**Performance Assessment of the Major Intersections along One of the Highly Congested Routes in Dhaka City**

**Abstract**

This paper analyzes the existing condition and factors behind the condition of major intersections of Dhaka city along one of the highly congested routes: Pallabi to Motijheel bus route. Dhaka city has been experiencing over extending growth in terms of population and development since last three decades. For satisfying the travel need of the ever increasing population, the transportation system of this city is undergoing enormous difficulties. Traffic congestion is one of the major problems regarding the transportation system of the capital for which the inhabitants are suffering in greater extent. The operational level of different intersections has remarkable influence on the holistic transportation management system. This paper tries to explore the condition of intersections and its impact from diverse perspectives. The performance of intersections of the study route has been assessed through the primary data collected from the intersections. The volume survey has been conducted to measure the queuing volume and stopping time of the vehicles in both morning and evening peak. Consequently, moving observer method has been followed to obtain the journey speed and running speed of the connecting link of the intersections. After data analysis, some major findings like level of service of the intersections have been obtained. It has been found that performance of most of the intersections in peak period is miserable. Finally some recommendations have been proposed.

**Keywords:** Traffic congestion, Queuing volume, Stopping time, Level of Service, Transportation Demand Management (TDM)

**1. Introduction**

Dhaka city, the capital of Bangladesh can be compared to the hub of commercial, cultural and political undertakings of the country. The city being national gateway has now been considered as top 16th mega city and 9th most populous city of the world (newgeography, 2012). The fast growth of population with concomitant limited available space for new transport infrastructures have been aggravated the high congestion rate in Dhaka (The World Bank, 2005). Albeit the area of Dhaka city is less than one percent of country’s total area, it supports about 6.2% of total population and 30% of total urban population (BBS, 2011). Lack of proper implementation of transportation planning as well as effective management systems and strategies are leading towards over saturated roads with vehicles and making the city motionless for hours every day. For the traffic congestion, working hours are wasted in the roads which affect the overall economy indirectly as well as decrease the productivity in a greater magnitude. The rise of scattered development without appropriate monitoring has been witnessed by the capital within a glimpse of last three decades, which has been resulted in huge urban transportation system difficulties (Khan and Hoque, 2013). Level of disparity in transportation demand and supply scenario is observed in the city transportation system. Total carriageway width is often unable to occupy vehicle according to its capacity as the right of way has been galloped by the on street parking, venders, loading-unloading of buses etc. Intersections are nodal points in the transportation network and efficiency of operation of these nodes has influence over the entire transportation network (Hadiuzzaman, 2008).

The major queuing and delay points are the traffic intersections of Dhaka. The delays witnessed in the roads are basically associated with the intersections where conflicting movements of vehicles are separated and simultaneously controlled by the traffic. In this paper, the performance of the intersections has been aimed to measure. The intersection assessment has been done by analyzing the teeming volume of traffic gathered at the intersections. From Pallabi to Motijheel bus route has been selected as the study area and the data has been collected from of surveys like volume survey, moving observer surveys in the consecutive 21 intersections. Different types of analysis have been done to perceive the impact of heterogeneous traffic pattern, queuing pattern, adjacent land use, measurement of stopping times of the intersections based on the volume survey and through the moving observer survey the traffic flow, journey and running speed of the link connecting intersections has been measured. Thus the entire study has been executed for assessing the performance of the intersections in a detailed oriented and precise way. The objectives of the study are to explore the existing condition of major intersections along the study route and to analyze the factors behind intersection congestion.

**2. Performance Assessment: A Universal Approach for Congestion Analysis**

Traffic congestion is one of the main social and economic problems in urban areas related to transportation industries in both developed and developing countries. However, performance of intersections or roadways is usually measured using Level of Service (LOS). It is generally used for categorizing highways/intersections based on traffic flow and assigning quality levels of traffic established on performance measure like delay, speed, density etc. LOS standards are represented using letters A through F where letter A is considered as the best and F is considered as the worst for representation highway capacity (Ryus et al., 2011). Performance assessment is a universal approach for analysis of road traffic congestion.

Tamin (2003) conducted a research in Indonesia on evaluation of traffic performance at several signalized intersections which was done using the standard of 1997 Indonesian Highway Capacity Manual (IHCM). Another research was performed by Bang and Hai-Long (1999) on traffic performance modeling for intersections on Interurban and township roads in mainland East Asia. Camp Dresser and McKee Inc. (2010) performed a study in Polson Area about transportation plan and existing intersections’ level of service (LOS). In that study, LOS used a means for identifying intersections which were experiencing operational difficulties as well as providing a scale to compare intersections with each other. According to another research by Chancey et al. (2010) on the effects of volume on driver critical gap acceptance at a two-way stop controlled intersection in Florida, level of service (LOS) was being defined as a function of the delay at the given intersection. Prasetijo (2007) conducted a study on capacity and traffic performance of unsignalized intersections under mixed traffic conditions to understand the traffic intersection context in the developing countries.

Traffic congestion in road network in developing countries like Bangladesh is a serious problem which is a result of rapid growth of number of vehicles and weak performance of intersections. Hoque and Imran (2007) conducted a research on the delay of non-lane based heterogeneous road traffic condition was reviewed to understand the present signalized situation of the intersections of Dhaka city. They modified Webster’s delay formula to make it applicable under non-lane based mixed road traffic condition. In another study, Hadiuzzaman (2008) considered saturation flow and delay model for performance assessment of intersections at signalized intersections in Dhaka city.

**3. Study Area**

Pallabi to Motijheel Route of Dhaka city has been selected as study area and twenty one intersections have been identified within the study route. The route has a length of 13.41 kilometers. As its one end there stands Shapla Chattar, Motijheel which is the central business district of Dhaka and at the other stand there exists Kalshi, Mirpur. This route runs through the following intersections.

|  |  |
| --- | --- |
| 1. Shapla Chattar | 12. Shahbagh |
| 2. Janata Bank | 13. Ruposhi Bangla |
| 3. Biman Office | 14. Bangla Motor |
| 4. Shilpa Bank  | 15. SAARC Fowara |
| 5. Shilpa Bank-02 | 16. Khamarbari |
| 6. RAJUK Intersection | 17. Bijoy Sarani (Novotheater) |
| 7. Gulishtan | 18. Bijoy Sarani |
| 8. Zero Point | 19. Agargaon |
| 9. Paltan | 20. Mirpur 10 |
| 10. Kadam Fowara | 21. Mirpur Benarasi Polli |
| 11. Matsha Bhaban |  |

**4. Methodology**

To analysis the existing conditions of the selected intersections, primary data has been collected through volume survey and moving observer survey. Through volume survey all the legs of an intersection have been surveyed for one hour both in morning and evening peak. Morning peak period has been considered from 8:00 AM to 11:00 AM and evening peak period has been considered from 4:00 PM to 6:00 PM. Survey has been done on three working days. Queuing volume data has been collected with stopping time at each signal. Moving Observer survey has been conducted from Kalshi to Motijheel in a working day starting from 9 AM to find out the journey and running speed in both northbound and southbound directions. After collecting all the data, the existing performance of intersections has been analyzed using level of service (LOS) of intersections based on average stopping time. The standard of Indian Highway Capacity Manual (Indo-HCM), 2011 has been used to determine the LOS of intersections in this paper since it is more applicable in the context of Dhaka. Factor analysis was another objective of the study which has been done based on literature review, surrounding land use of the route and intersections, the findings and observations of the study.

**5. Data Analysis**

***5.1 Queuing Volume Analysis***

Queuing volume at all legs of each intersection has been determined from volume survey both in morning and evening peaks. Figure 1 shows the comparison among all the intersections’ queuing volume in morning and evening peak.

Figure 1: Comparison between morning and evening Queuing volume in intersections

Figure 1 presents that the volume in morning peak period and evening peak period are close in terms of value in case of each intersection except from Agargaon intersection where the morning volume (549.51 PCU/min) is comparatively much higher than that of the evening volume (345.67 PCU/min). If only the morning Queuing volume is compared then it has been explicated that Agargaon intersection has the highest volume (549.51 PCU/min), Mirpur Benarasi Polli has the second highest volume (230.81 PCU/min) and Mirpur 10 has the third highest volume (221.09 PCU/min). In case of the evening queuing volume, these three intersections are found to have the highest queuing volume and the ranking is also similar. On the contrary, in evening peak Gulishtan (12.42 PCU/min), Shilpa Bank-02 (20.59 PCU/min) and Shilpa Bank (41.09 PCU/min) are three intersections having lowest volumes.

The factors behind such findings are manifold. At Agargaon, number of Government and International Organizations are located. For example Passport office, LGED office, SPARRSO, PSC, Bangladesh Betar, Sher-E-Bangla Nagar Agricultural University, IDB Bhaban, BICC conference center etc. These are the workplaces which generate plentiful traffic in the area. Agargaon intersection is connected with both Mirpur Road and VIP Road (through link road) which are two of the major roads of Dhaka city that leads to greater traffic volume. The second highest volume has been found at Mirpur 10 intersection which is defined as the center point of Mirpur area, creating access with all the sections of Mirpur. Mirpur is a high density residential and mixed land use area generating numerous queuing volumes. For the same reason, Mirpur Benarasi Polli has also higher queuing volume. The factor for lowest queuing volumes in evening peak in Gulishtan, Shilpa Bank-02 and Shilpa Bank is the peak period generates more volume in home direction. As these intersections are within work place (Motijheel), they generate less queuing volume.

To portray the comparative scenario of the legs of each intersection, which of intersection leg generate the highest queuing volume is identified. An analysis on the direction of the highest volume of intersection leg facing highest volume has been done through the findings of the table 1 and has been displayed in a simpler format below. The direction shows a relationship among the consecutive intersections.

Towards Motijheel -

Towards Mirpur -

Table 1: Legs having highest Queuing volume on the route (in consecutive intersections have been taken)

| **Consecutive intersection** | **Morning peak** | **Evening peak** |
| --- | --- | --- |
| Zero Point |  |  |
| Paltan |  |  |
| Kadam Fowara |  |  |
| Matsha Bhaban |  |  |
| Shahbagh |  |  |
| Ruposhi Bangla |  |  |
| Bangla Motor |  |  |
| SAARC Fowara |  |  |
| Khamarbari |  |  |
| Bijoy Sarani (Novotheater) |  |  |
| Bijoy Sarani |  |  |
| Agargaon |  |  |
| Mirpur 10 |  |  |
| Mirpur Benarasi Polli |  |  |

From table 1, it can be observed that in case of Zero Point and Paltan the direction is towards Mirpur. It means, many vehicles have come from places behind the starting point of the route and move forward to places like Bijoy Nagar, Secretariat, High Court or Dhaka University area. From Kadam Fowara to Bangla Motor; for the four consecutive intersections in between, queuing volume towards Motijheel is higher since employees living surrounding areas use this route to go to their workplace at Motijheel which is the largest CBD (commercial business district) in Dhaka. From SAARC Fowara intersection, vehicles go towards Karwan Bazar area which consists of number of government and private offices as well as the area are considered as second CBD of Dhaka city. So destinations of traveling and surrounding commercial land uses are the factors for higher queuing volume in consecutive intersections. Thus, this direction analysis helps to understand the origin-destination pattern of the passengers.

***5.2 Analysis on stopping time at intersections***

Stopping time at intersections caused by various impedance factors such as congestion, insufficient carriageway width, dense traffic flow, mixed traffic condition, large number of parked cars and heavy pedestrian flow. Greater stopping time at intersections of Dhaka city brings massive economic loss by wasting valuable time, lessening productive hours of workers, wasting fuel and increasing both air and noise pollution. Vehicles moving towards the study route usually have to face stopping time at all the twenty one intersections in two peak period. However, stopping time faced by vehicles are different in morning and evening peak which has been depicted in figure 2.

Figure 2: Comparison between morning and evening highest stopping time in each intersection

In figure 2, if the highest stopping time of the morning peak period is compared with the evening peak period for all the intersections then the highest stopping time in the evening peak period is greater than that of the morning peak period. The factors behind the result are evening peak period is smaller than morning peak period and this peak causes more stopping time than morning peak for homebound direction traffic flow in evening peak. Only in case of Kadam Fowara intersection opposite happens that is an exception.

In the morning the topmost three intersections having highest stopping time are SAARC Fowara (15.16 min), Bangla Motor (13.83 min) and Bijoy Sarani (13.69 min). Interestingly the first two intersections having topmost values are consecutive intersections. Hence the vehicles have to stop for longer time while crossing these two ensuing intersections. Same thing is applicable for Khamarbari and Bijoy Sarani (Novotheater) intersections since the highest stopping time for these intersections are same and these two are successive intersections. Again the three consecutive intersections Khamarbari, Bijoy Sarani and Bijoy Sarani (Novotheater) have greater value for highest stopping time. As a result, the vehicles crossing these three consecutive intersections have to face greater stopping time in the morning. This is the factor for higher stopping time in these intersections.

In case of the evening highest stopping time the topmost three intersections are Bangla Motor (30 min), SAARC Fowara (26.75 min) and Bijoy Sarani (26 min). Evening stopping time is higher for homebound trips which is the main factor for highest stopping time in these intersections. For SAARC Fowara intersection another the factor is attractions towards second CBD of Dhaka city. At Bangla Motor, there is an impact of construction work of one Flyover (Mouchak Moghbazar Flyover), which is the factor for higher stopping time. At Bijoy Sharani, it faces greater stopping time because of the frequent movement of VIPs and Member of Parliaments.

***5.3 Journey and Running Speed Analysis***

Journey speed is defined as overall travel speed or effective speed of a vehicle between two points. On the other hand, running speed is the average speed maintained by a vehicle over a given time while the vehicle is in motion (Kadiyali, 2003). From flow in northbound and southbound directions, journey and running speed has been determined using the following process.

*For Southbound Direction:*

Total flow in south bound direction, qs = (xn + ys) / (ts + tn)

xn = opposing traffic count of vehicles met when the test car was travelling to north

ys = number of vehicles overtaking the test car minus the number overtaken by the test car, when test car is travelling south

ts = journey time when vehicle travelling south

tn = journey time when vehicle travelling north

Mean journey time, t¯s = ts – ( ys / qs )

Mean running time = t¯s – delay time in southbound direction

*For Northbound Direction:*

Total flow in north bound direction, qn = (xs + yn) / (ts + tn)

xs = opposing traffic count of vehicles met when the test car was travelling to south

yn = number of vehicles overtaking the test car minus the number overtaken by the test car, when test car is travelling north

ts = journey time when vehicle travelling south

tn = journey time when vehicle travelling north

Mean journey time, t¯n = tn – ( yn / qn )

Mean running time = t¯n – delay time in northbound direction

For both directions:

Journey speed = Distance/ Total journey time (including delay)

Running speed = Length of course/ Running time

 = Length of course/ (Journey time – Delay) (Kadiyali, 2003).

Both journey and running speed has been measured for links between two consecutive intersections which has helped to understand the reason for greater stopping time at intersections or greater delay time facing in links. Figure 3 shows journey and running speed in southbound direction and figure 4 shows both speeds in northbound direction. Speeds in southbound direction represent the speeds of vehicles from home to workplace in morning peak since it has started from 9 AM. On the contrary, speeds in northbound direction show the vehicular speeds from workplace to home in off-peak period as it starts from 11 AM. The findings and factor analysis of figure 3 and 4 has been shown in three categories.

* The same journey speed and running speed in links
* Small Difference between journey speed and running speed in links
* Immense difference between journey speed and running speed in links

Same journey speed and running speed links means the links have not faced any delay time. As Non-Motorized Traffic (NMT) is restricted from Matsha Bhaban to Kadam Fowara, no delay time has been found in southbound direction. The link length of Shilpa Bank-2 and Shipla Bank is the shortest among other links. This is the factor for not facing any delay time within this link in northbound direction.

Small difference between journey speed and running speed in links means the links have not face much delay time as a resultant of congestion. Some links are attributed in this category such as in southbound direction Kalshi to Mirpur Benarasi Polli link. This link is not as much important link as some others links within the study route. From Mirpur 10 to Agargaon same

Figure 3: Journey and Running speed in Southbound Direction (from 9 AM to 11 AM)

Figure 4: Journey and Running speed in north bound Direction (from 11 AM to 1 PM)

scenario happens since this link is the longest among twenty one links within the study route, so the delay time is less for longer journey time.

Immense difference between journey speed and running speed in links indicates that the links face significant delay time due to congestion. For southbound direction, from Gulishtan to RAJUK intersection, the link has faced immense difference between journey and running speed. The factor behind that is because of the U-turn of the Jatrabari- Demra a bounded vehicle, this link is always congested. From Shahbagh to Matsha Bhaban link, congestion is a common scenario as the link is very important to go in CBD for the Mirpur and other area. From Khamarbari to SAARC Fowara, the difference between journey and running speed is significant since SAARC Fowara intersection is surrounded by second CBD of Dhaka city, Karwan Bazar, which is an important factor for significant amount of flow and delay time within this link. Surrounding land use of Khamarbari is mainly residential and the flow from residents to work place is highest on morning peak which results in immense delay time at this link. For northbound direction, immense difference between journey and running speed has been found in some links for important establishments near the links. For example, Matsha Bhaban to Shahbagh link faces delay time as Shahbagh is surrounded by some important hospitals and university area. Concentration of commercial and institutional land uses is the influential factor for facing additional delay time.

Journey speed has been increased from southbound direction (9.77 km/hr) to northbound direction (11.44 km/hr) because southbound direction flow is from home to work place in peak hour from 9 AM to 11 AM which generates greater delay than northbound direction.

***5.4 Level of Service (LOS) of intersections***

Level of service (LOS) of intersection has been ascertained by average stopping time at each intersection. The standard used for measuring LOS of intersections has been given in table 2.

Table 2: LOS of intersection based on average delay/stopping time

|  |  |  |  |
| --- | --- | --- | --- |
| **Category** | **Delay/ Stopping time (sec/vehicle)** | **Category** | **Delay/ Stopping time (sec/vehicle)** |
| A | <=20 | D | >80-120 |
| B | >20-50 | E | >120-170 |
| C | >50-80 | F | >170 |

*Source: Indian Highway Capacity Manual (Indo-HCM), 2011*

The average stopping time has been obtained from volume survey data for each leg at intersection. The mean of each leg’s stopping time has been considered.

Table 3 shows the level of service of intersections in morning and evening peak. In the evening, intersection from Gulishtan to Mirpur Benarasi Polli has been categorized F because of their higher average delay value. Some intersections, like Gulishtan, Zero Point, Shahbagh, SAARC Fowara, Bijoy Sarani etc. are always in category F. The factors are these intersections generate vast traffic volume in all of their legs because of highly commercial and institutional land use in the surroundings. In the evening peak, the stopping time increases in maximum cases since the evening peak period is smaller than morning peak. Most of the office ends at the same time (5 PM) which this the main factor for decreasing level of service in evening peak. The highest average stopping time has been observed in Bangla Motor for concentration of commercial land use in surrounding areas.

Table 3: LOS of intersection in morning and evening peak

| **Intersection** | **Morning Peak** | **Evening Peak** |
| --- | --- | --- |
| **Average Stopping Time (sec/veh)** | **LOS** | **Average Stopping Time (sec/veh)** | **LOS** |
| Shapla Chattar | 121.7 | E | 165.7 | E |
| Janata Bank | 97.9 | D | 175.9 | F |
| Biman Office | 0.0 | A | 0.0 | A |
| Shilpa Bank | 0.0 | A | 0.0 | A |
| Shilpa Bank-02 | 68.7 | C | 61.5 | C |
| RAJUK Intersection | 21.8 | B | 19.1 | A |
| Gulishtan | 150.8 | E | 177.0 | F |
| Zero Point | 239.3 | F | 259.7 | F |
| Paltan | 236.8 | F | 249.5 | F |
| Kadam Fowara | 120.3 | E | 288.8 | F |
| Matsha Bhaban | 109.7 | D | 159.2 | E |
| Shahbagh | 269.0 | F | 223.8 | F |
| Ruposhi Bangla | 51.5 | C | 275.7 | F |
| Bangla Motor | 167.8 | E | 949.6 | F |
| SAARC Fowara | 371.1 | F | 713.7 | F |
| Khamarbari | 347.6 | F | 525.2 | F |
| Bijoy Sarani (Novotheater) | 441.8 | F | 402.1 | F |
| Bijoy Sarani | 377.4 | F | 605.6 | F |
| Agargaon | 62.8 | C | 212.8 | F |
| Mirpur 10 | 149.1 | E | 253.5 | F |
| Mirpur Benarasi Polli | 47.7 | B | 217.9 | F |

Table 3 also shows that level of service of Biman Office and Shilpa Bank intersections has always been in A category since no stopping time has been observed in these intersections during volume survey. The factor behind the finding is these intersections are not very important compared to others, so vehicles face less stopping time.

***5.5 Modal Share Analysis***

In mixed traffic condition, modal share is an important factor for assessment of intersection performance (Prasetijo, 2007). In Dhaka city, mixed traffic condition is responsible for slower journey speed. Slower journey speed in between intersections causes higher delay time which even actually results in lower performance of the intersections.

Figure 5: Modal share in morning and evening peak period

Figure 5 represents the modal share of queuing volume in morning and evening peak period which has been obtained from volume survey. It has been found that during morning peak almost 40% of the total vehicles are cars and 12% of them are bus. In evening peak the share of car increases to 44% while the share of bus declines to only 11%. Moreover, there is no separate lane for bus service which slows down its speed under heterogeneous traffic condition. Non-motorized traffic (NMT) share a large portion in morning (24%) and evening (21%) peak though most of the links, there is no separate lane for NMTs. At the intersections from Shahbagh to Bijoy Sarani, the percentage of NMTs is less than the others since in these links, rickshaw movement is restricted. Since the share of car is highest in most of the intersections, the congestion condition is caused by higher dependency of car. This is one of the main factors for traffic congestion and poor performance of intersections in Dhaka city.

**6. Recommendations and Conclusion**

The immense difference between journey and running speed at links resulted in greater stopping time at intersections. If the journey speed of links could be increased, it would help to minimize stopping time which would serve to improve performance at intersections. Journey speed will be increased if traffic flow can be minimized. It has been detected that the modal share of cars is high compared to the modal share of buses. So if the dependency on private cars can be reduced, it will be conducive towards a reduction in traffic flow. Dependency on buses should be increased and Mass Rapid Transit system should be introduced immediately before the dependency on cars exceeds the capacity of roadways and intersections. However, in some portion of the study route Government of Bangladesh has already taken initiatives to establish an MRT route though the implementation process is very slow. Proper implementation and management of proposed MRT route will be helpful to minimize traffic congestion in the study route. One of the factors for high traffic flow and stopping time is the surrounding commercial land use. If the offices provide transit service (Bus) for their employees, it will help to lessen traffic flow and stopping time. Staggered work schedule can also help to increase the LOS of intersections since it has been found that the delay is greater for peak period in this study. Lastly, the scenarios of most of the intersections are worse for massive stopping time at intersections. This study is helpful in considering the necessary actions on transportation management. If the increasing demand of traffic cannot be controlled, it will reach an unbearable situation and performance of intersections worsen progressively. Thus, transportation demand management (TDM) techniques should be applied for better level of service and performance of intersections. (jyoti vaia der thesis recommendation a use kora lagbe)

**Reference**

Bang, K., & Hai-Long, G. (1999). Traffic Performance Modeling for Intersections on Interurban and Township Roads. *Journal of the Eastern Asia Society for Transportation Studies*, Page: 101-114.

Bangladesh Bureau of Statistics (BBS). (2011). *Population and Housing Census 2011.* Dhaka: Bangladesh Bureau of Statistics (BBS).

Camp Dresser and McKee Inc. (2010). *Polson Area Transportation Plan, Existing Intersection Levels of Service.* Polson: Montana Department of Transportation.

Chancey, T. B., Jackson, R. L., Laude, S. C., & Laude, M. C. (2010). *The Effects of Volume on Driver Critical Gap Acceptance at a Two-Way Stop Controlled Intersection.* Florida: Honors Thesis: University of Florida.

Hadiuzzaman, M. (2008). *Development of Saturation Flow and Delay Models For Signalised Intersection in Dhaka City.* Dhaka.

Hoque, S. M., & Imran, A. M. (2007). Modification of Webster’s delay formula under non-lane based heterogeneous road traffic condition. *Journal of Civil Engineering (IEB)*, Page: 81-92.

Kadiyali, L. R. (2003). *Traffic Engineering and Transport Planning.* Delhi: Khanna Publishers.

Khan, S. M., & Hoque, S. M. (2013). Traffic Flow Interruptions in Dhaka City: Is Smooth Traffic Flow Possible? *Journal of PU*, Page: 46-48.

newgeography. (2012). Retrieved January 25, 2016, from newgeography website: http://www.newgeography.com/content/003004-evolving-urban-form-dhaka

Prasetijo, J. (2007). *Capacity and Traffic Performance of Unsignalized Intersections under Mixed Traffic Conditions.* Bochum.

Ravinder, K., Velmurugan, S., & Gangopadhyay, S. (2013). Development of Indian Highway Capacity Manual (Indo-HCM): An Overview. *World Conference on Transport Research Society (WCTRS)* (pp. 1-16). Rio de Janeiro, Brazil: WCTRS.

Ryus, P., Vandehey, M., Elefteriadou, L., Dowling, R. G., & Ostrom, B. K. (2011). *Highway Capacity Manual 2010.* USA: New TRB Publication.

Tamin, E. (2003). The Evaluation of Traffic Performance at Several Signalized Intersections Using 1997 Indonesian Highway Capacity Manual. *Proceedings of the Eastern Asia Society for Transportation Studies*, Page: 615-629.

The World Bank. (2005). Retrieved January 25, 2016, from The World Bank website: http://web.worldbank.org