TRANSPORT MODELLING IN ASIAN DEVELOPING COUNTRIES

Dr Karl-L. Bang
President
Transport Research & Eng. Ltd (TRE)
Jl Sukabumi 3,
Bandung 40271 Indonesia
Fax +62-22-708421
email bang@server.indo.net.id

Mr Robert M. McLean
Technical Director
TRE Ltd
Jl Sukabumi 3,
Bandung 40271 Indonesia
Fax +62-22-708421
email tre@server.indo.net.id

abstract: The fast growing traffic demand in many developing Asian countries has lead to an increasing need for planning methods capable of evaluating the effects of road network expansion schemes. Conventional methods to obtain O-D trip information from home or roadside interviews tend to be too costly, and rapid land use shorten the 'shelf life' of data. A low-cost method was therefore developed based on a first estimate trip matrix obtained using standardised trip parameters, which was updated with maximum entropy estimation from traffic flow count data. Assignment of road traffic to links in a network is normally based upon the travel time estimates using speed-flow-capacity relations for links only. For the purpose of detailed planning in urban environment development of better methods including intersection delay based on local driver behaviour and traffic characteristics is needed.

1. INTRODUCTION

The fast growing traffic demand in many developing Asian countries has lead to an increasing demand for transport planning, since the capacity expansion needs can no longer simply be satisfied by widening of the roads. The road networks now need to be expanded with new links and improved public transport services. Evaluation of transport schemes where there is a choice between different routes and modes of transport must include all network elements whose traffic demand and performance may be affected by the proposed change. Such analysis requires development of origin-destination (O-D) trip matrixes and traffic assignment modelling with capacity restraint such as is available in international, licensed software products. However, in order to apply such methods successfully in developing countries they have to be calibrated or modified to represent actual conditions regarding travel and traffic characteristics such as trip rates, modal split, route choice and traffic performance as a function of road design and other site conditions. A study of these issues was undertaken for Directorate General of Highways in Indonesia (Bang et al 1997). The study primarily focused on two issues:

1) Low-cost methods and software for development of Origin-Destination trip matrix data from different types of information (e.g. traffic flow counts, roadside interviews, household interviews).

2) Traffic assignment with capacity restraint using traffic performance software developed within the Indonesian Highway Capacity Manual project (IHCM) (Bang et al 1997).

A broad overview of the needs in Indonesia for transportation models and network analysis software was obtained through interviews with government agencies and consultants engaged in physical planning and transportation development on different levels. Reports from 27 previous transportation planning projects were also reviewed.

The inventory showed that comprehensive transport planning and modelling is commissioned primarily by central government agencies (Bappenas, Ministry of Communications, Ministry of Public Works) and carried out by consultants and a number of universities acting as consultants. In the last few years most studies have been performed by local firms without support from an international partner.

A variety of data sources, methods and software were used, with TRANPLAN and MOTORS dominating as software tools. Only a few applications had been made with software for planning of urban street networks with detailed modelling of intersection performance, e.g. SATURN, although a growing need for such studies was reported. All studies involve traffic flow counts, and roadside interviews are also common. Detailed studies of trip generation and attraction such as home interviews were comparatively rare. Data tended not to be kept in an organised way for use on subsequent or related studies.

The O-D trip matrix data was normally obtained from basic land use and population data for each zone, and pre-knowledge of typical trip generation and attraction rates. Estimation of the O-D matrix from traffic flow counts using maximum entropy techniques was also common. The choice of transport mode was usually analysed based on simple vehicle composition (%) and diversion curve models , e.g. non-motorised, public transport and motorcycle modes related to trip purposes, income group and trip length for different modes of travel.

Traffic assignment was normally performed as all-or-nothing or equilibrium assignment with capacity restraint, usually with default speed-flow models for links available in the commercial software. In a few cases attempts had been made to calibrate the models using traffic performance and capacity data from IHCM. Attempts to calibrate the willingness to pay toll charges were also made, in spite of the difficulties due to the different scales of economics between developing countries in Asia and the countries from which the transport models originate.

The conclusion from this review was that the explosive increase in transport demand in Indonesia will require improved and integrated transport planning in the future. The Indonesian government (GoI) should therefore take an active lead in the development and dissemination of standardised procedures and guidelines for transport network analysis, which would provide an invaluable means to promote, unify and advance progress on all these crucial issues. The Directorate General of Highways should also consider to establish a "Transport Modelling Unit" responsible for development and dissemination of transport planning methodologies on interurban, urban and municipal levels.

2. DEVELOPMENT OF O-D TRIP MATRICES

Conventional methods for collecting O-D information from home or roadside interviews tend to be costly, labour intensive and time disruptive to the trip makers. The problem is even more acute in developing countries like Indonesia, where rapid changes in land use and population shorten the 'shelf life' of data. The need for developing low-cost methods to estimate the present and future O-D matrices is apparent.

The use of traffic count data has received considerable attention in recent years, as traffic counts represent assigned traffic volumes resulting from the combination of a trip matrix and a route choice pattern. As such, they provide direct information about the sum of all O-D pairs which use the counted links. Traffic counts are very attractive as a data source because they are :

- non-disruptive to travellers;
- generally available;.
- relatively inexpensive to collect;
- automatic collection is well advanced.

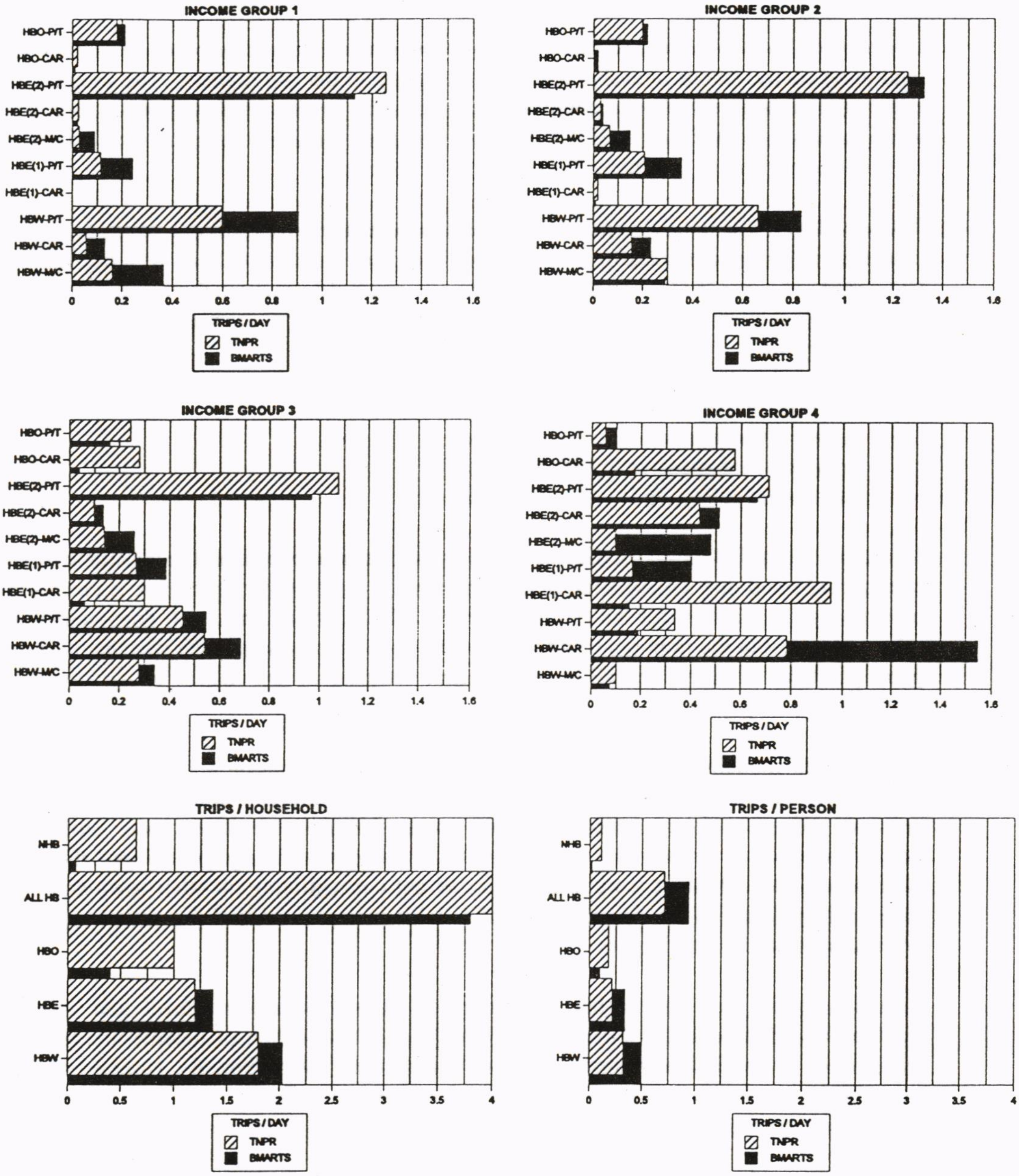
Investigations in Indonesia on the use of the matrix estimation method using traffic flow counts confirmed that a reasonable first approximation to the O-D trip matrix is crucial to obtaining good accuracy for the estimated matrix. This conclusion is well documented in other research, but the important finding from the work done in Indonesia was that there is good potential to create the all important first estimate of the matrix using low cost methods.

A simplified modelling method using standardised trip generation and trip distribution parameters was proposed to replace the expensive and time consuming O-D surveys. Analysis of data from different urban areas showed that there was sufficient correspondence to support the development of standardised trip generation and trip distribution rates. Further work will be carried out concentrating on other town and city types and sizes and on the determination of suitable measures of land use activity and the derivation of attraction trip rates.

Trip generation rates are highly dependent on household income level and vehicle availability. Consequently some form of simplified classification of income and vehicle availability is needed and analysis showed that there were broadly similar vehicle availability distributions within different income groups and so only the number of households by income group are needed for each traffic zone under consideration.

Four income groups (low, low middle, upper middle and high) were chosen and, as zonal income data would not be available or appropriate for the matrix estimation method, a way of allocating households to income group was developed. House type was found to correlate well with household income level, and zonal assessments could be made systematically from records or survey of the numbers of different house types or by more subjective methods involving local knowledge, maps and photographs.

Trip rates from Jakarta and Bandung data, see Figure 1, showed that for many of the mode/purpose and income group combinations there is a reasonable correspondence.



Key :

HBW - Trips/day/employed adult
HBE(1) - Trips/day/schoolchild
HBE(2) - Trips/day/student
HBO - Trips/day/unemployed person

HBW = Home Based Work trip; HBE = Home Based Education Trip; HBO = Home based Other trip
TNPR = Jakarta data; BMARTS = Bandung data

Figure 1: Comparison of trip rates from studies in Jakarta (9 M) and Bandung (3 M)

The high and low income groups exhibit some large differences particularly by mode of transport. However overall trip rates by purpose demonstrate good correspondence and it was concluded that standardised trip generation rates could be developed bearing in mind that the first estimate of the matrix is only required to be approximate.

A similar comparison between trip distribution functions was made for Jakarta and Bandung data. The deterrence functions calibrated for Jakarta and Bandung were applied to Bandung trip end data and the resulting trip length distributions compared, see Figure 2. All public transport distributions showed very close agreement. For private transport the Jakarta distribution was between or close to the Bandung car and motorcycle distributions for home based work and other purposes. The home based education trip distributions did not compare so well although it was thought that the Jakarta private transport distribution was anomalous.

It was concluded that estimating O-D trip matrices through analysis of traffic count data is a very practical method which should be further developed and documented in the form of guidelines for dissemination to government and private traffic engineers and planners. The standardisation of trip generation and trip distribution parameters enables simplified modelling to be used to produce the all important first estimate of the O-D trip matrix, and the development of a software module for this purpose will make the method easy and straightforward to use. Alternatively such an estimate can be obtained from new O-D surveys or from previous trip matrices produced by other models as shown in Figure 3. The traffic counts on selected links are used to revise the first estimate of the O-D matrices using an matrix estimation programme (e.g. through maximum entrophy estimates ME-2). The proposed method shown in Figure 3 is compatible with commercially available transport planning and matrix estimation software and can be linked with the traffic assignment module to be developed for Indonesian conditions.

3. TRAFFIC ASSIGNMENT WITH CONSIDERATION TO INDONESIAN TRAFFIC CHARACTERISTICS

3.1 Introduction

Traffic assignment to the road network is the fourth and last step in the traditional four stage transport planning process. Assignment of traffic to links in a network is normally based upon the time and cost (generalised or real) to get from the origin to the destination via various possible routes/paths. Very simple assignment algorithms disregard both speed-flow-capacity relations and oversaturation. Such simple methods are often sufficient for rough, long-range planning. Detailed planning requires better assignment methods which account for traffic flow characteristics and capacity restraint. Software for traffic assignment normally needs link data for length, free-flow speed, capacity and toll fees (if any). The junction data used in a more detailed assignment process are the total delays for different turning movements.

A review was undertaken of different possibilities to perform traffic assignment with consideration to Indonesian traffic characteristics as modelled in the Indonesian Highway Capacity Manual (IHCM) and its software package KAJI (Kapasitas Jalan Indonesia).

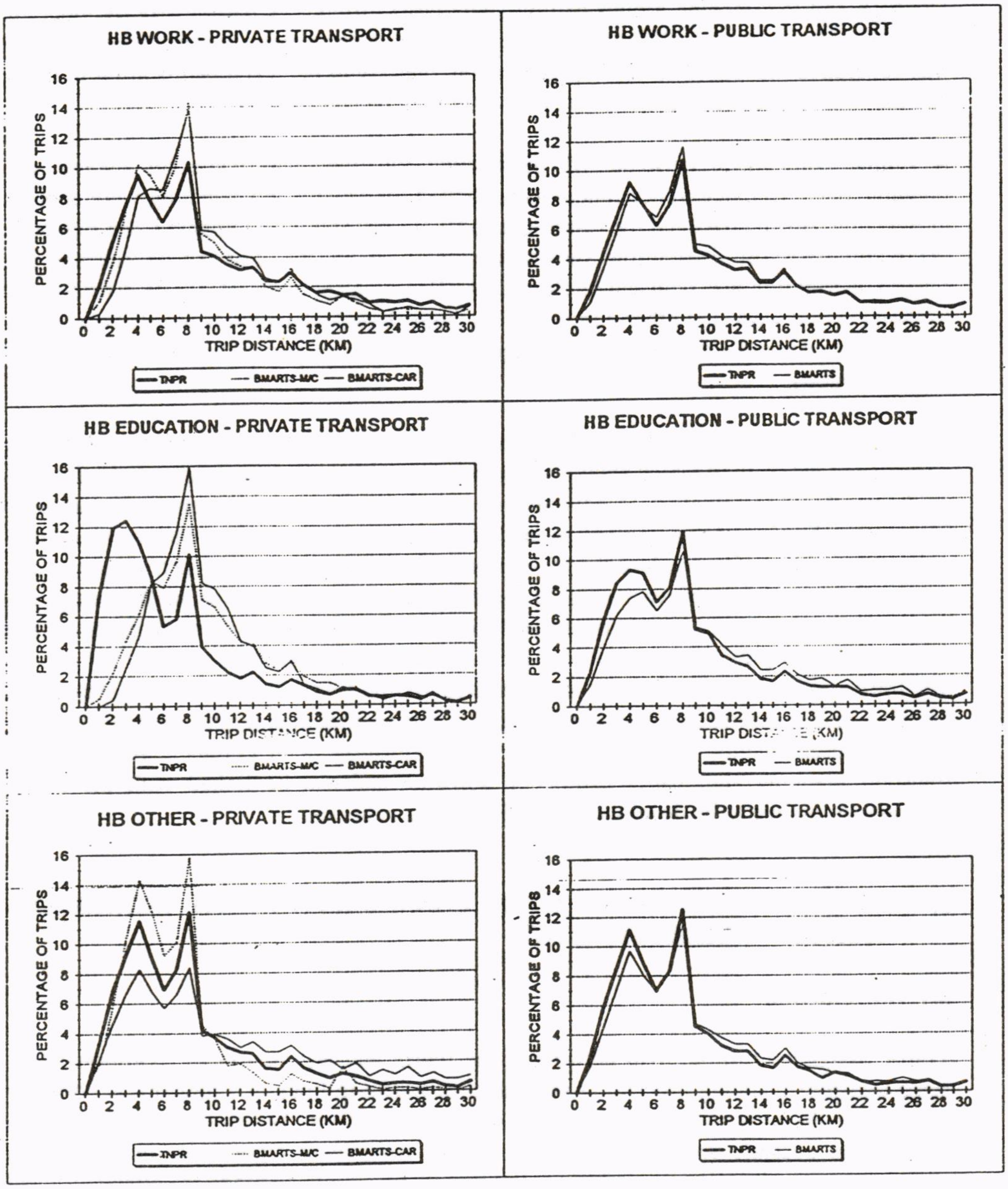


Figure 2: Comparison of trip length distributions from Jakarta and Bandung

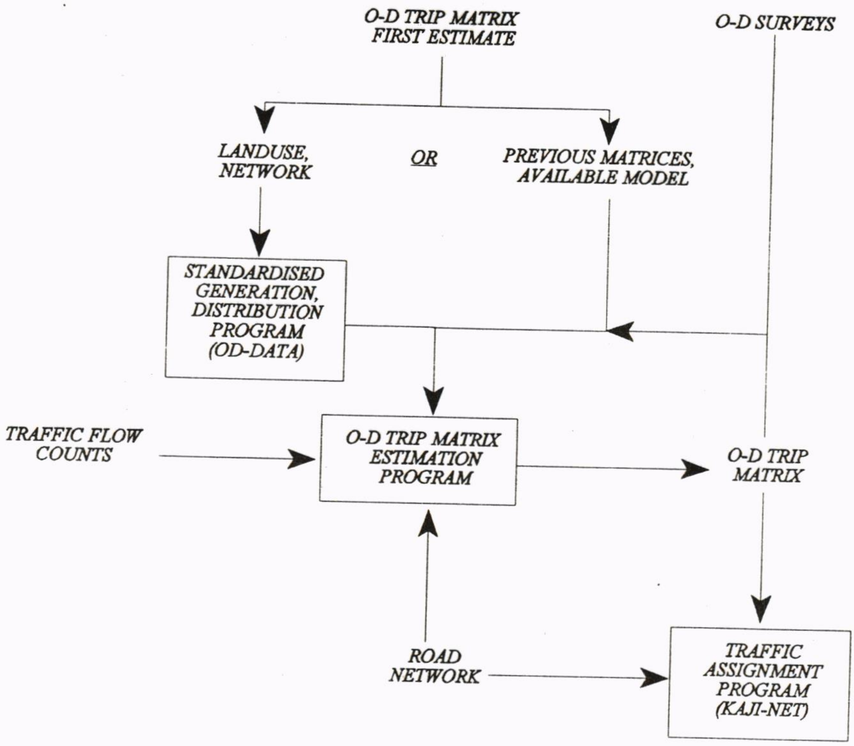


Figure 3: Overview of the recommended traffic modelling procedure

The main benefits would most likely be in short-term, detailed planning of urban street networks, where KAJI would give better estimates of consequences of improvements and traffic management schemes. Examples of such improvements are by-passes, circular roads, improvement of alternate roads etc. to alleviate city congestion or other measures like decrease of unmotorised traffic by offering separate facilities to such road users.

3.2 Review of software for traffic assignment

A number of commercially available software packages were tested in terms of traffic assignment modelling and calibration for Indonesian conditions. A preliminary prototype Indonesian assignment software without consideration to intersection delays was also made for testing. In order to learn more about the characteristics of this prototype, and ways to calibrate and operate selected commercial traffic assignment software products, a comparative test was undertaken on a "synthetic" network with an assumed O-D trip matrix, see Figure 4.

The following **speed-flow relationships** were used

1. The IHCM/KAJI Traffic Assignment Program (called KAJI-NET) and TRANPLAN used the speed-flow curves (converted into Speed/Free flow speed - Degree of saturation curves) according to the Indonesian Highway Capacity Manual.

2. SATURN has a different type of speed-flow curve which could not be exactly modelled to resemble the relationships used in IHCM/KAJI. SATURN uses the following equation:

   t = t0 + A * Q^n (1)

   where t travel time
   - t0 travel time under free-flow conditions
   - q traffic flow
   - n power to be estimated
   - A coeff. calculated by the program for Q=C and t=tc for a particular estimated power n

3. CORFLO uses the FHWA impedance function (or the modified Davidson's queuing function. The travel time on a path-link includes the time required to traverse the geometric link and the time required, at its downstream intersections, to perform the desired turning movement.

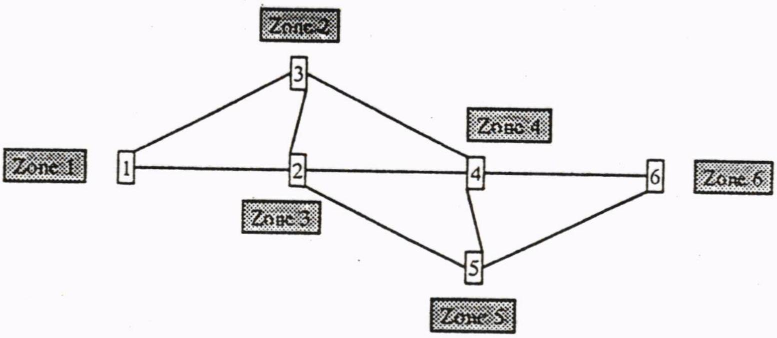
The FHWA formula is :

$$T = T_0 \times \left[1 + a \times \left(\frac{Q}{C} \right) b \right] \tag{2}$$

where T = mean travel time on the path-link,
T_0 = free flow (zero volume) travel time on the path-link,
Q = volume on the path-link,
C = capacity of the path-link,
a,b = parameters to be specified, default are as follows :
FHWA: a = 0.60, b = 4 (coded as 60 and 40)

4. MOTORS uses an impedance function similar to CORFLO.

A small network.



1) Assign the traffic between zones on the links in the network.

O/D matrix (pcu/h)

	to zone						
from zone	1	2	3	4	5	6	Σ
1	0	500	1000	1500	250	750	4000
2	150	0	300	350	50	250	1100
3	150	100	0	200	100	150	700
4	200	200	250	0	150	200	1000
5	100	50	700	750	0	150	1750
6	500	100	750	1000	250	0	2600
	1100	950	3000	3800	800	1500	11150

Link characteristics:
(all links 2-directional)

Link	Length(m)	Type	Width(m)	Cap(2-d)	FFV,LV
1-2	500	4/2D	2×6.76	2×3042pcu/h	54.9kph
2-4	500	4/2D	2×6.76	2×3042	54.9
4-6	500	4/2D	2×6.76	2×3042	54.9
1-3	700	4/2UD	2×6.46	5340	49.8
2-3	200	2/2UD	7.86	2989	44.7
3-4	700	4/2UD	2×6.46	5340	49.8
2-5	600	4/2D	2×6.13	2×2321	41.8
4-5	100	2/2UD	7.86	2989	44.7
5-6	600	4/2D	2×6.13	2×2321	41.8

Capacity and free-flow speed calculated using KAJI, Urban roads with no other input than road type and width, except links 2-5 and 5-6 (city size 0.3, very high side friction).

Node characteristics: 2 and 4: signal controlled
1, 3, 5 and 6: no control

Figure 4: Network and input assumptions for tests with assignment software

The results in terms of assigned traffic flows and resulting travel speeds in Table 1 show that the TRANPLAN and the IHCM/KAJI equilibrium assignments produced very similar results except for a few links. The resulting overall travel time spent in the network was also very similar (TRANPLAN: 207, IHCM/KAJI 209 veh.hours/hour). SATURN and the other programmes which could not be calibrated to closely represent the IHCM speed-flow relationships showed larger differences in assigned link flows and speeds. The result of the tests cannot be used to evaluate the different assignment programmes, this can only be done if real traffic data are available as explained above. The test however indicated the following:

- It was possible with a very limited effort to create a preliminary IHCM/KAJI traffic assignment prototype software (KAJI-NET) for road links without nodes which functioned properly compared to commercial software.

- TRANPLAN, which could be calibrated to closely resemble the IHCM speed flow relationships for the links in the test example, produced very similar results as the IHCM/KAJI prototype.

From this could be concluded that the need for a special Indonesian software for traffic assignment in interurban road networks is small if the transport planner is successful in calibrating the commercial model. For an urban network the assignment results would probably show larger differences because of the different levels of detail with which the delays at intersections can be treated. It would therefore primarily be in urban areas that KAJI-NET would be needed. None of the commercial models can be calibrated to represent Indonesian intersection traffic performance characteristics as modelled in the IHCM. The main problems in this context are as follows:

- The traffic composition, vehicle types and passenger car equivalents (passenger car equivalents (pce) developed for Indonesia are very different from western conditions. Indonesian cities typically have a 25-50 % motorcycle ratio and high rates of paratransit and un-motorised vehicles.

- The driver behaviour in crossing conflicts in roundabouts, unsignalized intersections and opposed approaches in signalised intersections which is entirely different, since no right-of-way rules are applied in Indonesia.

- The high degree of "side friction" slowing down the traffic in Indonesian cities, including pedestrians, unmotorized vehicles and stops by paratransit vehicles.

3.3 Methods to incorporate IHCM/KAJI in the assignment process

The methods for prediction of traffic performance developed in IHCM and implemented in the KAJI software are based on a large amount of survey data (285 sites) representing Indonesian traffic characteristics and driver behaviour. Use of this information would

Link#	Node From	Node To	Free Flow Speed km/h	Free Flow Time sec	Length m	CAP	LINK FLOWS						
							IHCM TRAFFIC ASSGMNT PROGRAM			TRANPLAN	SATURN	CORFLO	MOTORS
							INCR. LOADING (1)	SUCC. AVERAGE (2)	EQUI-LIBRIUM (3)	EQUI-LIBRIUM (4)	EQUI-LIBRIUM (5)	EQUI-LIBRIUM (6)	EQUI-LIBRIUM (7)
1	1	2	54.91	33	500	3042	3426	3306	3494	3497	3101	3350	2586
2	1	3	49.82	51	700	2670	576	694	506	503	899	650	1414
3	2	1	54.91	33	500	3042	1026	968	951	951	1048	950	950
4	2	3	44.71	16	200	1495	355	194	103	105	244	325	126
5	2	4	54.91	33	500	3042	2851	2577	2692	2600	2503	2185	2146
6	2	5	41.8	52	600	2321	71	194	254	348	74	1155	62
7	3	1	49.82	51	700	2670	76	133	149	149	52	150	150
8	3	2	44.71	16	200	1495	570	389	303	304	604	690	480
9	3	4	49.82	51	700	2670	684	828	656	652	929	560	1409
10	4	2	54.91	33	500	3042	2447	2184	2238	1706	2247	2320	2003
11	4	3	49.82	51	700	2670	246	312	349	348	293	275	349
12	4	5	44.71	8	100	1495	720	522	510	451	645	980	521
13	4	6	54.91	33	500	3042	1504	1501	1500	1500	1493	1230	1484
14	5	2	41.8	52	600	2321	160	356	263	796	208	555	516
15	5	4	44.71	8	100	1495	1593	1395	1487	954	1498	2260	1257
16	5	6	41.8	52	600	2321	0	0	0	0	51	270	16
17	6	4	54.91	33	500	3042	2589	2516	2564	2599	2548	2600	2344
18	6	5	41.8	52	600	2321	13	83	36	1	87	0	256

Notes: - IHCM Traffic Assignment Program is a Prototype/Preliminary Version written under Borland Pascal Language.
- Methods (1), (2), (3), (4) use the Speed-Flow (or V/Vf vs DS) relationships according to Indonesian Highway Capacity Manual.
- Method (5) use the best fit of "n" (t = to + A V^n, where: t=time, to=time under free-flow conditions, n=power to be estimated, A=calculated for V=Capacity and t=time at capacity for a selected "n")
- Methods (6) and (7) use their default speed-flow curves

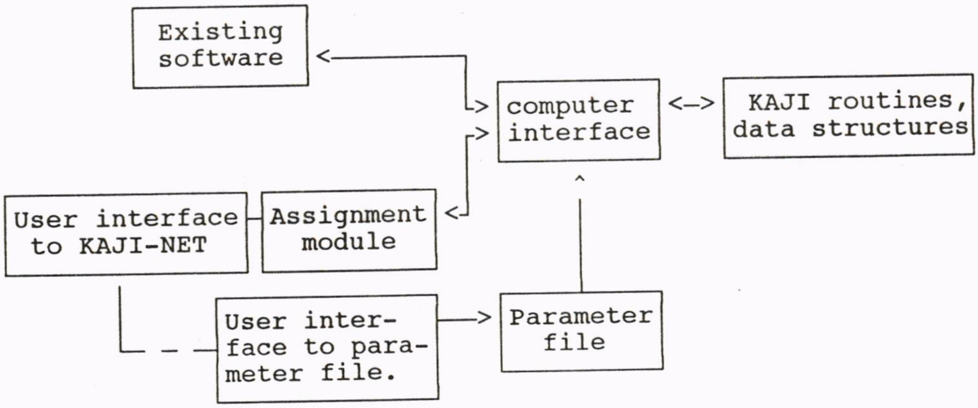
Table 1: Assignment of traffic flows (q) on the links

undoubtedly improve the accuracy of the traffic assignment process compared to the currently common application of default values in western traffic planning models. The magnitude of the benefits would vary depending upon the purpose for which traffic assignment was applied, but would be highest in urban environment. The following different ways in which IHCM/KAJI information or software could be used to improve the traffic assignment process were identified:

Method A:.
Use of general IHCM values and KAJI results for capacity, speed-flow relationship, delay, capacity etc. for standard road types and intersections as input parameters if possible for calibration of the transport planning software used. This alternative applies mainly to long-range planning, and only requires that the user has the IHCM manual. Such calibration can be performed for road links in a simple way for some software products, but is generally not possible for intersections. This approach should be encouraged as the minimum effort required in any Indonesian transport planning project.

Method B:.
Interface and/or integration of KAJI with the transport planning software used if possible. This method requires usage of a specially designed KAJI version to get better link and junction traffic performance estimates by added input variables. It could also mean to use KAJI to operate on and modify intermediate files created during the (usually) iterative assignment procedure

This method requires a considerable effort and skill in interfacing a specially revised KAJI module with a suitably adapted existing transport planning software. The source code for both KAJI and the transport planning software in question must be available, as well as possible permits to perform the actual modifications from the licensing bodies. KAJI integrated with some existing software would be suitable for long-range planning and/or large networks, where there is less detail known about the network parts. The configuration of the combined software would be as follows:



Although method B is possible to carry out on some of the studied software products (e.g. TRANPLAN, SATURN and MOTORS), it would involve the following types of problems:

- The combined transport planning software + KAJI package would be more complicated to run than the original software, and require careful consideration of input data describing the links and the nodes in the network.

- The combined package will need to be updated whenever KAJI and the transport planning software is revised, for which there will be no external support available from any of the licensing bodies.

The recommendation to the Indonesian government was therefore **not** to embark on this path, but to leave this to the private sector (e.g. individual consultant's and universities) to do on their own if they so wish.

Method C:
Extension of the KAJI software with a traffic assignment submodule, so that it becomes an "Indonesian Network Traffic Assignment Package" (KAJI-NET). This software would call the original KAJI software in much the same way as in "B", and would have the following possible types of use:

.1 As replacement for the highway traffic assignment step in a commercial transport planning software package.

.2 As a planning tool on its own for short-range planning of improvements in small or medium-sized networks or road corridors (e.g. toll road + existing road; bypass of small city and old through road) where the O-D trip matrix can be obtained without the use of a full-scale transport planning software.

.3 As a method to produce traffic flow inputs to simulation packages (e.g. TRAF-NETSIM, CORSIM and SATURN micro) for detailed analysis of urban traffic management schemes.

.4 As a sub-module in road management systems.

The input O-D trip matrix data in case 2 and 3 could also be obtained from the trip distribution output of a standard transport planning software package, or be constructed manually from roadside interviews or similar available data.

The magnitude of the benefits would vary depending upon the purpose for which the traffic assignment was applied, with the major benefits obtained in assignments in road networks where the intersections contribute to a large share of the overall travel time.

ACKNOWLEDGEMENTS

The authors acknowledge the support from the Directorate General Highways of Indonesia, Mr Gandhi Harahap, and the World Bank, Mr William Paterson, without whose help this study would never have been accomplished.

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