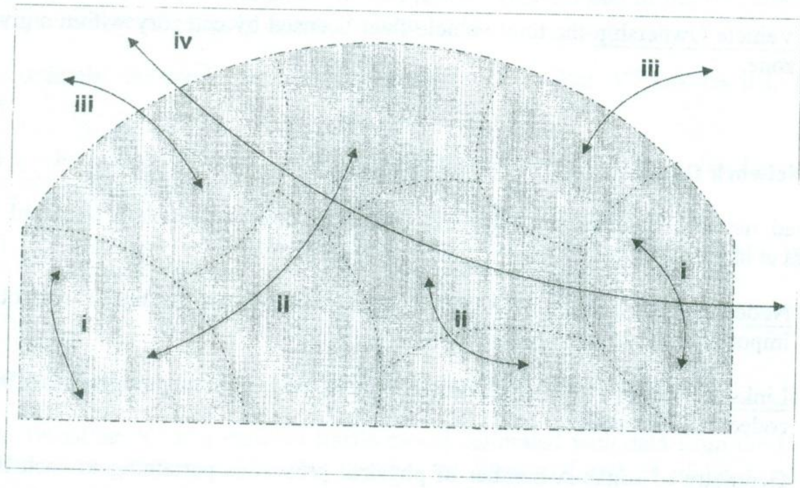

Figure 2: Trip types in a Region

Trip Purposes

Trips in a region can also be categorized according to purpose. The usual practice in transport planning is to separate them by home-based trips and non-home based trips.

The former may be further sub-divided to work trips and other trips. Thus the following trip purpose classification is adopted in the regional model.

- Home-Based Work Trips (HBWT)
- Home-Based Other Trips (HBOT)
- Non Home-Based Trips (NHBT)

Vehicle Types

The TransPlan Model identifies any given set of vehicle types. In the case of the CMR, this comprises of four primary categories given as:

- Private Vehicles
- Para-Transit Vehicles (Three Wheelers, School Vans, Taxis)
- Public Transport Vehicles (Buses)
- Freight Vehicles

The secondary classification is by operational classification. Motor cycles and vans would form sub categories under private vehicles, while delivery vans, small trucks, multi-axle trucks would form sub categories under freight vehicles.

MODEL VALIDATION

Thus, in TransPlan V2, a separate estimate could be made for each combination of the above categories and sub-categories. For example, an estimate could be made for inter-zonal home-based work trips by motor cycle. A set of algorithms is then required if indeed separate estimates are to be made.

In the case of the application of TransPlan V2 in Case Study, it has been limited to the three combinations as given below for estimating trips from any zone i to any other zone j:

- Home-Based Inter-Regional Work Trips by all Private Vehicles ($HBWT_{ij}$)
- Home-Based Inter-Regional Other Trips by all Private Vehicles ($HBOT_{ij}$)
- Non-Home Based Inter-Regional Trips by all Private Vehicles ($NHBT_{ij}$)

The calibration of these three models using survey data is documented in Kumarage and Wijeratne (1998) and Wijeratne (1999). These are expanded gravity type direct demand models with the following input variables:

- Population – as the basic socioeconomic parameter.
- Household – as a measure of trends in urbanization, where household sizes are decreasing in the long term.
- Vehicle Ownership – as a surrogate variable for income, which was not available in the application context.
- Jobs – by category as per State, Semi- Government, Public, Industrial and Agricultural.
- Travel Time – free flow travel speed between zones
- Distance – Minimum travel distance between zones

The three models calibrated in the Case Study and the calibration results are as follows;

$$HBWT_{ij} = \frac{7.03*10^{-3}*POP_i^{0.46}*JOB_j^{0.78}*Exp(1.37*TPV_{ij})}{Time_{ij}^{0.52}*Dis_{ij}^{0.98}} - 10 \quad \text{..............(1)}$$

$$HBOT_{ij} = \frac{2.03*POP_i^{0.27}*POP_j^{0.27}*JOB_j^{0.32}*Exp(1.69*TPV_{ij})}{Time_{ij}^{0.35}*Dis_{ij}^{1.46}} - 10 \quad \text{.........(2)}$$

$$NHBT_{ij} = \frac{5.05*10^{-2}*POP_i^{0.74}*JOB_j^{0.57}*Exp(1.08*TPV_{ij})}{Time_{ij}^{0.94}*Dis_{ij}^{1.26}} - 10 \quad \text{.........(3)}$$

Where

POP_i	-	Population in i^{th} zone
JOB_j	-	Jobs (State sector, Semi Government, Public Sector, Industrial and private sector) in j^{th} zone
TPV_{ij}	-	Product of total private vehicle ownership rates per household in i^{th} and j^{th} zones
$Time_{ij}$	-	Travel time between i and j DSD
Dis_{ij}	-	Minimum distance between i and j DSD

Table 1: Calibration results

Equation	R^2	F-Statistics	F-Significance
HBWT	0.90494	2010.0	0
HBOT	0.85156	1009.72	0
NHBT	0.84765	1175.01	0

Equation	T-significance of independent variables						
	Constant	POP_i	POP_j	JOB_j	TPV_{ij}	DIS_{ij}	$Time_{ij}$
HBWT	0	0	-	0	0	0	0
HBOT	0.5704	0	0.0581	0.0001	0	0	0.0002
NHBT	0.0013	0	0	0	0	0	0

TRIP ASSIGNMENT

The TransPlan model can accept any given specification as a criterion for assigning trips between two zones on the road network. In the Case Study, the criterion is given as the path, among all possible paths, having the minimum distance between each of the nodes of the origin zone and each of the nodes of the destination zone in a given zonal origin-destination pair. A separate algorithm is used to determine the minimum distance paths between any rode pair based on the information available in the road network database. The trips are distributed on the basis of the relative weights assigned to nodes in each zone. For example, to estimate trips between two zones, each of which have three nodes, each of which has equal weight, then the total trips between the two zones would be assigned to the minimum paths between each of the nine nodal pairs on an equal basis.

This is a compromise between the all or nothing assignment technique, which is simpler to apply but results in many links not being assigned any traffic at all, and the multi-path assignment technique, which is more accurate but complex to apply.

In the Case Study, the three models collectively estimate the total inter-zonal private vehicle traffic between any two zones within the region. The links and routes through which this traffic will find its way is then determined by taking the minimum path between the two zones.

MODEL ESTIMATION

A regional traffic model can be used for a number of planning applications. It has three estimation approaches representing three planning/management scenarios. Each of these enables the estimation of impacts on the traffic conditions on the existing or proposed road network when:

(i) An anticipated land use development takes place within the region, in the form of demand driven growth.

(ii) Planned road network improvements takes place within the region, in the form of either new links or improvements to existing links.

(iii) Changes takes place to the cost of traffic in the form of either changes to the cost of vehicle operation (e.g. increase in fuel costs) or the introduction of tolls or other forms of external costs and controls.

MODEL OUTPUT

The output of the model is directed at obtaining a set of performance indicators of the road network. These indicators can be used for a number of different analytical assessments to determine the economic and even environmental impacts of the network under different scenarios tested by the model.

The TransPlan V2 improves this potential even further by incorporating a Geographic Information System (GIS) interface for the display of such results. Some of the outputs of this model are discussed as follows.

Network Free Flow Speed

The free flow speed on the road network within the region can be estimated for each link based-as link geometry information and shown on a color-coded GIS display (Figure 3). This helps to identify where the high mobility routes exist and where speeds are low.

Network Capacity

The capacity in terms of vehicles per hour or vehicles per day for each link within the regional road network can be estimated and shown on a color-coded GIS display. This helps to identify where capacity constraints exist.

Assigned Network Speeds

The network speed for a given planning scenario can be estimated by assigning the forecast traffic between zones and thereby using the speed flow relationships to estimate the speeds on each of the links in the network. This helps to identify where traffic bottlenecks that would occur under the different scenarios. Observed and estimated traffic flows, travel time and speed for some selected road link are given in Table 1;

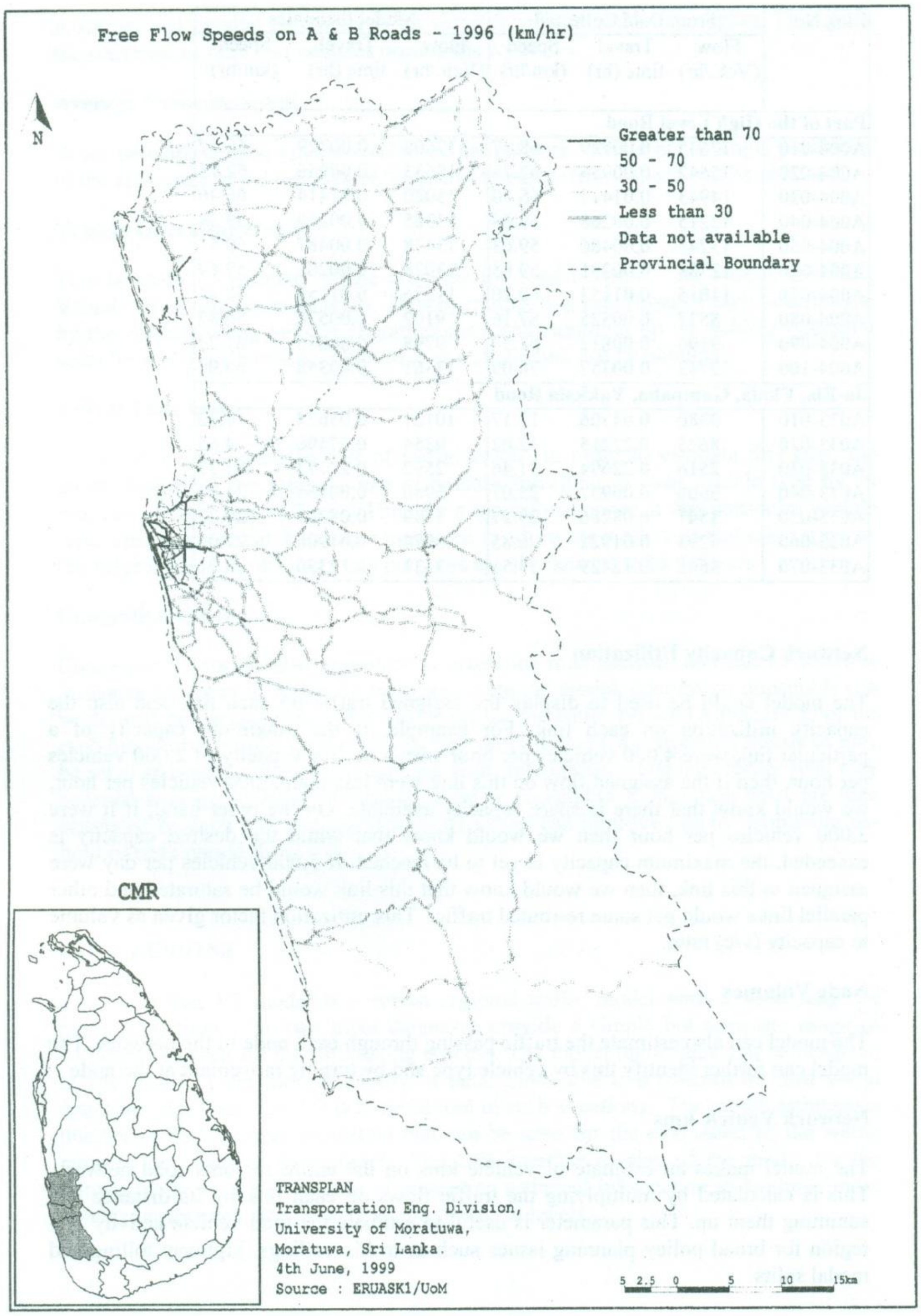
Free Flow Speeds on A & B Roads - 1996 (km/hr)
N
Greater than 70
50 - 70
30 - 50
Less than 30
Data not available
Provincial Boundary
CMR
TRANSPLAN
Transportation Eng. Division,
University of Moratuwa,
Moratuwa, Sri Lanka.
4th June, 1999
Source : ERUASK1/UoM
5 2.5 0 5 10 15km

Table 2: Comparison of model estimates

Link No	From Data Collected			Model Estimates		
	Flow (Veh./hr)	Travel time (hr)	Speed (km/hr)	Flow (Veh./hr)	Travel time (hr)	Speed (km/hr)
Part of the High Level Road						
A004-010	17645	0.00729	68.57	17605	0.00729	68.57
A004-020	15642	0.00956	62.75	15633	0.00956	62.73
A004-030	14943	0.01414	66.50	15020	0.01414	66.46
A004-040	13215	0.00268	59.64	13385	0.00269	59.54
A004-050	13245	0.00486	59.63	13438	0.00487	59.51
A004-060	12788	0.00201	59.85	13078	0.00201	59.69
A004-070	11015	0.01153	60.70	11536	0.01158	60.44
A004-080	8537	0.00525	57.16	9102	0.00528	56.82
A004-090	9190	0.00812	61.54	9798	0.00816	61.27
A004-100	12743	0.00357	70.09	13361	0.00358	69.90
Ja-Ela, Ekala, Gampaha, Yakkala Road						
A033-010	9380	0.04306	12.17	10121	0.05624	9.32
A033-020	8625	0.22215	12.02	9354	0.57396	4.65
A033-030	2516	0.22694	31.46	2592	0.22773	31.35
A033-040	5606	0.00937	25.07	5980	0.00965	24.34
A033-050	3547	0.08286	29.21	3539	0.08283	29.22
A033-060	5293	0.01922	26.85	5074	0.01906	27.07
A033-070	3645	0.12429	33.51	3431	0.12356	33.71

Network Capacity Utilization

The model could be used to display the assigned traffic on each link and also the capacity utilization on each link. For example, if the maximum capacity of a particular link were 4,000 vehicles per hour with a desired capacity of 2,000 vehicles per hour, then if the assigned flow on this link were less than 2,000 vehicles per hour, we would know that there is spare capacity available. On the other hand, if it were 3,000 vehicles per hour then we would know that while the desired capacity is exceeded, the maximum capacity is yet to be reached. If 5,000 vehicles per day were assigned to this link, then we would know that this link would be saturated and other parallel links would get some re-routed traffic. This utilization factor given as volume to capacity (v/c) ratio.

Node Volumes

The model can also estimate the traffic passing through each node in the network. The model can further identify this by vehicle type and by turning movement at the node.

Network Vehicle kms

The model makes an estimate of vehicle kms on the entire regional road network. This is calculated by multiplying the traffic flows on each link by its distance and summing them up. This parameter is useful to estimate the total vehicle activity in a region for broad policy planning issues such as traffic ceilings, highway tolling and modal splits.

Network Vehicle hrs

A similar and parallel parameter is the network vehicle hours of a region. This gives the sum total of time that vehicles occupy the road.

Average Network Speed

When network vehicle kms is divided by the network vehicle hrs, a single parameter of the efficiency of the network in terms of average network speed can be obtained.

Vehicle Operating Costs

This is useful to estimate traffic costs on the road network. As speeds decrease, Vehicle Operating Costs increase. Thus by multiplying link flows of each vehicle type by the corresponding vehicle operating costs and summing up the vehicle operating costs for the entire network, a part of it or a single link can be obtained.

Travel Time Costs

Travel time costs are also part of traffic costs. In order to estimate this cost, the model multiplies the total number of persons travelling in each vehicle type by an estimate of the Value of Travel Time for a typical passenger in that particular vehicle type. This estimate can be further improved to adjust for work trips and other trips, as the value of time for different trip purposes are also known to be different.

Congestion Costs

Congestion Costs are also important to determine road network and other corrective measures and rates of return on investments. In the model, congestion thresholds can be defined as a preset level. This can be set for the entire system (Appendix 1) or for each link. For example, for a four-lane high mobility road, a congestion threshold may be set at an average speed of 40 kms per hour. In contrast, a two lane feeder road may consider average speed of 20 kms or more as acceptable. Congestion costs are then estimated by each link and added up. The model can improve this by estimating per hour or peak period flow.

CONCLUSIONS

The TransPlan V2 model is a robust regional traffic model with a wide range of planning outputs. The two input databases provide a simple but adequate range of variables required for the forecasting process. The model algorithms can be designed to specifically meet the availability of data. Since this is a concern in third world countries, the TransPlan V2 is a useful tool in such situations. The model estimates a number of performance indicators that can be used for the evaluation of the whole network or a part of the network. The GIS interface display of the model for the outputs gives it a superior level of presenting technical information to facilitate more knowledgeable decision making at non-technical levels.

ACKNOWLEDGEMENTS

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Appendix 1 : Estimation of Congestion Costs in CMR by TransPlan V2

Box 1: Congestion Costs in CMR

1. Estimate of Vehicle hours for the CMR (Without trips made exclusively within in CMC Limits for 1996) = 332,953 vehicle hrs per day (TransPlan V.2)
2. Estimated of vehicle km for the CMR without trips made exclusively in CMC limits for 1996 = 7,519,657 vehicle kms per day (TransPlan V.2)
3. Estimated speed of the network = 22.58 km/hr.
4. Thus if desired speed is set at 30 km/hr, then the vehicle hours = 250,655 vehicle hrs. per day
5. Therefore the lost vehicle hours due to congestion = 82,299 vehicle hrs. per day
6. Furthermore, if traffic

- Number of days for the year is assumed as 300
- V1 – Congested speed 22.58 km/hr. (TransPlan V.2)
- V2 – Desired speed 30 km/hr.
- C1 – Cost for van (average vehicle) at speed of V1 = 11.82 Rs./Veh km (Halcrow Fox , 1996)
- C2 – Cost for van, at congested speed of V2 = 9.8 Rs./Veh km (Halcrow Fox, 1996)
- VOT – Value of Time for hypothetical average vehicle = 135.50 Rs./Veh hr (Kumarage, 1996)

Vehicle Operating Cost (VOC) per Annum

VOC = Veh km × (C1 - C2) × 300
= 7,519,666 × (11.82 – 9.8) × 300
= Rs. 4,556,911 per annum
= **Rs. 4.6 bn per annum**

Value of Time (VOT) per Annum

VOT = Veh. km × (1/V2 – 1/V1) × VOT × 300
= 7,519,657 × (1/22.58 – 1/30) × 135.40 × 300
= Rs. 3,345,774,339
= **Rs. 3.3 bn per annum**

9. Total Cost (without trips made exclusively within CMC) 1996 = Rs. 7.9 bn per annum
10. Adjustment for trips made exclusively within CMC + Rs. 1.2 bn per annum
11. After Adjustment; all trips within CMR for 1999 = Rs. 11.5 bn per annum