Newly Developed Link Performance Functions Incorporating the Influence of On-Street Occupancy for Developing Cities: Study on Dhaka City of Bangladesh

Conference Paper · January 2011

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Newly Developed Link Performance Functions Incorporating the Influence of On-Street Occupancy for Developing Cities: Study on Dhaka City of Bangladesh[1]

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Word Count: 5,423 words + 2 tables and 6 figures = 7,423 equivalent words (max. = 7,500)

Key Words: Link performance function, on-street occupancy, constrained non-linear regression model, travel time, and parameter

Submission date: August 01, 2010

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[1] Presented in 90th Annual Meeting of the Transportation Research Board, January 23-27, 2011, Washington D. C. USA
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Included in compendium of Paper, the 90th Annual Meeting of the Transportation Research Board (TRB), Washington, D.C., USA, January 23 – 27, 2011. (Available online) URL: http://amonline.trb.org/12kq7p/12kq7p/1

ABSTRACT
On-street occupancy (legal or illegal) makes a substantial fraction of the traffic flow in many developing countries like Dhaka City of Bangladesh and is often the source of localized traffic congestion due to road capacity reduction. In developing countries, especially, illegal occupancy is prevalent. However, little has been done in literature to incorporate the influence of such occupancy on traffic performance. This study therefore attempts to fill in this gap. To the authors' best knowledge, this is the first attempt in developing countries. Taking Dhaka City as an example, this study first conducted a probe vehicle survey to collect the information about travel time over the course of a day (only workdays), which is divided into four time periods (different between Ramadan and non-Ramadan periods), in August and September, 2009. At the same time, on-street occupancy was also counted with respect to each time period. As a result, 30 road sections (links) at Dhaka City Corporation area were selected randomly over the city considering main corridor. Next, using the collected data as well as relevant data from secondary sources, this paper developed new link performance functions that recommend the updated volume – delay relationships by incorporating the influence of on-street occupancy. The functions were estimated for both peak and off-peak hours, and several other types of functions were also estimated for comparisons, where a constrained non-linear regression method was used for the estimation. Empirical studies statistically confirm the effectiveness of the proposed link performance functions. Finally, it is found that completely eliminating on-street occupancy could shorten travel time by more than 20%.

1. INTRODUCTION

On-street occupancy in a major arterial within the city decreases road capacity and increases delays and accidents due to the physical occupation of the space, manoeuvres, pedestrians appearing in between vehicles and other activities associated with parking and street occupancy. There are several examples over the world in developing countries that the on-street occupancy is common (Figure 1). Two types of on-street occupancy are mostly familiar in developing cities like Dhaka City.

In HCM (Highway Capacity Manual), the link capacity has been set to design capacity which is ideal capacity of a link indeed. Due to various activities performed by human being on the street especially in developing countries, the ideal capacity of link is being reduced eventually which is still unaddressed by the current research in the world. But in the real field, the link capacity is reduced because of on-street occupancy e.g. on-street parking, shops etc. As a result, the active lane capacity is shrunk that expedites longer travel time. The capacity reduction factors for adjacent lanes resulting from parking manoeuvres are given in the Highway Capacity Manual. For example, on average 20 manoeuvres reduces capacity by 20% on one lane, 11% on two lanes and 7% on three lane roads (*1*). Therefore, if the lane is occupied by vehicles or temporary structures, it has a significant impact on the reduction of road capacity. On-street occupancy accounts for a substantial fraction of the traffic stream in many regions and is often the source of localized traffic congestion.

There is evidence of on-street parking on many developing cities like Dhaka city of Bangladesh whether it is legal or illegal. On-street parking tends to be more prevalent in CBD (central district business) areas as well as other busy areas in the city. This is particularly the case where intensity of trip demand is high but the off-street parking facility is low. In this way, the motorists block the lanes so as to make it unusable to pass through the traffic smoothly. As a result ultimately the traffic capacity is reduced. Under the traffic regulations, it is an offence to park on a street if the road space is not allocated for parking by the city authority. The city authority can however resolve that part of a street can be designated for parking. In such cases the area needs to be clearly marked out using road markings and signs. It should be noted however that a consequence of formalizing areas of the road space where parking is permitted may require strengthening of the traffic flow and/or increased maintenance expenditure otherwise parking on street remains illegal. On-street shops are also common feature in developing cities like Dhaka City from last a couple of decades. Because of the obstruction for smooth traffic flow and nuisances caused by on-street shops activities, the city authority is employing various policies such as (i) areas allocated as "hawker market with hawker permitted places", (ii) hawker licenses etc. Hawking on the street should be regulated through these kinds of policies to keep traffic flow smooth.

The most common approach to reflecting the overall impact of travel time in travel demand models is the Bureau of Public Roads (BPR) type curve. BPR function is very commonly used in traffic assignment analysis to find out the shortest path considering lower travel time. One advantage of the BPR type curve is that the parameters of the curve can be calibrated to reflect locally observed volume–delay relationships that may vary depending on roadway class and driver behavior. A disadvantage of the standard BPR formulation is that it does not realize the influence of road capacity reduction due to on-street occupancy such as parking and shops and how that occupancy may contribute to congestion which is very common scenario in developing city like Dhaka. Thus, the common and traditional BPR type function does not work properly under severe traffic congestion due to influence of on-street occupancy especially in case of developing cities.

Nowadays, it is very common in developing countries that the road capacity is reducing due to on-street occupancy. On-street parking is one of the most relevant on-street occupancy in urban areas because of limited parking facility over the city. Simultaneously, some on-street shops are playing role to reduce the road capacity which promotes the longer travel time. In a nutshell, the on-street occupancy has momentous impact on travel time determination. As a result, this research was motivated to analyze whether the travel time might be improved or not if the on-street occupancy (e.g. on-street parking, on-street shop etc) could be eliminated. Therefore, with the consideration of this new concept, the present research has introduced new Link Performance (LiP) Functions incorporating the influence of on-street occupancy. With considering this concept, the travel time improvement can be observed by the elimination of on-street occupancy.

This paper is organized as follows. Section 2 gives a short review of recent works relating to BPR and link performance function as well as travel time function. Section 3 provides the data sources and data collection process. Sections 4 covers the characteristics of traffic flow in Dhaka City. In section 5, new link performance function has been derived. Section 6 expresses travel time improvement trails through newly developed LiP functions. Finally, section 7 offers some concluding remarks as well as suggestions for further research.

2. PREVIOUS STUDIES

Link performance functions play a central role in models of traffic systems (*2, 3, 4 and 5*). However, whilst a considerable body of research exists on various elements of the modeling process relatively work has been done on practical aspects of estimating link performance functions from observed data. A fundamental reason for this is the relative scarcity of the necessary of data sets. Paired travel time-flow data is both difficult and expensive to obtain (*6*). Nevertheless, there is a danger that the potential benefits of increasingly detailed transport models will not be realized because of the lack of precision introduced by poorly chosen or calibrated travel time-flow functions.

The travel time function proposed by Davidson (*7 and 8*) for transport planning purposes has been subject to much discussion and efforts of calibration and improvement including some controversy over the meaning of its parameters. A general discussion on the usefulness of the Davidson function has been discussed by Rose, et al. (*9*). Modified forms of Davidson's function have been proposed to obtain finite values of travel time for flows near and above capacity. Tisato (*10*) makes new suggestions for improving Davidson's function based on the author's earlier work (*11 and 12*). From the derivation of the original Davidson function discussion, it is concluded that the function suffers from an inconsistency in its basic parameter definitions as pointed out by Golding (*13*). An alternative interpretation of the delay parameter is considered, but this leads to another inconsistency. A new travel time function is proposed as an alternative to Davidson's function to overcome the conceptual and calibration problems. In the proposed function, the delay parameter takes a meaning consistent with the formulae used for estimating intersection delays. Both the steady-state and time-dependent forms of the new function are given for detailed discussion on the subject of steady-state and time-dependent function forms (*14*).

The explicit measurement or quantification of congestion has many uses. Such measures help communities identify and anticipate traffic problems, by location, severity, and time of day. The magnitude of increased travel time due to congestion and improvement of travel time provides a basis for targeted investment and/or policy decisions. This paper provides dynamism of travel time by developing new LiP functions for Dhaka city incorporating the influence of on-street occupancy.

Referred to as the traditional "BPR (Bureau of Public Roads) Formula" (*15*), the following is a common travel-time assumption:

$$Ta_i = T0_i\,(1 + \alpha(V_i/C_i)^{\beta}) \tag{1}$$

Where: Ta_i= Congested travel time in link i;
$T0_i$ = Free-flow travel time in link i;
V_i = Traffic volume in link i;
C_i = Capacity in link i; and
α and β are parameters (generally α = 0.15 and β = 4.00)

Alpha (α) is the scale parameter and beta (β) is the shape parameter. These α and β can vary city to city. This equation assumes that parameter α is the ratio of travel time per unit distance at practical capacity to that at free-flow, and parameter β determines how fast the curve increases from the free-flow travel time. Yet actual travel time relationships remain poorly understood in developing cities like Dhaka. On-street parking and shops occupy edge of road sections which makes complexity of traffic flow and eventually it precedes higher travel time.

If capacity of 10,000 vehicles per hour corresponds to a four-lane high-design freeway, then the loss of one of these four lanes (by a crash or creation of a construction work zone or illegal occupancy, for example) results in an effective capacity of 7,500 vehicles per hour. At a demand of 13,000 vehicles per hour, travel times will jump by 115 percent, from 2.0 minute per mile to 4.3 minute per mile. This is now 330 percent longer than travel time under free-flow conditions. Under this dramatic situation, speeds would be just 14 mile per hour – far less than the free-flow speed of 60 mile per hour and well below the four-lane speed of 30 mile per hour (*16*).

The study on BPR functions in developing countries is not available to describe here. At the same time, the application of BPR function in developing counties is not also obtainable in previous research archive. To the authors' best knowledge, this is the first attempt to research in developing countries relating to BPR functions.

After investigating the previous studies, the research gap is identified between what factors are currently considered for estimation of link performance functions (α and β) and what would be necessary to incorporate for more effective estimation of LiP functions for developing cities. Based on the information gathered through review and discussions above, it is evidence that in context of link performance functions all the researchers have discussed about the practical road capacity and volume to determine the travel time function i.e. volume – delay function previously. There is no research with regards to road capacity reduction due to on-street occupancy such as on-street parking and shops to determine the α and β. This is a new concept to include the capacity of on-street occupancy into the link performance functions. In the previous study conducted by other researchers, they assumed all the lanes active for traffic flow but as a matter of fact it is not true specially for developing cities. In developing cities, most of the cases at least one lane per link is obstructed by the on-street occupancy; therefore the overall road capacity is reduced which has effect in link performance functions. This is the new strength of this present study.

3. DATA SOURCES AND METHODS OF DATA ANALYSIS

Most of the data of this research was collected from primary source. Nevertheless, a substantial amount of information regarding this research was also collected from secondary source such as Department of Environment (Bangladesh), Dhaka Transport Coordination Board, Dhaka Integrated Transport Study, the Strategic Transport Plan for Dhaka, Dhaka City Corporation (DCC), RAJUK (Dhaka Development Authority) etc. However for primary data relating to traffic count survey, the following features were emphasized:

- Identification of links of Dhaka city;
- Traffic volume;
- Travel time with a probe vehicle;
- Link length and road width (no. of lanes); and
- On-street occupancy

The field study was carried out in Dhaka city from the early August 2009 to mid of September 2009. For the traffic count survey, the following 30 links (Figure 2) over DCC area were selected randomly by considering the characteristics of main corridor, connected to commercial, educational and residential areas and it was also intention to cover entire Dhaka city approximately. The traffic count survey was implemented in work days i.e. from Sunday to Thursday. Two links were surveyed each day and traffic was counted four hours per link. Each hour was divided into four time segments as follows:

08:00 to 09:00*	12:00 to 13:00	17:00 to 18:00*	21:00 to 22:00
1. 0800 – 0815	1. 1200 – 1215	1. 1700 – 1715	1. 2100 – 2115
2. 0815 – 0830	2. 1215 – 1230	2. 1715 – 1730	2. 2115 – 2130
3. 0830 – 0845	3. 1230 – 1245	3. 1730 – 1745	3. 2130 – 2145
4. 0845 – 0900	4. 1245 – 1300	4. 1745 – 1800	4. 2145 – 2200

* During Ramadan, changed survey times 08:30 – 9:30 and 15:30 – 16:30 were applied only in morning and afternoon respectively.

In terms of travel time survey, a car was rented as probe vehicle. The car was driven through all the selected links and the travel time was counted by the authors at the same 16 times as traffic count survey a day in between 8:00 to 22:00.

In this research, relevant and required factors were investigated i.e. (i) congested travel time, (ii) free flow travel time; (iii) traffic volume; (iv) traffic capacity; and (v) link length and road width. Among these variables, free flow travel time, volume and capacity were used as independent variables while congested travel time was put as dependent variable to estimate the link performance function parameters. To estimate the parameters, constrained nonlinear regression model was applied. Finally, travel time improvement trails have been investigated to quantify the travel time improvement scenarios.

4. CHARACTERISTICS OF TRAFFIC FLOW IN DHAKA CITY

4.1 Travel Time – Flow Relationship

Figure 3 portrays the raw data with the traffic flow in PCU on the horizontal axis and the speed in kmph on the vertical axis. This curve is also known as Q – V curve. From this figure, it is observed that the Q – V curve developed by the primary data collected from Dhaka city does not match perfectly with the ideal Q – V curve due to severe traffic congestion situation in Dhaka city but it is evidence that there are similarities to each other. In this figure, 60 km per hour was considered as free flow speed.

Figure 4 depicts that the association between travel time per km in minutes and volume-to-capacity ratio. The relationship between travel time and v/c ratio is also positive. In terms of the regression equation of this figure, the rate of change of travel time is 5.62 as a function of changes in v/c which is moderately acceptable with the level of significance of $R^2 = 44\%$. .

4.2 Impact of On-Street Occupancy

Figure 5 delineates percentages with time segment a day on horizontal axis and percentages on vertical axis. The time segment has been also categorized into four time slots. Two (morning and afternoon) of them are treated as peak time and others (noon and night) are off-peak time. From the figure 5 it is apparent that afternoon is mostly affected by the on-street occupancy because of floating shops and not in service vehicles on the streets.

Table 1 illustrates the relationship by analyzing the co-efficient of correlation between on-street occupancy and some selected travel indicators. From the table 1, it can be observed that the strength of relationship is very strong between on-street occupancy and selected travel indicators. The changes of average delay time (which is related to travel time) have the highest coefficient of correlation (0.983) which was also highly significant as P-value < 0.05. On the other hand, the changes of average speed and changes of average travel time didn't meet the minimum significance level statistically.

As the strength of co-relation between travel indicators and on-street occupancy mentioned in table 1 is very high, it implies that on-street occupancy is playing a vital role on required travel time. As a result, on-street occupancy has been employed to improve the LiP functions.

5. IMPROVEMENT OF LINK PERFORMANCE (LiP) FUNCTIONS

As discussed earlier, BPR function proposed by Federal High Way Administration of US Transport Department uses to achieve the effect of capacity restraint. In short, capacity restraint assignment is an iterative process in which the travel impedance is adjusted in terms of a predetermined relationship between the capacity of the link and the volumes assigned to the link. Many functional forms of volume-delay functions have been proposed and used in the practice in the past. In the previous studies, the severe traffic congestion condition was not included and also the on-street parking and street occupancy was not incorporated to estimate the LiP function parameters. To fill in the gap, the concept of on-street occupancy has been incorporated to estimate LiP function parameters for Dhaka city of Bangladesh.

It is known to us that Dhaka is a city of traffic congestion. For example, two hours to get to the place that would under normal circumstances would take only half an hour is a usual phenomenon in Dhaka city now. Most of the day one faces one or the other traffic jam on the way to his/her destination. Therefore, Dhaka city is the appropriate area to investigate the LiP function parameters under the severity of traffic congestion due to on-street occupancy. In fact, till today the city dwellers assume roughly the increase of travel time in Dhaka. But through this analysis, the scale and shape of the travel time has been quantified due to on-street occupancy.

5.1 Function and Factors

The most widely used volume-delay function has been modified to illustrate the LiP function parameters incorporating the on-street occupancy. One lane has been excluded once on-street occupancy is appeared. The LiP functions have been categorized considering on-street occupancy and day time period as follows.

(1) Incorporating on-street occupancy

LiP function for whole day
LiP function for peak hour
LiP function for off-peak hour

(2) Without incorporating on-street occupancy

LiP function for whole day
LiP function for peak hour
LiP function for off-peak hour

These LiP functions are expressed by the following equations:

(1) Incorporating on-street occupancy

LiP function for whole day: $Ta_i = T0_i[1 + \alpha(V_i/(C - C_{io}))^\beta]$ (2)

LiP function for peak hour : $Ta_{i(p)} = T0_{i(p)}[1 + \alpha(V_{i(p)}/(C - C_{io}))^\beta]$ (3)

LiP function for off-peak hour : $Ta_{i(op)} = T0_{i(op)}[1 + \alpha(V_{i(op)}/C - C_{io}))^\beta]$ (4)

(2) Without incorporating on-street occupancy

LiP function for whole day: $Ta_i = T0_i[1 + \alpha(V_i/C)^\beta]$ (5)

LiP function for peak hour : $Ta_{i(p)} = T0_{i(p)}[1 + \alpha(V_{i(p)}/C)^\beta]$ (6

LiP function for off-peak hour: $Ta_{i(op)} = T0_{i(op)}[1 + \alpha(V_{i(op)}/C)^\beta]$ (7)

Where:

Ta_i = Congested travel time in link *i*;
$Ta_{i(p)}$ = Congested travel time in link *i* at peak hour;
$Ta_{i(op)}$ = Congested travel time in link *i* at off-peak hour;
$T0_i$ = Free-flow (60kmph) travel time in link *i*;
$T0_{i(p)}$ = Free-flow (60kmph) travel time in link *i* at peak hour;
$T0_{i(op)}$ = Free-flow (60kmph) travel time in link *i* at off-peak hour;
V_i = Traffic volume in link *i*;
$V_{i(p)}$ = Traffic volume in link *i* at peak hour;
$V_{i(op)}$ = Traffic volume in link *i* at off-peak hour;
C = Capacity [1741 PCU per lane per hour (*18*)];
C_{io} = Capacity occupied by on-street parking and street occupancy in link *i*; and
α and β are parameters to be estimated.

Networks originally prepared with the default coefficients of the volume-delay function (α=0.15 and β=4.0) without taking into consideration of the lane occupancy. With these coefficients, link capacity was set to design capacity, normally taken to be level-of-service *C* in earlier editions of the Highway Capacity Manual. More recent travel forecasting packages have generally retained these traditional coefficients and definition of link capacity. Technically, design capacity should be interpreted as the volume that causes free speed to drop by 15 percent. There are valid reasons for trying to retain this definition of capacity in previously calibrated networks. In previous studies, the severe congestion condition due to on-street occupancy is not considered. Therefore, the current study has compensated this gap.

5.2 Parameters Estimation

To determine the parameters α and β, the LiP functional form was first transformed as follows:

$$ln\ (Ta_i/T0_i\ -1) = ln(\alpha) + \beta\ ln(V_i/C) \quad (8)$$

A constrained nonlinear regression analysis was performed where the dependent variable is $ln(Ta_i/T0_i\ -1)$; and $ln(\alpha)$, and $\beta\ ln(V_i/C)$ are the independent variables. In this model, α and β were defined as parameters to be estimated. The road lane capacity (*C*) was followed by the findings of the report of Strategic Transport Plan for Dhaka city (*17*) and travel time and traffic volume used in the analysis were determined from the field survey directly during August and September in 2009 by the authors.

It is already mentioned earlier that α is the scale parameter and β is the shape parameter in the link performance function. That means, the α value determines how much speed is dropped or how much travel time is increased compared to the free flow condition when volume equals to the capacity. On the other hand, the β value determines how fast the curve increases from the free-flow travel time.

Table 2 elucidates the estimations results considering and without considering the on-street occupancy in the equations accordingly. The value of α parameter is 3.59 and value of β parameter is 0.40 in terms of LiP function for whole day with consideration of on-street occupancy.

In the same table, α value 3.34 was found considering whole day at a stretch without considering on-street occupancy and it was taken into account also that all lanes were active. It means that the travel time is increased at 334% i.e. by 3.34 times. On the other hand, according to LiP function for whole day incorporating on-street occupancy, the increased travel time is 359% i.e. 3.59 times with compared to free flow time.

Regarding LiP function for peak hour, the value of α is mostly higher at 3.82 as the on-street occupancy was included. It implies that the speed has been reduced at higher percentage (382%) with compared to free flow speed at peak time. As a result, the travel time has been increased by 3.82 times during peak hour incorporating the on-street occupancy whereas without incorporating the on-street occupancy the travel time is increased by 3.67 times. With respect to off-peak hour, α value is 3.36 if on-street occupancy is considered while α value is 3.01 if on-street occupancy is not considered which illustrates that the speed are 336% and 301% dropped with compared to free flow during off-peak time respectively. As β values are not high for all the cases (table 2) it signifies that the speed does not drop abruptly. Indeed, it is already dropped due to severe traffic congestion in Dhaka city.

Considering the statistical measures of the model for LiP function parameters determination, the obtained R^2 and t-value show better performance as a model. In case of incorporating on-street occupancy, the goodness of fit are satisfactory with R^2 of 0.70, 0.67 and 0.66 for LiP function for whole day, peak hour, and off-peak hour respectively whereas in case of without incorporating on-street occupancy, the goodness of fit are satisfactory with R^2 of 0.60, 0.61 and 0.63 for LiP function for whole day, peak hour and off-peak hour respectively. In terms of t-value, the estimates are passed at 95% and more level of significance. So it can be said that the overall fit of the model is reasonable with R^2 and t-value which mean the estimated parameters in the model statistically acceptable. However, among these model fits, the LiP function with considering on-street occupancy is better than LiP function without considering on-street occupancy due to higher R^2 value. In the following section, the LiP function for whole day, peak and off-peak hour incorporating on-street occupancy have been considered since these functions show the comparatively better model fit than others and also these LiP functions are suitable for Dhaka case.

6. TRAVEL TIME IMPROVEMENT TRIALS THROUGH IMPROVED LiP FUNCTIONS

As it is said earlier that the on-street occupancy has momentous impact on travel time determination. It is already evidence through link performance analysis described in section 5 that on-street occupancy reduces road capacity which contributes to make travel time longer. In this section, trails considering different percentages of on-street occupancy has been examined to quantify the variation of travel time improvement.

In this section, the travel time improvement has been evaluated using the newly developed LiP functions. Elimination of on-street occupancy was tested in this section to assess its suitability as travel time improvement indicator. In context of LiP functions, it was observed specifically that the on-street occupancy has significant impact to improve travel time. In table 2, the LiP functions lead the better estimation as the R^2 value is 0.70, 0.67 and 0.66 respectively. On the other hand, these LiP functions with considering on-street occupancy are more suitable for Dhaka city in the real field. Accordingly, the equations 2-4, the α and β values have been used to analyze travel time improvement trails.

Therefore, this section has been discussed about the various trails relating to on-street occupancy to determine the travel time improvement. There are five trails such as (1) If 100% capacity of on-street occupancy lane is considered (trial 1); (2) If 75% capacity of on-street occupancy lane is considered (trial 2); (3) If 50% capacity of on-street occupancy lane is considered (trial 3); (4) If 25% capacity of on-street occupancy lane is considered (trial 4); and (5) there is no on-street occupancy (trial 5).

Suitability of elimination of on-street occupancy can be realized in some ways which are presented in figure 6. From this figure1, it is evidence that the travel time can be improved at 21.60% in case of whole day at a stretch if the on-street parking and street occupancy is removed. So if it is assumed that the capacity of on-street occupancy lane is lessening at different percentages (trails 2 – 5), travel time improvement is appeared gradually. In terms of trail 2 which means only the consideration of 75% capacity of on-street occupancy lane, the travel time is improved at 7.87% with compared to consideration of 100% capacity of on-street occupancy. Similarly, the travel time has been improved at 10.27% and 12.40% in terms of trails 3 and 4 respectively. Relating to peak hour condition, the travel time can be improved at 24.93% if there is no on-street occupancy. From the trails 2 to 5, it is evidence that the travel time is improved gradually, i.e. at 8.7%, 11.57%, 14.01%, and 24.93% respectively. In the same way, from the figure 6, with regard to off-peak hour case, the travel time can be improved at 22.33% if on-street occupancy is assumed zero. From the trails 2 to 5, it supports that the travel time have been improved progressively, i.e. at 7.12%, 9.45%, 11.51%, and 22.33% respectively.

7. CONCLUDING REMARKS

This paper presented the newly developed Link Performance (LiP) function for severe congested city like Dhaka city of Bangladesh. At the same time, it is also accounted for the influence of on-street parking and street occupancy. The traditional BPR function representing the speed–flow relationships for roadway facilities is modified to estimate the α and β of LiP functions specifically incorporating the impact of the severe traffic congestion condition and proportion of on-street parking and street occupancy.

Some interesting properties of the speed–flow curves may be explored through considering the on-street parking and street occupancy. First, the functional form performs reasonably under certain extreme conditions. For example, when V is close to zero, indicating a near free flow condition, the congested travel time estimated from the equation is close to the free-flow travel time. Also, when on-street occupancy = 0.00, meaning there are no on-street occupancy, the functional forms becomes the standard BPR function, although the values of coefficients are different. Second, as compared to the LiP functions under severe congested city like Dhaka, the congested speed estimated from the speed–flow curve is much lower when volume is at capacity. For the BPR function represented by Equation 1, the multiplier is 0.15, indicating there is a 15% drop in speed when the volume approaches capacity. For the newly developed LiP functions, the multipliers are a monotonically increasing function of on-street occupancy, which means the estimated speed will drop at the value of α when the V/C ratio is close to 1. Finally, a smaller value of exponent (β) of V/C in the LiP functions indicates that the speed is not so sensitive to changes in traffic flow. However, the speed drops when V/C gets close to 1.0 is not as abrupt as the standard BPR function, where the standard exponent of V/C is 4.0.

After analyzing the travel time improvement trails, it can be concluded precisely that elimination of on-street occupancy can improve travel time radically. Therefore, new aspect of flexible link performance to utilize road space by incorporating on-street parking and street-occupancy should be recommended. And also travel time improvement to increase the mobility should be enhanced. Therefore, the future research is required on parking and street trading management in order to travel time improvement and also re-estimation of travel demand based on the proposed function is imperative for transportation planning and management.

ACKNOWLEDGEMENT

Entire cost of traffic count survey of this study was provided by the Global Environmental Leaders Education Program for Designing a Low Carbon Society (GELs) of Hiroshima University, Japan.

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Included in compendium of Paper, the 90th Annual Meeting of the Transportation Research Board (TRB), Washington, D.C., USA, January 23 – 27, 2011. (Available online) URL: http://amonline.trb.org/12kq7p/12kq7p/1

List of Tables/Figures

TABLE 1 Correlation Co-Efficient (r) between On-Street Occupancy in Percentage and Some Selected Factors

Variables	On-street occupancy	Change of avg. travel time per km in min	Change of avg. speed (km/hr)	Change of volume-to-capacity (v/c)	Change of avg. delay time min/km	Change of avg. PCU lane/15 min
On-street occupancy	1.00	0.841	0.815	0.974 *	0.983 *	0.977 *
p-value	-	0.159	0.185	.026	0.017	0.023

* Correlation is significant at the 0.05 level
(Source: Field survey, 2009)

TABLE 2 Parameter Estimation Results Incorporating and Without Incorporating On-street Occupancy

Types of LiP functions	LiP function parameters (N = 480; free flow 60km/hour)									
	Incorporating on-street occupancy					*Without incorporating on-street occupancy*				
	Alpha (α)		*Beta (β)*		R^2	*Alpha (α)*		*Beta (β)*		R^2
	Estimates	t-value	Estimates	t-value		Estimates	t-value	Estimates	t-value	
For whole day	3.59	5.189	0.40	3.259	0.70	3.34	3.984	0.41	2.948	0.60
for peak hour	3.82	4.931	0.47	3.951	0.67	3.67	4.967	0.55	3.025	0.61
for off-peak hour	3.36	4.591	0.46	2.893	0.66	3.01	4.333	0.49	2.003	0.63

(Source: Field survey, 2009)

FIGURE 1 On-street Occupancy

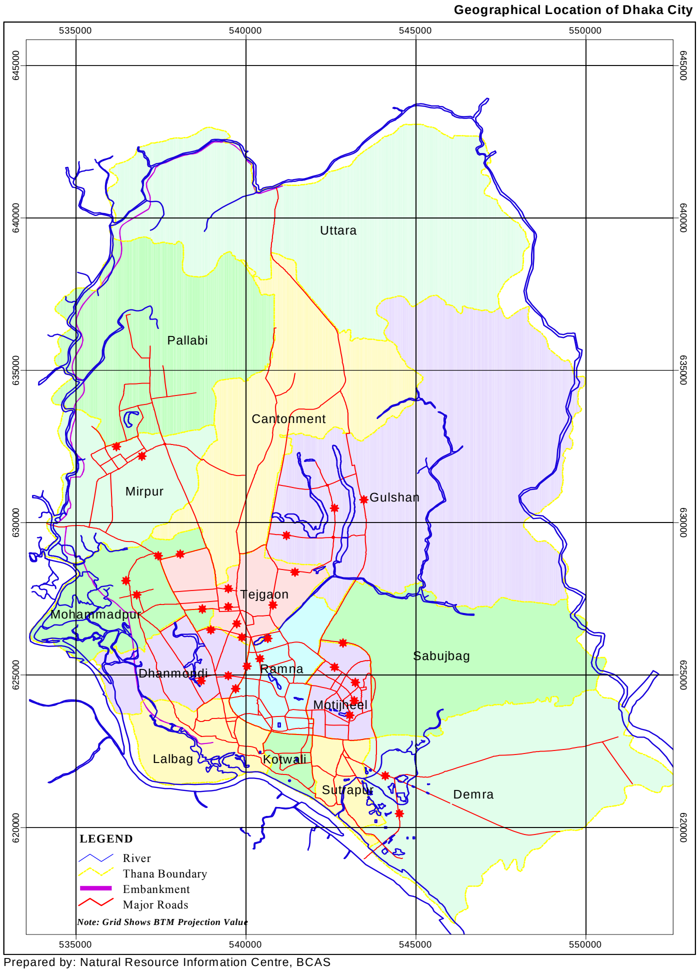

FIGURE 2: Location of Surveyed Links on Dhaka City Map

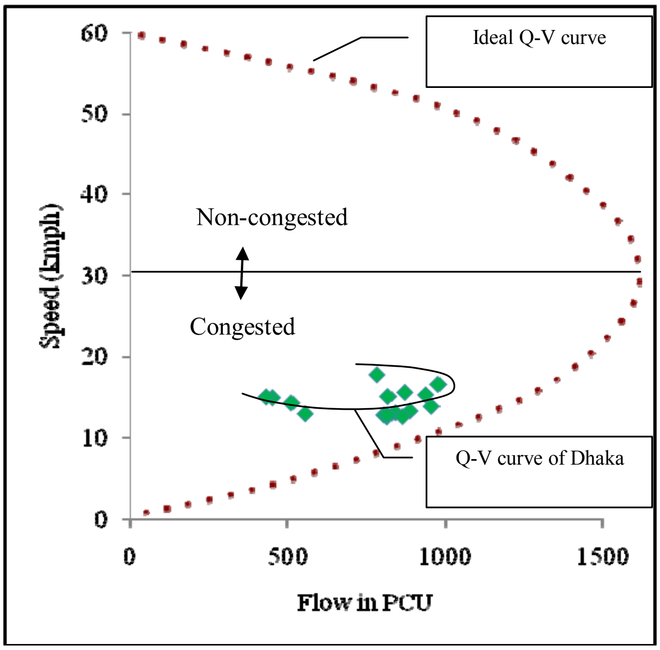

FIGURE 3 Comparison between Q – V Curve Based On Primary Data Collected From Dhaka City and an Ideal One

(Source: Field survey, 2009)

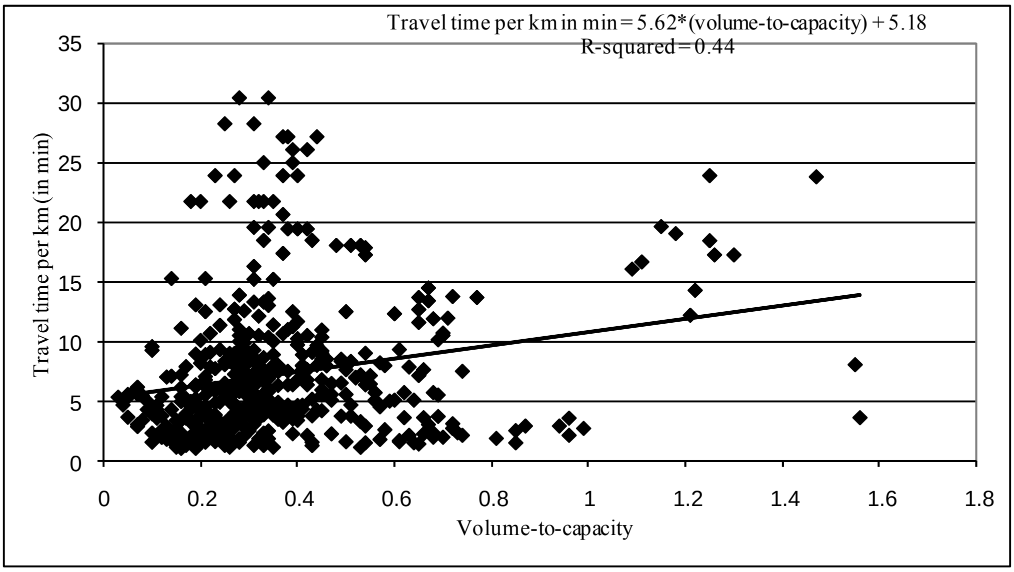

FIGURE 4 Regression to Predict Travel Time by V/C Ratio

(Source: Field survey, 2009)

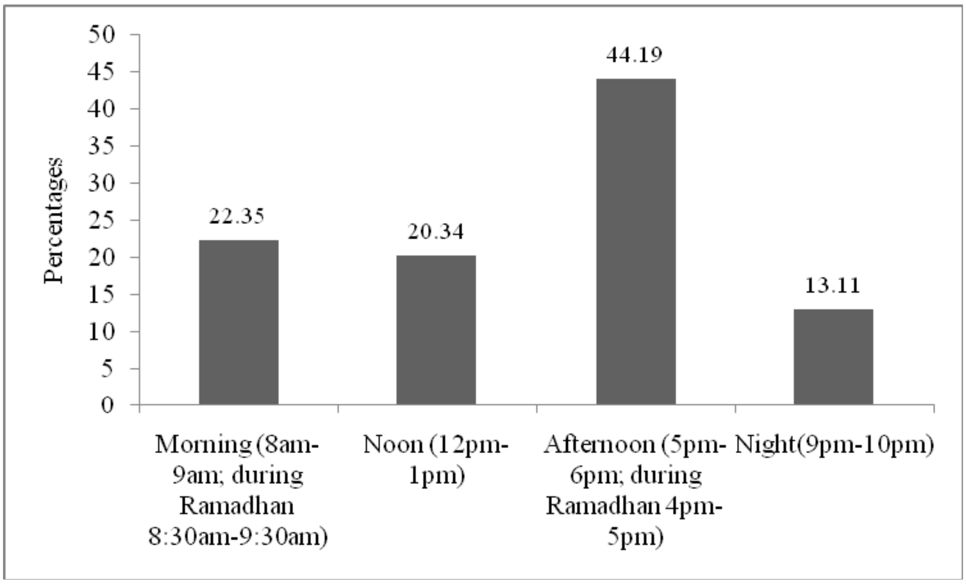

FIGURE 5 Status of On-Street Occupancy by Time Segment a Day

(Source: Field survey, 2009)

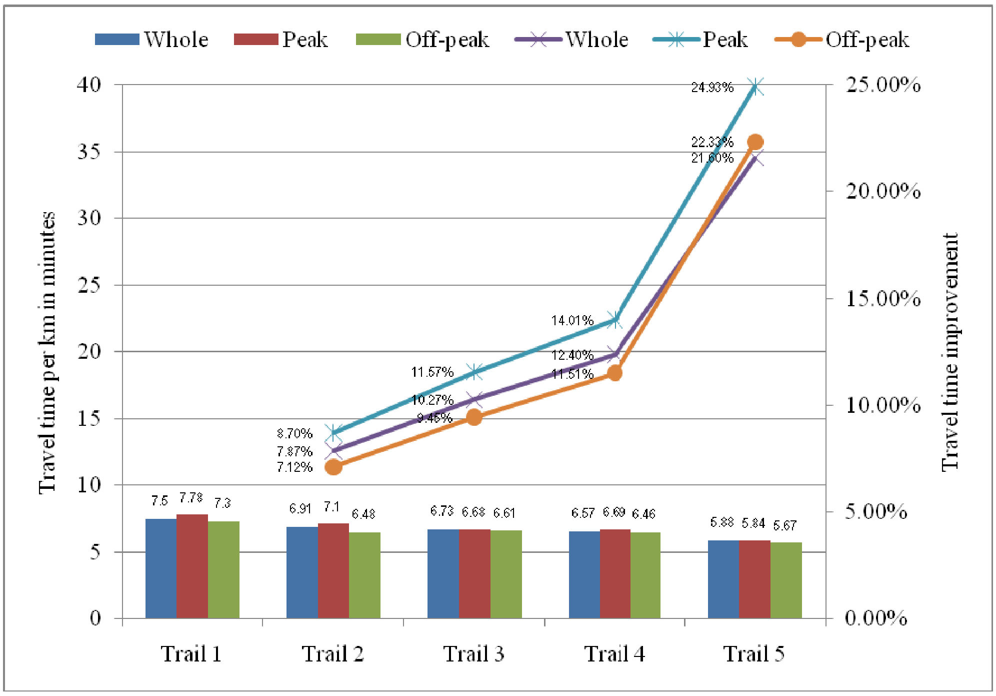

FIGURE 6 Illustrations of Travel Time Improvement Trails through Newly Developed LiP Functions

Source: Field survey, 2009