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IDENTIFICATION OF TRANSPORTATION IMPROVEMENT PROJECTS IN PHNOM PENH CONSIDERING TRAFFIC CONGESTION LEVEL

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Abstract: This paper aims to identify the transportation improvement projects by extending the solution on traffic congestion proposed by JICA study team, in November 2000, in which the network improvement was focused. In this study, the policy of urban planning is introduced to be incorporated with network improvement to successfully eliminate the traffic congestion on road network in Phnom Penh. The extensions include incorporation of urban planning policy, network improvement and reformulation of the four step models by using different data set. Three different scenarios, With and Without network improvement and With both network improvement and traffic volume reduction, are set up and compared to find out the appropriate measure to reduce traffic congestion. This study shows that a comprehensive approach, that provides commuters with an integrated transport system for relieving traffic congestion, should include proportional strategies to increase the capacity of transport system and to decrease traffic volume particularly at the main entrances to urban area.

Key Words: traffic congestion, traffic assignment, transportation improvement project

1. INTRODUCTION

The increase of traffic congestion is the less desirable results of Phnom Penh's continued population growth without a corresponding expansion of its transport system. The previous study by JICA experts shows that some urban routes have been reached the flow capacities or slightly beyond the capacities. It means that the urban community has not been successful at lowering, or even maintaining traffic congestion levels.

High level of traffic congestion has caused the reduction of economic activities and the augmentation of transport costs, which strongly affect the metropolitan economy. Moreover, traffic congestion has a significant impact on the communities' livability. It hinders an ability to attract residents and businesses; and degrades the local lives' quality. Without control, this congestion also has been cited as a cause of urban sprawl because of resident's relocation to outlying areas for the sake of less congested communities. Another effect by high level of traffic congestion is to diminish air quality. Conversely, any technique that reduces traffic congestion by improving traffic flow can result in improved air quality.

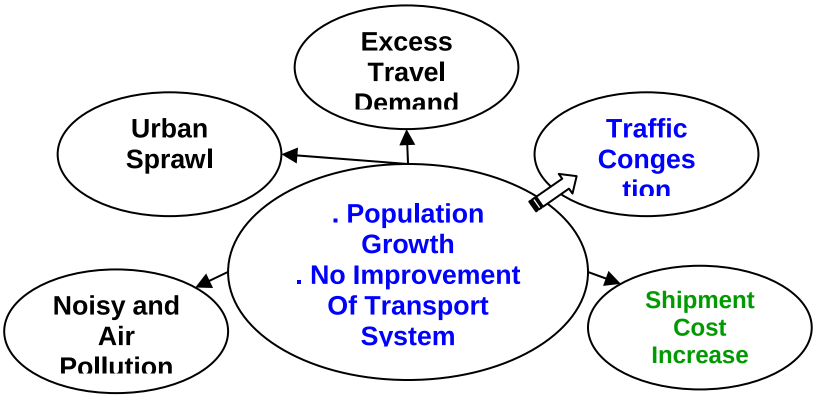


Figure 1: Problem Encountered

In this sense, the purpose of this research is to identify the most congested key roads in Phnom Penh and to make a guideline for transportation improvement project. This will identify which area needs more roads surface or new road construction and which existing link needs to be enlarged its capacity or the improvement of its flow capacity. This study will also identify the causes of traffic congestion and make a set of recommendations for a comprehensive approach to release local traffic congestion.

2. STUDY AREA

2.1 Location of the Study Area

Cambodia is located in south-east Asia. It shares the international boundary with Thailand, Laos and Vietnam at the following part of North-West, North and East ~ South-East. The study area is Phnom Penh, the capital of Cambodia, and the three partial districts of Kandal province, which is located in southern of Phnom Penh. Actually, this city is located in the core of Kandal province.

2.2 Population of the Study Area

The population data are available only for years of 1986, 1993, 1995, 1996, 1998 and 1999. Among these data, only the one in 1998 is precise due to the population census was undertaken in that year. These data are provided by the Ministry of Planning.

Based on this trend, JICA study team made the population projection for the Municipality of Phnom Penh, and then added the population of a part of Kandal Province which is included in the study area.

According to the population control policy in Urban Area, the population 184,000 people out of 343,000 of present population-trend increase need to be induced from Urban Area to Suburban Area by the year of 2015. Then the population growth rate, in the suburban area, is sharply high. These rates are ranged from 5.06% in 2005 to 3.68% in 2015. To respond to the high population increase in the suburban area, sound urbanization must be achieved with the proper support of the transport system.

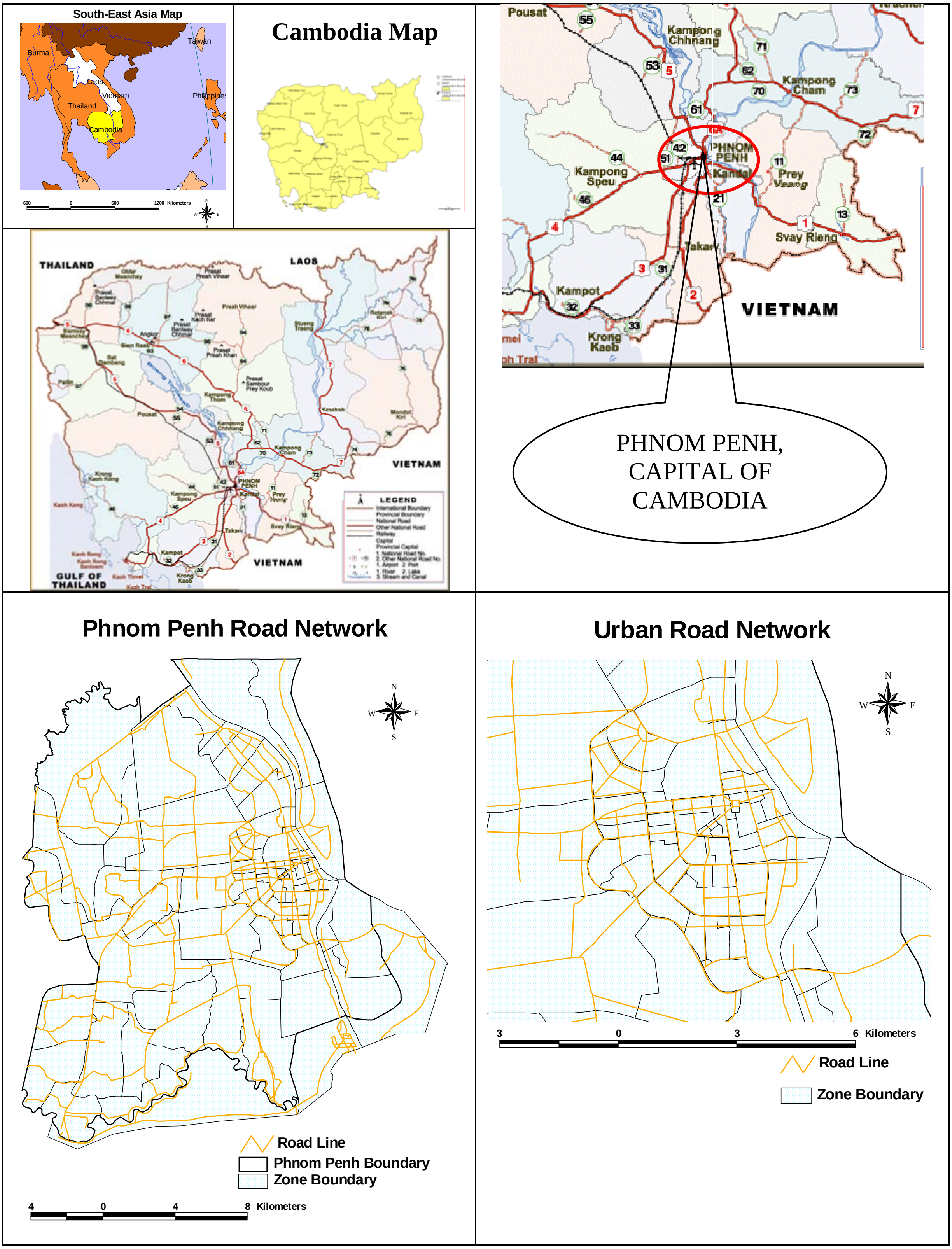


Figure 2: Location of Study Area

2.3 Road Network Review

Road network is a basic infrastructure to support a transport system. Without an appropriate road system, many modes of transport including buses, passenger cars, trucks and motorcycles can not be operated properly. Consequently, a road system's role in a transport master plan is very significant. Field surveys were carried out to investigate the present road conditions in the Study Area. Using the data collected during the field survey, a considerable portion of road inventory was updated and supplemented with data of suburban areas.

Present road condition

a. Pavement Condition of Urban Street

Compared to the developed condition of the urban road network, pavement condition of the urban roads in Phnom Penh is very poor. Figure 3 shows the percentages of each class of surface condition of the arterial streets. About two-thirds are classified as “fair” or “good”, while the rest (32 %) is “bad” or “very bad”.

Figure 4 shows the surface condition of the collector streets. Contrary to the case of the arterial streets, the total of “good” and “fair” remains only 41 percent, while “bad” and “very bad” occupy the rest, 59 percent.

Figure 5 shows the pavement condition of the local streets. It is clearly seen that the percentage of “very bad” is very high compared with those in arterial streets and collector streets.

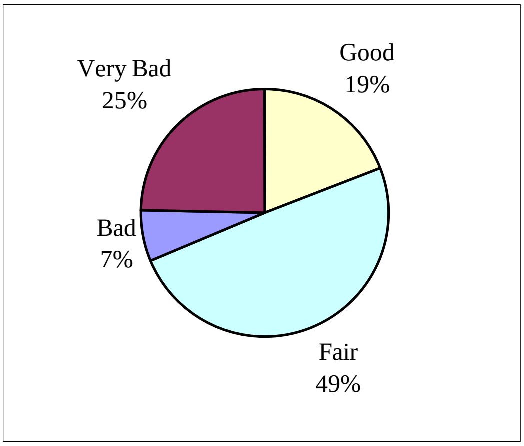
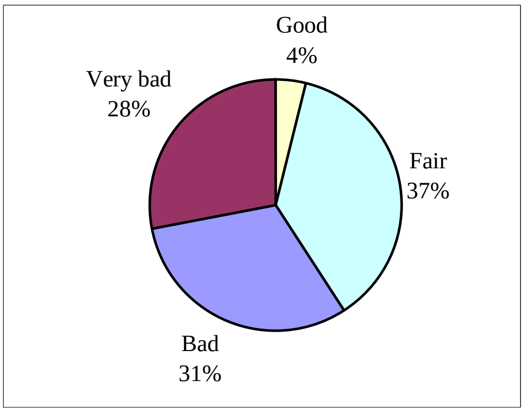


Figure 3: Pavement Condition of Arterial Streets



Good: Structurally intact with smooth surface

Fair: Structurally intact but rough surface; may need repair in near future

Bad: Many cracks with some pot holes; need careful drive to avoid pot holes

Very Bad: Many pot holes; substantial decrease in travel speed

Figure 4: Pavement Condition of Collector Streets

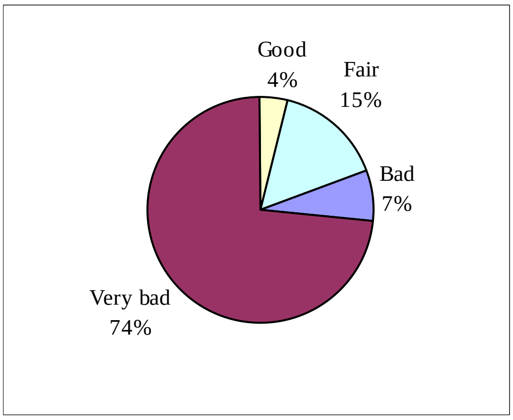


Figure 5: Pavement Condition of Local Streets in Central Districts

Because of the very poor condition of pavement on the local streets, drivers prefer to use the arterial streets, and traffic concentrates on these roads. Table 1 and Figure 6 show the comparison of the pavement conditions, surveyed on a random basis, of the four Central Districts (Daun Penh, Prampi Makara, Chamkar Mon, Toul Kork). There is a substantial difference in pavement conditions among the Districts. Pavement conditions in Chamkar Mon and Toul Kork are very poor.

Table 1: Pavement Conditions of Local Streets in Central Districts

No	Name of District	Good (Km)	Fair (Km)	Bad (Km)	Very bad (Km)	Total (Km)
1	Daun Penh	3.53	8.88	2.75	4.20	19.35
2	Chamkar Mon	0.10	2.40	1.50	32.50	36.50
3	Prampi Makara	0.50	3.85	2.40	6.85	13.60
4	Toul Kork	-	0.25	0.50	29.90	30.65
Total		4.13	15.38	7.15	73.45	100.10
Percentage		4%	15%	7%	73%	100%

Source: The Study on the Transport Master Plan of the Phnom Penh Metropolitan Area, Final Report

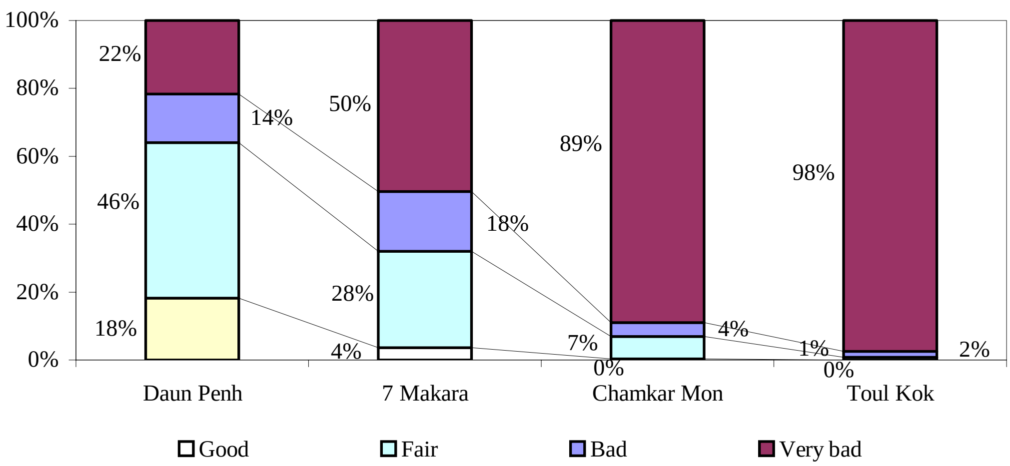


Figure 6: Pavement Conditions of Local Streets in Central Districts

b. LOS by Travel Speed

Table 2 shows the average travel speeds over the entire sections of major roads in Phnom Penh. As can be seen in the table, average travel speeds of the major arterial roads are still within the lowest acceptable range (LOS D). However, Highway Capacity Manual defines that “LOS D” is the situation where “small increase in flow may cause substantial increase in delay and hence decrease in (arterial) speed.” Therefore, even a small increase in traffic volume on these roads will lead to severe traffic congestion. In addition, travel speeds of those sections with LOS C are close to that of LOS D. Based on these facts, it can be said that the traffic condition on the urban arterial roads is approaching an unacceptable level.

Travel speeds on Charles de Gaulle, Inner Ring Road (St. 271) and Sihanouk/Jawharal Nehru Blvd are lower than those of other major arterial roads. Suspected reasons for these lower travel speeds are as follows:

- Charles de Gaulle: Traffic congestion at three roundabout intersections on the route and very bad pavement condition.
- Inner Ring Road: Very bad pavement condition
- Sihanouk/Jawaharal Nehru: Severe traffic congestion

Table 2: Travel Speed and Level of Service on Arterial Streets

Street Name		Direction	AM Peak Hr.		Noon		PM Peak Hr.		Average	
			km/hr	LOS	km/hr	LOS	km/hr	LOS	km/hr	LOS
Radial Roads	France / Norodom	N-bound	21.3	C	28.2	C	24.8	C	26.3	C
		S-bound	22.3	C	29.0	C	20.7	D	25.4	C
	Monivong	N-bound	19.9	D	26.2	C	20.6	D	23.3	C
		S-bound	22.4	C	26.3	C	20.7	D	23.8	C
	Charles de Gaulle / Monireth	NE-bound	14.1	D	20.4	C	16.4	D	17.4	D
		SW-bound	18.9	D	17.5	D	17.2	D	18.0	D
	Confederation de la Russie	E-bound	27.6	C	39.1	B	26.7	C	31.9	B
		W-bound	27.8	C	37.2	B	25.8	C	32.0	B
Ring Roads	Inner Ring Road	S/E-bound	18.7	D	21.9	C	20.4	D	20.5	C
		W/N-bound	18.7	D	21.1	C	19.4	D	20.1	C
	Kim Il Sung / Mao Tse Toung / Sisowath	S/E/N-bound	20.6	D	29.8	C	21.9	C	24.9	C
		S/W/N-bound	21.5	C	27.4	C	20.0	D	24.3	C
	Jawaharal Nehru / Sihanouk	S/E-bound	14.6	D	24.2	C	18.3	D	21.0	C
		W/N-bound	18.5	D	24.0	C	16.6	D	20.6	C

Source: The Study on the Transport Master Plan of the Phnom Penh Metropolitan Area, Final Report

c. LOS by *V/C* Ratio

The ratio of traffic volume, *V*, to the capacity of the road, *C*, is also commonly used as an index for LOS for uniform road segments. Table 4 shows the LOS of the sections of Urban Arterial Roads in Phnom Penh based on the *V/C* ratios (*VCR*). In the calculation of this table, the assumptions shown in Table 3 were adopted.

Table 3: Basic Assumption for Evaluating LOS

Basic Capacity in PCE	2,500 PCE/hour/lane
PCE Conversion Factor	Motorcycle: 0.33 Cyclo/bicycle: 0.33 Car, Van: 1 Heavy vehicle: 2.5
Basic Capacity in PME	7,575 PME/hour/lane
PME Conversion Factor	Motorcycle: 1 Cyclo/bicycle: 1 Car, Van: 3.03 Heavy vehicle: 7.58

Table 4: Road Sections with VCR Larger than 0.8

Name of Road	Section (From→ To)	VCR	LOS
(a) Morning Peak Hour			
Tep Phan	Mao Tse Toung→J. Nerhu	1.08	E – F
	IRR→Mao Tse Toung	1.16	E – F
	Mao Tse Toung→IRR	1.29	E – F
Sihanouk	St 163→Monivong	1.05	E – F
	Monireth→St 163	0.90	E
	St 163→Monireth	1.25	E – F
Mao Tse Toung	St 163→Monivong	1.22	E – F
Monivong	Tep Phan→Sihnouk	0.82	E
	Sihonouk→Tep Phan	0.91	E
Confederation de la Russie	Tchecoslovaquie→J. Nerhu	0.86	E
	J. Nerhu→ Tchecoslovaquie	0.86	E
Kim Il Song	St 608→Conf. De la Russie	0.80	E
(b) Evening Peak Hour			
Name of Road	Section (From→ To)	v/c	LOS
Tep Phan	IRR→Mao Tse Toung	1.36	E – F
	Mao Tse Toung→IRR	1.18	E – F
Sihanouk	St 163→Monivong	1.07	E – F
	Sothearos→Norodom	0.85	E
Mao Tse Toung	Monireth→St 163	1.06	E – F
	St 163→Monireth	0.83	E
Conf. De Russie	Tchecoslovaquie→J. Nerhu	0.94	E

Source: The Study on the Transport Master Plan of the Phnom Penh Metropolitan Area, Final Report

3. METHODOLOGY

The analyses conducted in this study are based on the assumption that the single transportation mode of motorcycle is loaded to the traffic because the motorcycle is a dominant mode in the study area, about 80% of total mode share.

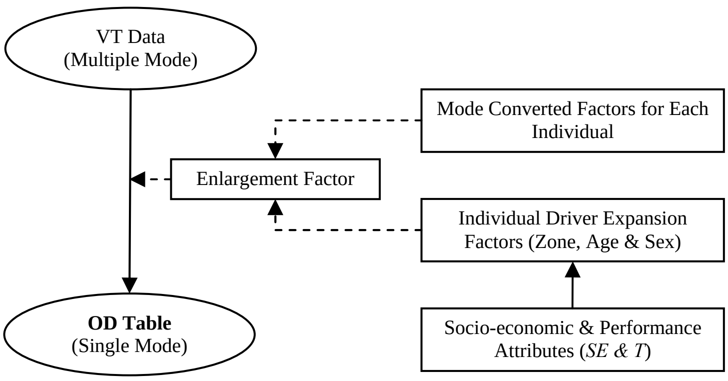


Figure 7: Formation of Trip Distribution Table

Therefore, the other trip modes are needed to be converted to the passenger motorcycle equivalent. And the second assumption is that the bigger traffic flow represents the higher level of probable traffic congestion.

3.1 Data Arrangement

To expand the sample to a whole population, an expansion factor is needed. This factor is formulated from three variables of the socio-economic attribute namely residence zone's number, sex and age of the individuals. Then, the expansion factor is combined with mode equivalent factor to create a single factor by multiplying. The latest factor is used in the enlargement process.

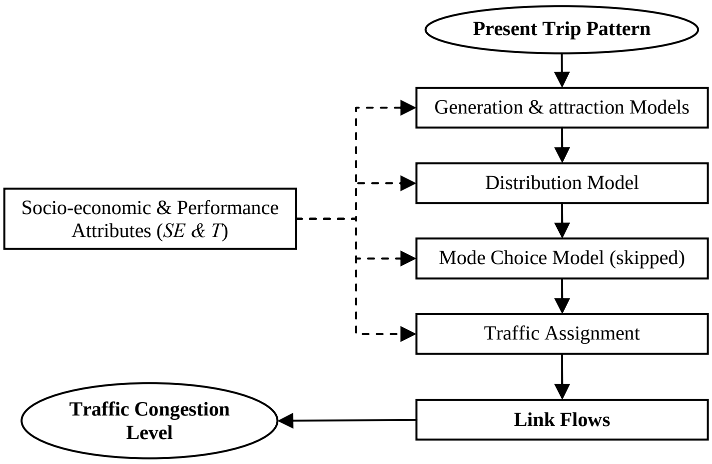


Figure 8: Model Structure and Estimation Process

3.2 Description of Trip Generation and Attraction Models

Simple regression and multiple linear regression models, that have one or several explanatory variables of the socio-economic framework component, have been formulated to represent the present condition of the trip generation and attraction from/to each traffic zone.

Trip generations are formulated by aggregate models as shown in equation (1) through (6):

For Home purpose:
The socio-economic attribute used in trip generation for home purpose are some kind of activities that create the trip to return home. These activities belong to some kind of jobs such as Government job, student and so on. In this study, only two attributes of socio-economic framework are Government job and Student which have a best relationship for the model.

$$G^i_{\mathrm{home}} = \beta_{gvmnt} E^i_{gvmnt} + \beta_{stdnt} E^i_{stdnt} + a_{\mathrm{home}} \tag{1}$$

For Work purpose:
For this purpose only one attribute, Population, that provides good relationship to the model.

$$G^i_{work} = \alpha_{pop} P^i + a_{work} \tag{2}$$

For Business purpose:
A good relationship for this model can obtain from the attribute of Household and dummy variable of Urban status of the zone.

$$G^i_{bsns} = \alpha_{hhold} H^i + \gamma U^i_d + a_{bsns} \tag{3}$$

For School purpose:
The attributes that have a good relationship for this model are the same two variables applied in business purpose.

$$G^i_{schl} = \alpha_{hhold} H^i + \gamma U^i_d + a_{schl} \tag{4}$$

For Shopping purpose:
Government job has a better relationship in this model.

$$G^i_{shop} = \beta_{gvmnt} E^i_{gvmnt} + a_{shop} \tag{5}$$

For Other purpose:
Traveling for other purpose has an unspecific trip pattern but only one variable can best describe this kind of trip, the number of Households in that zone.

$$G^i_{oth} = \alpha_{hhold} H^i + a_{oth} \tag{6}$$

Where, G^i_{home} : Trip generation in zone i;
P^i : Population in zone i;
H^i : Number of Households in zone i;
E^i_{gvmnt} : Work base government employments in zone i;
E^i_{stdnt} : School base students in zone i;
U^i_d : Urban dummy for zone i;
α_{pop}, α_{hhold}, β_{gvmnt}, β_{stdent}, γ : Parameters;
a_{home}, a_{work}, a_{bsns}, a_{schl}, a_{shop}, a_{oth} : Specific adjustments.

Trip attractions are formulated by aggregate models as shown in equation (7) through (12):

For Home purpose:
The socio-economic attribute used in trip attraction for home purpose is the one that relates to the trip whose destination is home. This attribute can be the accessibility that can attract trips to the zone. In this model, the number of Household is preferred.

$$A^j_{home} = \alpha_{hhold} H^j + \gamma U^j_d + b_{home} \tag{7}$$

For Work purpose:
For this purpose, there are two variables that provide good relationship to the model.

$$A^j_{work} = \beta_{gvmnt} E^j_{gvmnt} + \gamma U^j_d + b_{work} \tag{8}$$

For Business purpose:
A good relationship for this model can obtain from the attribute of Market jobs and dummy variable of Market status of the zone.

$$A^j_{bsns} = \beta_{mrket} E^j_{mrket} + \gamma M^j_d + b_{bsns} \tag{9}$$

For School purpose:
The attributes that have a good relationship for this model are the number of Government jobs and the number of Students in that zone.

$$A^j_{schl} = \beta_{gvmnt} E^j_{gvmnt} + \beta_{stdnt} E^j_{stdnt} + b_{schl} \tag{10}$$

For Shopping purpose:
Market job and dummy variable of Market status give a better relationship in this model.

$$A^j_{shop} = \beta_{mrket} E^j_{mrket} + \gamma M^j_d + b_{shop} \tag{11}$$

For Other purpose:
Traveling for other purpose has an unspecific trip pattern, there are two variables can best describe this kind of trip, the number of Government jobs and dummy variable of Market status in that zone.

$$A^j_{oth} = \beta_{gvmnt} E^j_{gvmnt} + \gamma M^j_d + b_{oth} \quad (12)$$

Where, A^j : Trip attraction to zone j;
H^j : Number of Households in zone j;
E^j_{gvmnt} : Work base government employments in zone j;
E^j_{mrket} : Work base market employments in zone j;
E^j_{stdnt} : School base students in zone j;
U^j_d : Urban dummy for zone j;
M^j_d : Market dummy for zone j;
$\alpha_{hhold}, \beta_{gvmnt}, \beta_{mrket}, \beta_{stdent}, \gamma$: Parameters;
$b_{home}, b_{work}, b_{bsns}, b_{schl}, b_{shop}\ b_{oth}$: Specific adjustments.

Each above model needs to be added the constant term to ensure the equality between the actual value and the value derived from the model. This constant term can be called “the specific adjustment” for each purpose model. The above trip generation and trip attraction models are used for each purpose trips. It comes out with more variety of attributed variables. Therefore, trip generation and attraction models are specified for each purpose analyses.

3.3 Description of Trip Distribution Model

The voorhees gravity model is used for the distribution step for both inter zonal and intra zonal trips (eq (13)). The origin of trips from each zone is assumed to be originated from the nearest intersection of the center of the zone (zone centroid). Traffic resistance is applied to the distance between zone centroids and the summation of the ratios between the attracted trips in zone j and the power function of the corresponded distance. The distance, d_{ii} corresponded to T_{ii}, is assumed to be equal to half of the minimum of d_{ij} (half of the nearest distance).

$$T_{ij} = G_i \cdot \frac{A_j \cdot d_{ij}^{-\lambda}}{\sum_j A_j \cdot d_{ij}^{-\lambda}} \quad (13)$$

Where T_{ij} : Trip between zone i and zone j;
G_i : Trip generated in zone i;
A_j : Trip attracted to zone j;
d_{ij} : Distance between zone centroid [km].
λ : Parameter.

3.4 Traffic Assignment

This step uses a static user equilibrium assignment model. The link performance function is the BPR formula which suggested by the Bureau of Public Road as shown in equation (14).

$$T'_c = T_0 \left[1 + K_x \cdot \left(\frac{Q}{C} \right)^{\alpha} \right] \quad (14)$$

Where T'_c : Congested link travel time [mn];
T_0 : Free-flow link travel time [mn];
Q : Daily Traffic volume [veh];
C : Link capacity [veh/day];
$K_x=0.15$, $\alpha=4$;

Note: the unit of [veh] is [PME].

3.5 Definition of Traffic Congestion

As shown in the previous chapter, the first step in the process of estimation of traffic congestion’s cost is to define the travel demand on the road network. Some authors have identified the traffic congestion by observing the level of service of the road network and some others have identified by checking the ratio of traffic volume to the road capacity *(V/C)*. The second method is chosen for considering in this study. Therefore, the definition of traffic congestion in this study is the level that is observed by the ratio of traffic volume, *(V)*, to the road capacity, *(C)*.

The levels of traffic congestion are divided into four levels in sequences such as normal flow, congested flow, moderate congested flow and severe congested flow status. These levels are described below and summarized in table 5.

a. Normal Flow or the Status of No Congestion
The status of normal flow or no congestion is the status in which the traffic can smoothly flow. In this case, the *V/C* ratio is less than 0.8 which is the status of free flow as stated in Khisty and Lall (2003).

b. Congested Flow Status
The congested flow status is the status in which the traffic flow is reached close to the road capacity and started to be disrupted by the increase of the traffic itself. In this case, the *V/C* ratio is laid between 0.8 and 1.2 which is the starting point of congestion.

c. Moderate Congested Flow Status
Moderate congested status is the status in which the traffic is more and more increase far above the road capacity. In this case, the *V/C* ratio is ranked between 1.2 and 1.5. This level of congestion can temporary stuck the traffic and the road is temporary become a parking lot.

d. Severe Congested Flow Status
The severe congested flow status is the status in which the traffic is increased to a high point that reached a very tight status of traffic flow. In this case, the *V/C* ratio is higher than 1.5 which is the level that the temporary congestion is stretched for longer time. If this status occurs so often and the congestion time is stretched to a long time, the road network is deteriorated. This problem may harm the local environment and cost too much for the society to spend on time lost, more fuel consumption and environment diluted.

Table 5: Summarized of traffic congestion levels

No.	**Congestion Level**	**Indicator (*V/C* ratio)**
1	Normal Flow	$V/C < 0.8$
2	Congested Flow	$0.8 \leqslant V/C < 1.2$
3	Moderate Congested Flow	$1.2 \leqslant V/C < 1.5$
4	Severe Congested Flow	$1.5 \leqslant V/C$

The Road Information Program (May 2002) described that the steps needed to relieve traffic congestion are the efficient strategies in which the transport network is improved proportionally to the reduction of traffic volume at the road links with high probable traffic congestion.

4. RESULTS OF MODELS ESTIMATION

4.1 Estimation of Trip Generation and Attraction Models

The relation between trips generation, attraction, with the explanatory variables is poor as shown in Table 6 because of the small sample size which appears to be bias.

Table 6: Result of Trip Generation and Attraction Models

Purpose & No. of Zones	Model	Variables	Coefficient	Standard Error	*t* Value	Corr. Coef.
For Home	Gen.	GVMNT	2.38	0.59	4.02	**0.55**
		STDNT	0.42	0.23	1.80	
(54 Zones)	Attr.	HHOLD	0.17	0.69	0.24	**0.45**
		UBN-D	10,561.47	2,985.84	3.54	
For Work	Gen.	PPLTN	0.34	0.13	2.65	**0.34**
	Attr.	GVMNT	2.89	0.72	4.04	**0.59**
(56 Zones)		UBN-D	7,347.36	3,102.20	2.37	
For Business	Gen.	HHOLD	0.46	0.28	1.65	**0.39**
		UBN-D	1,888.44	1,149.54	1.64	
(28 Zones)	Attr.	MRKET	0.18	0.10	1.79	**0.52**
		MKT-D	1,209.73	587.80	2.06	
For School	Gen.	HHOLD	0.38	0.21	1.84	**0.28**
		UBN-D	774.67	893.69	0.87	
(44 Zones)	Attr.	GVMNT	2.11	0.50	4.25	**0.57**
		STDNT	0.16	0.20	0.78	
For Shopping	Gen.	GVMNT	0.33	0.11	2.97	**0.50**
(29 Zones)	Attr.	MRKET	0.05	0.07	0.65	**0.45**
		MKT-D	1,113.47	466.84	2.39	
For Other	Gen.	HHOLD	0.25	0.10	2.49	**0.43**
	Attr.	GVMNT	0.08	0.08	1.09	**0.26**
(29 Zones)		MKT-D	309.28	289.82	1.07	

4.2 Estimation of Trip Distribution

Distribution model shows that there is a good relation between distributed trip T_{ij} and the distance d_{ij} .

Table 7: Result of Trip Distribution Model

Distribution model type:	Voorhees gravity	Parameter	λ	0.0879
Number of zones:	54	Correlation coef.	r^2	0.6525

4.3 Traffic Assignment

In this study, the flow on each link is estimated through the four steps models of travel demand forecasting. Each model is developed by using the STRADA program. These models are used to predict the future link flow with and without network improvement. Then, another prediction is made with the pattern of both “network improvement” and “traffic volume reduction”. These patterns are compared to seek out the appropriate one.

The three scenarios discussed to predict the future link flow are:

- **Without Network Improvement** “do-nothing”
- **With Network Improvement** (Improve Pavement & Connect Missing Links…)
- With both **Network Improvement** and **Traffic Volume Reduction** (For traffic volume reduction, 50% of Congested-Source of Urban Inbound Trip is Diverted to suburb)

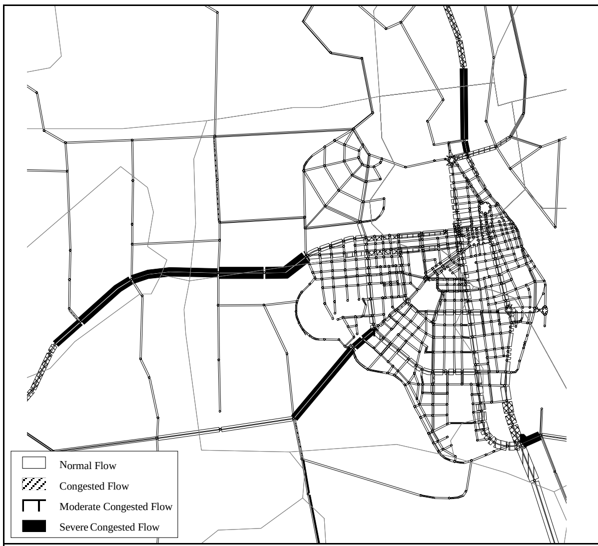


Figure 8. Congestion in Urban Base Year of 2000

Figure 9. High Congestion 2015 With Do-Nothing Pattern

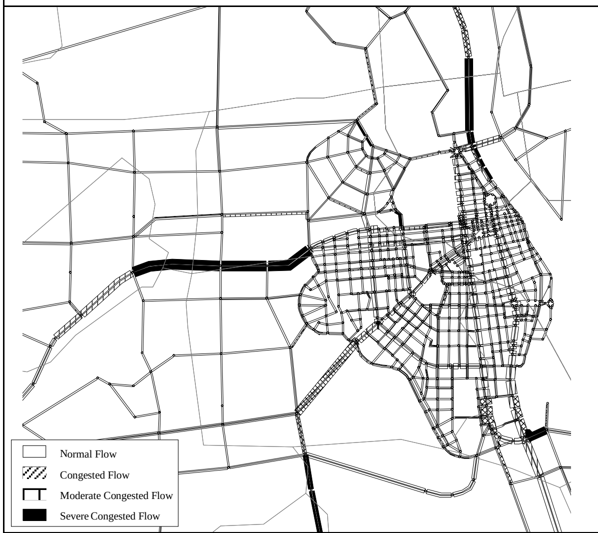


Figure 11: Low Congestion 2015 With Network Improvement

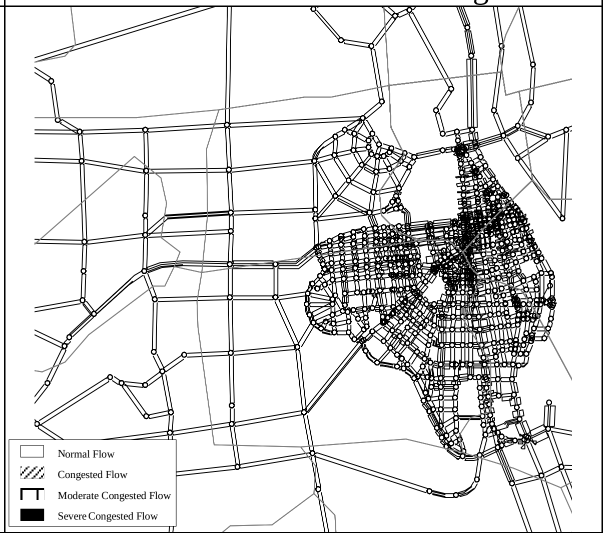


Figure 12: No Congestion 2015 Network Improvement &Traffic Volume Reduction

Table 8: Congestion levels at the main entrances to urban and the average level in Phnom Penh with do-nothing pattern

	2000	2005	2010	2015
NR1 Entrance	2.11	2.38	2.56	2.56
NR3 Entrance	2.07	2.36	2.58	2.78
NR4 Entrance	1.97	2.31	2.55	2.77
NR5 Entrance	2.72	3.17	3.46	3.56
Avrg in P.P	0.28	0.32	0.36	0.38

In the second scenario, with network improvement, traffic congestion is still remained on some road segments especially at the entrances to urban area but its level is significantly reduced to a low one. This shows that the improvement project is inadequate for the solution on traffic congestion. Of course, expansion of the improvement projects, such as more constructions of new roads, can completely eliminate these congestions. More constructions of outer ring roads can escape some trips from entering the urban area. This may reduce some trips from urban entrances but the problem is that the community have a constrain budget for every projects. Moreover, the construction of outer ring roads can reduce only the trips on the urban entrances, not the urban roads. Then the congestion still remain in the urban area where there is no ability to construct more roads.

Table 9: Congestion levels at the main entrances to urban and the average level in Phnom Penh with network improvement pattern

	2000	2005	2010	2015
NR1 Entrance	2.11	2.38	1.92	1.52
NR3 Entrance	2.07	1.63	1.60	1.44
NR4 Entrance	1.97	1.94	1.77	1.71
NR5 Entrance	2.72	2.16	2.00	1.96
Avrg in P.P	0.28	0.30	0.34	0.33

Cascetta (2001) described that the demand for traveling cannot be reduced but travel pattern can be changed if its purposes or reasons of traveling are clearly identified. In this sense, the aim to reduced traffic flow from the high congested links is to alter the destination of some congested-source trips. Thus, the solution to support the improvement project is to reduce the traffic volume to a suitable level that matches the road capacities. This scenario aims to reduce the traffic volume on the roads that support high traffic flow especially at the main entrances to urban area.

Table 10: Congestion Levels at the main entrances to urban and the average level in Phnom Penh with network improvement and trip reduction pattern

	2000	2005	2010	2015
NR1 Entrance	2.11	0.37	0.31	0.28
NR3 Entrance	2.07	0.07	0.08	0.07
NR4 Entrance	1.97	0.11	0.11	0.11
NR5 Entrance	2.72	0.22	0.24	0.23
Avrg in P.P	0.28	0.06	0.06	0.06

Table 11: Total Trip Length in 10^6 Vehicle-kilometer

	2000	2005	2010	2015	Remarks
Do-Nothing	7.41	8.55	8.83	9.35	High Congestion
Network Improvement		8.38	8.21	8.65	Low Congestion
NI and Trip Reduction		5.91	6.42	6.62	No Congestion

Table 12: Average Speed in km/h

	2000	2005	2010	2015	Remarks
Do-Nothing	25.7	25.5	25.3	25.2	High Congestion
Network Improvement		27.0	31.1	32.1	Low Congestion
NI and Trip Reduction		28.2	32.5	33.4	No Congestion

5. CONCLUSIONS

Through the above discussion, it can be concluded that the source of traffic congestion is not only the big volume of travel demand but also the condition of transport facility and traffic pattern especially the concentration of trips in a small area such an urban of Phnom Penh. And the efficient strategy to remove this concentration is to divert the destination of congested-source trips. As shown above, the efficient and effective technique to divert those trips is to provide a corresponded number of jobs to the suburb to alter the trip attribute of this area.

This study shows that a comprehensive approach, that provides commuters with an integrated transport system for relieving traffic congestion, should include proportional strategies to increase the capacity of transport system and to decrease traffic volume particularly at the main entrances to urban area of this city.

In this stage of study, the causes of traffic congestion were identified and a set of recommendation for a proper solution was made. Nevertheless, the comparison of three different scenarios was made to find the appropriate one. This comparison should be made not only on the outcome of traffic congestion released but also on the cost benefit analysis of each scenario. The comparison base on benefit cost analysis can evaluate the proposed project thus quantify how much budget is necessary for the project and how much benefit will be received for the community in term of money and time saving, less fuel consumption, less noisy and air pollution. Thus, to deeply understand the effects of the implemented project in each scenario the cost benefit analysis should be made.

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