Transferability of HCM to Asian Countries: An Exploratory Evidence From Bangkok's Multilane Highways

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Synopsis

This paper aims to examine fundamental issues related to the operational quality of urban multilane traffic. A methodology is developed to investigate to what extent the current capacity analysis procedures outlined in the HCM can be applicable and transferred to urban highways in Bangkok. A number of multilane highways located in Bangkok area are selected for the present study and traffic data are collected by video cameras so that traffic movement as well as congestion could be visually observed. Several microscopic traffic flow characteristics such as vehicular speed, flow, and density are decoded and extracted by image processing unit. Based on the collected traffic data, a set of models for determining highway capacity is proposed and underlying factors that affect highway operations are identified. The proposed models are evaluated and compared against HCM in terms of predicting accuracy of highway capacity. Preliminary results show that the models developed in this study can provide more accurate means in predicting highway capacity and quality of service pertaining to Bangkok highways, and the application of the models could sufficiently serve the needs for transportation engineers. Despite an exploratory study, the findings in the present study provide a promising ground for developing a country-wide comprehensive capacity analysis manual similar to those used in the western region.

INTRODUCTION

The highway capacity concept outlined in the Highway Capacity Manual (HCM) has been extensively used for planning, design, analysis, and operations in many countries, including Thailand. Given the fact that the kingdom's Department of Highways, as well as its local transportation engineers, planners, and practitioners, currently utilizes the HCM concept as a primary source of reference to identify capacity and quality of service for highways in Bangkok, it is questionable whether this direct approach could be straightforwardly transfer from western countries to eastern region. Primary reasons for potential discrepancies basically lie from three distinct issues: traffic flow patterns, vehicle characteristics, and physical road geometry. Some past studies have shown that traffic flow patterns have a significant impact on highway capacity, and behavioral difference in driving can be of importance, which can significantly influence operational conditions. In terms of vehicle characteristics, traffic flow patterns in Bangkok usually consist of a wide variety of vehicle composition in traffic stream. This is also the case for other Asian countries such as Malaysia and Vietnam. In addition, road geometry in Bangkok is quite unique; several access points can be readily found along multilane highways and could have a substantial effect on highway capacity, not only due to interruptions on mainline traffic stream but also caused by inappropriate traffic controls. Combining all three effects, the results could significantly shape the way the capacity and quality of service should be computed. With a straightforward use of the HCM, the capacity as well as its quality of service is apparently debatable.

The main propose of this paper is to investigate highway capacity on urban highways in Bangkok area, where the traffic congestion has been considered a serious problem for travelers. Multilane highways are the focus of the study, in which highway of this type constitutes up to 18 percent of highway system in Thailand (Bureau of Traffic Safety, 2004). Study sites are carefully selected such that no traffic signal, at grade U-turn, U-turn bridge, crossing bridge and large intersection are presented nearby in order to eliminate their potential effects on the basic multilane segments. Traffic data are collected by means of video cameras installed at pedestrian crossing bridges above traffic stream of interest. Several traffic flow characteristics such as speed, flow, and density are decoded using image processing unit. Results are plotted in terms of speed–density, speed–flow, and flow–density relationships. Maximum flow on the roadway, or commonly known as the capacity of highway, can then be identified.

The outline of the paper is as follows. First, the introduction section provides underlying background of the research, followed by the literature review, which covers extant literature pertaining to the study. Next, site selection process are discussed, along with data collection procedures. Output extracted from image processing unit is then analyzed and compared with HCM in terms of capacity of the roadways. Finally, the conclusion provides a discussion on the results and its implications as well as some suggestions for further study.

LITERATURE REVIEW

HCM Analysis of Multilane Highways

Many highway and transportation engineers, including those in Thailand, traditionally utilize the HCM for operation, design, and planning of highways. The analysis of performance and quality of service of multilane highways can be found in Chapter 21 of the HCM2000, the up-to-date version of HCM (TRB, 2000). According to the outlined methodology, identifying "base" conditions (i.e. good weather, good visibility, and no incidents or accidents) is the first step in the analysis. The base condition is defined for traffic flow and roadway characteristic consisting of a minimum lane width of 3.6 m, a minimum total lateral clearance of 3.6 m, only passenger cars in traffic stream, no direct access points along the roadway, divided highway, and free flow speed (FFS) more than 100 km/h (TRB, 2000).

Although the HCM methodology provides a straightforward analysis of highway capacity, certain limitations should be realized. For instance, care should be taken when analyzed segments are blocked by construction, accident or railroad crossing. In addition, several scenarios may considerably reduce the capacity of roadway. Examples are vehicles parked at shoulders, effects of slow vehicles and frequently stopped vehicles (such as buses), and physical lane drop/increase along the roadway. The aforementioned concerns can be easily found in a typical Bangkok multilane highway.

One of the major issues for the HCM analysis of multilane highways is the assumption of homogeneous traffic flow across all travel lanes. Under this postulation, the entire traffic stream is equally distributed on the highway. This assumption may be acceptable for those in western region; however, this is not the case of local traffic in Bangkok, and perhaps in other Asian cities, essentially due to the presence of parked vehicles along the shoulders and the abundance of access points along the multilane highways. Due to these reasons, it is not uncommon for some countries to develop their own procedures to take into account these effects on highway capacity. See, for example, the development of Indonesian Highway Capacity Manual (Marler, Harahap, and Novara, 1994).

Highway Capacity Research in Asian Countries

Several research activities on highway capacity in Asian countries can be found from literature review. Many of them are reported in the International Symposium on Highway Capacity. For example, Marler, Harahap, and Novara (1994) studied speed-flow relationship and side friction on Indonesian urban highways in order to estimate urban roadway capacity and suggest appropriate adjustment factors for lane width, lateral clearance, directional split, side friction, and city size. In their study, video camera was used during data collection process for 35 sections across 11 Indonesian cities. The capacity values were estimated for each type of roadway to be 2,900 pc/h for two-lane two-way highways, 5,700 pc/h for four-lane two-way highways, 3,200 pc/h for one-way roads, and 4,600 pc/h for urban motorways with 2 lanes per direction.

In Singapore, Weng and Olszewski (1994) investigated capacity for several highway types, including area-wide, open expressway, tunnel, and arterial road. Apply traffic models resulting from the analysis of loop detector data, predicted area-wide capacity to be nearly 67,300 veh/h. The estimated capacities were found to be approximately 3,000 pc/h/lane, 2,600 pc/h/lane, and 800 veh/h/lane for open expressway, tunnel, and arterial, respectively. The authors also argued that saturation flows of nearside lanes are lower than those of non-nearside lanes. In India, Reddy (1994) purposed highway capacity research and application that focused on two lane rural highway sections, where the nature of mixed traffic and its behavior on rural highways in the country induced some problems in quantifying the capacity and level of services. The appropriate passenger car equivalence (PCE) was adopted and extensive field survey was conducted to analyze highway capacity under mixed traffic condition. Field observations revealed that HCM was found inappropriate for Indian rural highways, and speed flow relationships should be studied through analytical methods and developed simulation models. In Japan, Nakamura (1994) introduced research and application of highway capacity in Japan. The number of lane deciding methods were be revised and the roadside effects ware integrated into adjustment factors for converting “basic” capacity (maximum service flow) to “possible” capacity (service flow). In his study, roadside adjustment factors were divided into 3 areas that include undeveloped area, slightly developed area, and urbanized area.

Olszewski (2000) compared two methods of modeling the travel speed and traffic flow relationships that HCM method based on estimating delay at individual intersections and required a lot of detail data to input but the method of CTS in Singapore was required only intersection spacing and minimum signal delay. The comparison result of two models indicated that HCM predict lower speeds for uncongested traffic. CTS model was more appropriate for planning applications in Singapore.

Recently, Minh and Sano (2003) proposed the effect of motorcycle to saturation flow rate at signalized intersection in Hanoi and Bangkok. The result of their study indicated that motorcycles strongly affect to saturation flow rate or traffic capacity at the signalized intersection and suggested to be consideration on geometrical design when there are high ratio of motorcycle on particular signalized intersection.

DATA COLLECTION

In the present study, multilane highways located in Bangkok area are selected as the primary focus. Four roadways, including highways number 3, 302, 304 and 3344, are chosen as shown in Figure 1. Note that all of the selected highways are under the jurisdiction of the Department of Highways, Ministry of Transportation. A section in each roadway is selected according to the criteria that roadway segments are not disturbed by u-turn and signalized intersections. Table 1 presents selected roadway segments, including their locations and associated geometric and traffic characteristic information.

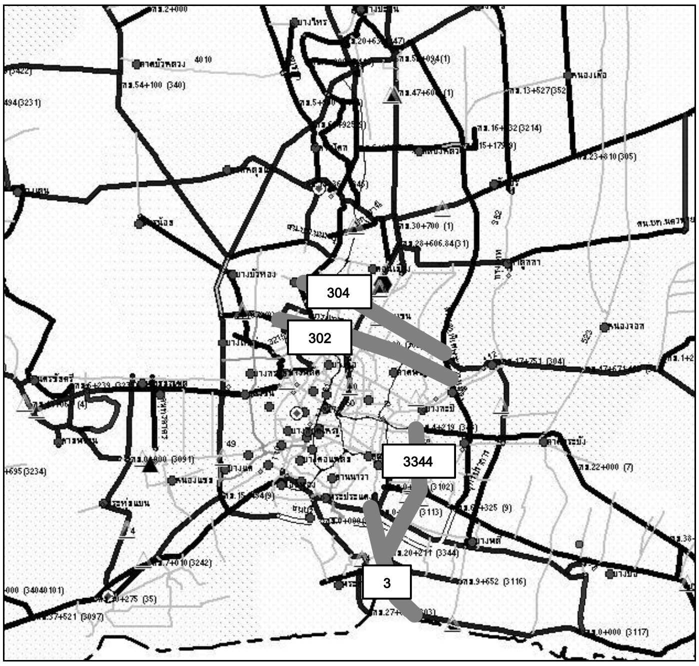

Figure 1 Selected highways

Table 1 Selected roadway segments

Highway Number	Location	Number of Lane (one direction)	Lane width (m)	Direction (from CBD)	AADT	%HV
3	Km. 20+700	3	3.50	Outbound	32,100	24.31
302	Km. 5+500	5	3.50	Outbound	93,358	3.60
304	Km. 6+830	4	3.50	Outbound	43,674	5.98
3344	Km. 14+090	3	3.50	Outbound	51,765	16.30

Ideally, traffic data collection should be conducted via magnetic loop detectors, infrared detectors, or microwave detectors. However, the permanent count stations currently maintained by the Department of Highways monitor simply aggregated traffic volume counts, thus being inappropriate for the present study due to the inability to reflect microscopic traffic characteristics. To cope with this issue, several alternatives are investigated, and it is found that employing video camera recording could be suitable for the study, because recorded positions can be easily moved from one location to another and, with the image processing technology, microscopic traffic parameters can be decoded and extracted in the laboratory after field data collection.

Figure 2 illustrates the data collection process, which could be broadly divided into 2 parts, i.e., field data collection and post-data processing in the laboratory. During the field data collection, video camera is installed on the pedestrian crossing bridge over each roadway. In each station, traffic stream is digitally recorded for 6 hours, covering 3 hours in the morning period (7.00 a.m. to 11.00 a.m.) and 3 hours in the afternoon period (3.00 p.m. to 6.00 p.m.). For calibration purpose, segment geometries of the roadway are measured, including lane width, shoulder width, number of lane, camera height, spacing between street lighting poles, etc.

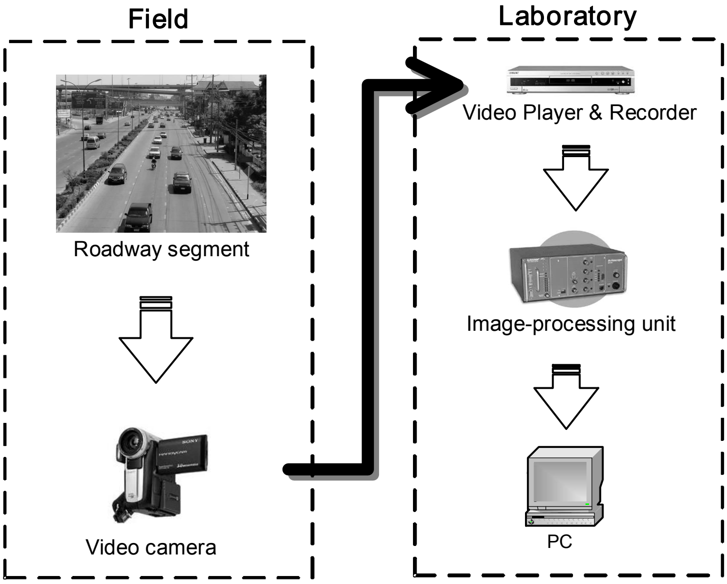

Figure 2 Data collection process

The second step of data collection process involves extracting traffic flow parameters from the recorded video from the field. Image-processing unit (AUTOSCOPE, 2001) is utilized in the Transportation Research Laboratory of Chulalongkorn University (TRL). To adjust perspective view of the video, the sight of view of each roadway segment is calibrated using measured lane width, camera height, and spacing of street lighting poles. Count and speed detectors are built on computer screen at suitable location of roadway segment for the purpose of counting and classifying type of vehicles. Figure 3 graphically presents views from recorded video at various stations. Note that lane numbering is defined on traffic lanes that start on the left side (i.e. from the road median) as lane 1, lane 2, and so on. With Autoscope2004, 10-second microscopic traffic parameters including vehicular flow, speed, and density are decoded and extracted for each travel lane.

(a) Highway Number 3

(b) Highway Number 302

(c) Highway Number 304 (d) Highway Number 3344

Figure 3 Count and speed detectors on roadway

To convert traffic flow into passenger car equivalence, vehicle classifications are defined generally based on vehicle length. Five classifications are determined, i.e. Class A for motorcycles, Class B for passenger cars, light buses, and pick-ups, Class C for heavy buses and medium/heavy trucks, Class D for semi trailers, and Class E for full trailers. The passenger car equivalent (PCE) factors used in the present study are adapted from those suggested by past JICA study (Masuda, 1987). Table 2 summarizes vehicle classifications and corresponding PCE values.

Table 2 Vehicle classifications and corresponding PCE values

Class	Definition	Length (m)	PCE
A	Motorcycle	Less than 3	0.33
B	Passenger Car, Light Bus, Pick up	< 5	1.00
C	Heavy Bus, Medium Truck, Heavy Truck	< 12	2.00
D	Semi Trailer	< 16	2.50
E	Full Trailer	More than 16	2.50

ANALYSIS RESULTS

Table 3 shows distribution of traffic stream across lanes. It can be clearly seen that lane distribution is one of the major impacts in terms of highway capacity. Lane 1 is occupied by more than one-third of the total traffic for 5-lane highways. Similarly, for 3-lane highways such as Highway No 3344, Lane 1 comprises up to 40 percent of total traffic during peak periods. The effect of imbalanced distribution of traffic stream would not be captured had the HCM assumption be applied directly for multilane highways in Bangkok.

In terms of service flow, data is summarized into 5-minute intervals and traffic flow (pc/h), speed (km/h), and density (pc/km) are computed. It is found that the computed service flow values differ significantly from those calculated using HCM formulas. Table 4 contrasts the service flow at LOS E, in other words capacity values, from HCM approach with those obtained from observed data, classifying by lane.

Table 3 Vehicle distributions

Highway No.	Period	Vehicle distribution (%)					
		Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Total
3	Morning	41.52	38.82	14.19	5.47	-	100
	Afternoon	38.03	34.89	19.11	7.97	-	100
302	Morning	33.95	27.46	18.87	13.36	6.36	100
	Afternoon	36.16	28.38	15.38	11.01	9.07	100
304	Morning	24.6	38.54	28.06	8.79	-	100
	Afternoon	22.86	38.97	29.25	8.92	-	100
3344	Morning	41.77	39.09	19.14	-	-	100
	Afternoon	42.21	40.35	17.43	-	-	100

Table 4 Comparison of service flow (in pc/h) between observed data and HCM2000

Highway No.	SF@LOS E (HCM2000)	SF from observed data				
		Lane 1	Lane 2	Lane 3	Lane 4	Lane 5
3	1,873	2,278	1,994	972	533	-
302	2,062	2,060	1,617	1,588	1274	697
304	2,039	1,365	1,968	1,424	486	-
3344	1,943	2,894	2,588	1,299	-	-

As mentioned earlier, the composition of vehicle type is considered a substantial factor. It can be seen from Table 4 that Highway No. 3344 possesses considerably high values of service flow, particularly on Lanes 1 and 2. This is due to the fact that this highway is composed of a large proportion of heavy vehicles (more than 16 percent). Similar setting can be also found in Highway No. 3, where almost a quarter of the total traffic is heavy vehicles. Therefore, the service flow computed from observed data is much higher than the value computed using HCM approach. It can also be observed from Table 4 that the shoulder lane (i.e. the right-most lane in Figure 3) is able to hold a relatively small number of service flow rate. This is mainly because of the adverse interactions of traffic between multilane highways, which are normally not accessed controlled, and access points along the road.

The relationships among vehicular flow, speed, and density are also investigated, and a set of models is estimated according to various single-regime models, such as Greenshields, Greenberg, and Underwood models (McShane et al., 1998). Table 5 summarizes the best-fitted models for each highway of interest. Different set of equations are tested for each lane and it is interesting to note that traffic flow characteristics found on each lane for Bangkok multilane highways are quite unique.

Table 5 Estimated single-regime models for Bangkok multilane highways

Lane	Highway No. 3	Highway No. 302
1	$u = -0.318k + 44.664$ (R^2 = 0.8145)	$u = 9.5467\ln\left(\frac{402}{k}\right)$ (R^2 = 0.2692)
2	$u = -0.3468k + 40.654$ (R^2 = 0.6074)	$u = 6.6043\ln\left(\frac{535}{k}\right)$ (R^2 = 0.2202)
3	$u = 7.9817\ln\left(\frac{267}{k}\right)$ (R^2 = 0.4532)	$u = -0.0716k + 13.163$ (R^2 = 0.1067)
4	$u = -0.0125k + 8.0556$ (R^2 = 0.0042)	$u = -0.0422k + 8.8045$ (R^2 = 0.0451)
5	-	$u = -0.0326k + 5.851$ (R^2 = 0.1137)

Table 5 (Cont'd) Estimated Single regime models for Bangkok multilane highways

Lane	Highway No. 304	Highway No. 3344
1	$u = 24.811\ln\left(\frac{95}{k}\right)$ (R^2 = 0.3488)	$u = -0.5443k + 53.899$ (R^2 = 0.3354)
2	$u = 28.107\ln\left(\frac{133}{k}\right)$ (R^2 = 0.6089)	$u = -0.4613k + 49.381$ (R^2 = 0.5087)
3	$u = 59.306 \cdot e^{-\frac{k}{50}}$ (R^2 = 0.5559)	$u = 29.96 \cdot e^{-\frac{k}{84}}$ (R^2 = 0.5248)
4	$u = 17.79 \cdot e^{-\frac{k}{116}}$ (R^2 = 0.0143)	-

DISCUSSION AND CONCLUSIONS

This exploratory research attempts to investigate fundamental traffic flow parameters as well as the capacity of multilane highways in Bangkok. It is first hypothesized that the HCM approach cannot be directly transferred to Asian countries. Results of the present study reveal some notable evidence that such hypothesis may be justified. Unlike multilane highways in the western region, those in Bangkok possess different traffic patterns, more variety of traffic compositions, and distinctive physical road geometry. All effects combined result in a different value of highway capacity in Bangkok.

There are several key findings from the paper. First, it is found that applying the HCM approach directly for Bangkok's multilane highways is not appropriate. Therefore, local transportation and highway engineers must be very cautious in using HCM formulas for their operation, design, and analysis of highways. Second, due to the significantly high number of access points along multilane highways in Bangkok, the capacity for multilane highways, especially those in shoulder lane, might be substantially reduced. This is mainly because of the lack of traffic control devices and interruptions of local traffic on mainline traffic stream. Thus, applying the capacity values from HCM approach seems to be overstated. Lastly, the traffic composition in Bangkok cannot simply classified into automobiles, trucks, and buses, as normally done in HCM. To estimate for a sound value of capacity, a variety of vehicle composition must be considered, which could lead to different values of adjustment factors.

Results from the present study are still far from definite. Several improvements can be made for future research. As this study suggests a different value of capacity in each lane, it is interesting to further develop a sound methodology to precisely estimate these discrepancies across lanes. It is also encouraged for local engineers to investigate the transferability issue of HCM's capacity for other kinds of highways such as expressways and two-lane highways. Finally, the development of a local version of HCM should be seriously considered in the future to better justify capacity and quality of service of highways.

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