Assessing the Performance of Highway based on Speed Study Analysis: A Case Study of Khulna-Jessore Highway

Redwan Kabir[1], Farhana Kabir Zisha[1], Md. Asif Ali Siddique[1], Md. Salaha Uddin[2], Md. Mokhlesur Rahman[3]

[1]Undergraduate Student, Department of Urban and Regional Planning, KUET, Bangladesh (redwan.kuet@yahoo.com)
[2]Assistant Professor, Department of Urban and Regional Planning, KUET, Bangladesh
[3]Lecturer, Department of Urban and Regional Planning, KUET, Bangladesh

Abstract

Khulna is the third largest city and one of the economic and industrial hubs of Bangladesh. In this respect highway corridor plays a very important part for goods and passenger transport. Due to the ongoing connectivity through construction of Padma Bridge will accelerate the economic activities of this area in near future as well as increase pressure on entry corridor of the city which is directly linked to Khulna-Jessore highway. There are possibilities which can result in low highway performance state. Under the above circumstances, Khulna-Jessore highway was selected as study to evaluate the performance of highway for future perspective. In this regard a field survey was conducted based on various speed study (i.e. spot speed, running and journey speed) analysis. Based on this information various calculation were done such as speed performance index, road congestion index, network assessment index, locational speed fluctuation, speed fluctuation, delay times by moving average method. The speed performance index is 38.59%, road congestion index is 0.36 in peak hour and 0.46 in off peak hour. The lesser the value the more the congestion state of that point. The mean, median and modal speed of the Khulna-Jessore highway is 29.2 km/hr., 27.5 km/hr. and 37.5 km/hr. respectively. The speed falls to 10 to 15 km/hr. due to funneling effect in Khulna-Jessore highway due to uncontrolled on street parking. Moreover, frequent pedestrian crossing and movement of slow moving vehicles also interrupts vehicular speed. Based on these analyses, the results can be significant enough to assess the traffic congestion conditions of urban road networks.

Keywords: *Highway Performance; Speed Study; Speed Performance index; Road Congestion Index; Speed Fluctuation.*

1 Introduction

The performance state of a highway is crucially depended on its state of traffic condition. The consequences of traffic congestion highly affect the highway performance. It reduces the highway capacity, efficiency, passenger's comfort as well as causes loss of fuel and economy. Since 1986 the number of time loss measured in Netherlands due to vehicle-hours per year e.g. has increased from 11 million up to 19 million in 1997 (Hansen, 2001). According to the commission of Toronto the cost of loss due to congestion to the regional economy in Toronto is valued at over $6 billion per year. Both developed and developing countries are facing experience in severe traffic congestion and mismanagement of traffic. In some cities around the world intolerable traffic congestion has become an everyday certainty and a horrible situation for the city dwellers. The traffic congestion of a highway can be depicted in numerous ways by analyzing traffic volume, vehicular speed, physical features, control system and other related facilities of traffic system. Traffic congestion condition on highway occurs due to unreasonable use of road infrastructure beyond capacity, and it is characterized by slower speeds, longer trip hours and increased vehicular queuing (Takyi Harriet, et al., 2013). Speed is an important transportation consideration because it relates to safety, time, comfort, convenience, and economics (M.Zainora Asmawi, et al., 2014). Speed study mainly includes analysis of spot speed, running speed and journey speed. Spot Speed is considered as the average speed of vehicles passing a point and these studies are used primarily to determine the distribution of traffic speeds, or vehicle speed at specific location. From journey speed and running speed the condition of traffic flow can be determined.

Khulna is the third largest city in Bangladesh and Khulna-Jessore highway is the main entering corridor to the heart of Khulna city. It not only performs as a highway but also as a secondary and tertiary road which are directed to different local and district level roads. So the performance of Khulna-Jessore highway is a major considerable issue of Khulna city. The increasing number of population tends to increase the number of vehicles which causes congestion and affects highway performance. Besides, vehicular speed study is one of the basic

requirements for planning of road network development and management schemes. Under the above circumstances this paper aims to assess the performance index, road segment congestion index and road network congestion index as the traffic state indicator formed by the average travel speed and the maximum permissible road speed according to field survey of Khulna-Jessore highway. These indexes are simple and can be easily used for urban traffic management and control. In short this paper aims to evaluate the performance of Khulna-Jessore highway considering speed study as its measure. Good highway performance includes smooth network system i.e. less fluctuation and interruption of vehicular speed. It also represents the congestion state which is important for traffic management and traffic control policy. Speed study simulates vehicular volume, land use impact, pedestrian movement and parking condition.

2 Methodology

This study contains mainly primary data which were collected from the field survey of Khulna-Jessore Highway that were conducted in November, 2015. According to various speed study data like spot speed, journey speed, running speed, volumetric survey etc. were conducted using various methods and followed by some calculation for further analysis of Speed performance index, Road segment congestion index and Road network congestion index etc. The speed study data were collected in various period of time during the weekdays and weakened and classified as peak and off peak hour.

2.1 Survey Method

2.1.1 Direct Observation Method:

The volumetric survey was conducted by direct observation method in which we used manual tally process to keep count of our passing vehicles from a cross section.

2.1.2 Moving Observation Method:

Moving observation method was used for determining the average journey speed, running speed and the overall delay time of Khulna-Jessore Highway in various point by using a private car. So, Journey Speed = Total Distance covered during the journey / Total journey time considering delay time. And Running Speed = (Total Distance covered during the journey / Running time (Journey Time – Delay Time)

2.1.3 Spot Speed Survey:

Spot speed was determined for each type of vehicle ran on the highway during the peak and off peak hours of the day. Spot speed was determined with the manual method using a measurement tape of 100 feet. The average time for each vehicle type was determined counting three vehicles of each type and the distance was divided by average time and spot speed was calculated for peak and off-peak hours.

2.2 Calculation Method

2.2.1 Speed performance index:

Vehicle speed is an important indicator for measuring the road traffic state. Speed performance index is the evaluation indicator of urban road traffic state (Equation 1). The index value (ranging from 0 to 100) reflects the ratio between vehicle speed and the maximum permissible speed. This study uses this speed performance index to measure the road traffic state, but adopts three threshold values (25, 50, and 75) as the classification criterion of urban road traffic state, as shown in Table 1.

$$R_v = (v/V_{\max}) * 100 \quad \ldots\ldots\ldots \quad (1)$$

Where, Rv denotes the speed performance index; v denotes the average travel speed, km/h; V_{max} denotes the maximum permissible highway road speed, km/h. (80 km/hr.) *{Source: Bangladesh Road Transport Corporation}*

Table 1: Traffic state according to speed performance index

Speed Performance Index	Traffic State Level	Description of Traffic State
0-25	Heavy Congestion	The average speed is low, road traffic state poor.
25-50	Mild Congestion	The average speed is lower, road traffic state bit weak.
50-75	Smooth	The average speed is higher, road traffic state better.
75-100	Very Smooth	The average speed is high, road traffic state good.

2.2.2 Road segment congestion index:

In order to measure the degree of road segment congestion, this paper chooses the average road segment state and the duration of non-congestion state in the observation period to define the road segment congestion index, expressed in Equation (2) & (3). The value of the road segment congestion index Ri is between 0 and 1, and the smaller the value of Ri, the more congestion of road segment.

$$R_i = (R_v * R_{NC})/100 \quad (2)$$

$$R_{NC} = t_{NC}/T_{NC} \quad (3)$$

Where, R_i denotes the road segment congestion index; R_v denotes the average of speed performance index; R_{NC} denotes the proportion of non-congestion state; t_{NC} denotes the duration of non-congestion state, (minute); T_t denotes the length of the observation period, (minute).

2.2.3 Road Network Congestion Index:

The road network congestion index is formed by many road segments and expressed in Equation (4). Similarly, the value of the road network congestion index R is between 0 and 1, and the smaller the value of R, the more congestion of road network.

$$R = Summation of (R_i * L_i)/Summation of\ L_i$$

L_i is the length of particular road segment and R_i was determined previously by equation (2).

2.2.4 Mean Speed:

Mean is the central tendency of the data and is calculated from the below equation:

$$V_t = \Sigma f_i V_i / n$$

Where V_t is the mean or average speed, V_i is the individual speed of the $i_{th\ vehicle}$, f_i is the frequency of speed and n is the total no of vehicle observed.

2.2.5 Median Speed:

Median speed is defined as the speed that divide the distribution in to equal part. In the cumulative frequency curve 50 percentile speed is the median of the speed distribution.

2.2.6 Standard deviation:

The standard deviation is calculated through the average value of the difference between individual observations and the average value of those observations. The equations is:

Standard deviation= $\sqrt{\sum f_i (V_i - V_b)/n-1}$

Where, f_i is the frequency of speed, V_i is the individual speed of the $i_{th\ vehicle}$, V_b is the average of the speed and n is the total no of vehicle observed.

2.2.7 Percentile speed:

These speed values are found graphically from the cumulative frequency distribution curve.

3 Results and Discussion

3.1 Speed Performance Index and Road Segment Congestion Index

By using equation (1) the speed performance index of Khulna-Jessore highway is calculated which is 38.59 %. It is in mild congestion state according to table no. 1. This indicates that the average speed is lower, road traffic state is bit weak.

ArcGIS Desktop 10.1 was used to show the Khulna-Jessore highway traffic states, and adopted the road segment congestion index to assess the road segment congestion. In figure 1 maps shows that the road segment congestion during the four observation periods: morning peak period, evening peak period, flat peak period and weekend time respectively. The road segments with red color shows that this road is more congested having lower index value (0.27) and with green color road is less congested having higher index value (0.46). The congested road segments are Dakbanglo to Shantidham mor, Fulbarigate to Notun Rasta and Baikali to New Market during morning and evening peak hours. During the morning and evening peak hours the overall road congestion situation is almost similar to all the way. However, the most common point of congestion is Baikali, Fulbarigate, Dakbanglo and New Market section where the average congestion index is 0.36. On the other hand, it is observed that the smooth flow is directed outward of the town area because of having less heavy congested road segments. In off peak period, traffic congestions are decreasing respectively to the peak period and most of road segments are in mild congestion condition. On weekends, there are only several mild congested road segments focused on the city center. Other areas are less congested and vehicle can easily move. From table no. 2 it is observed that Ri is higher in Notun Rasta to Baikali that means very smooth traffic flow and New market is the most congested point overall for peak hours.

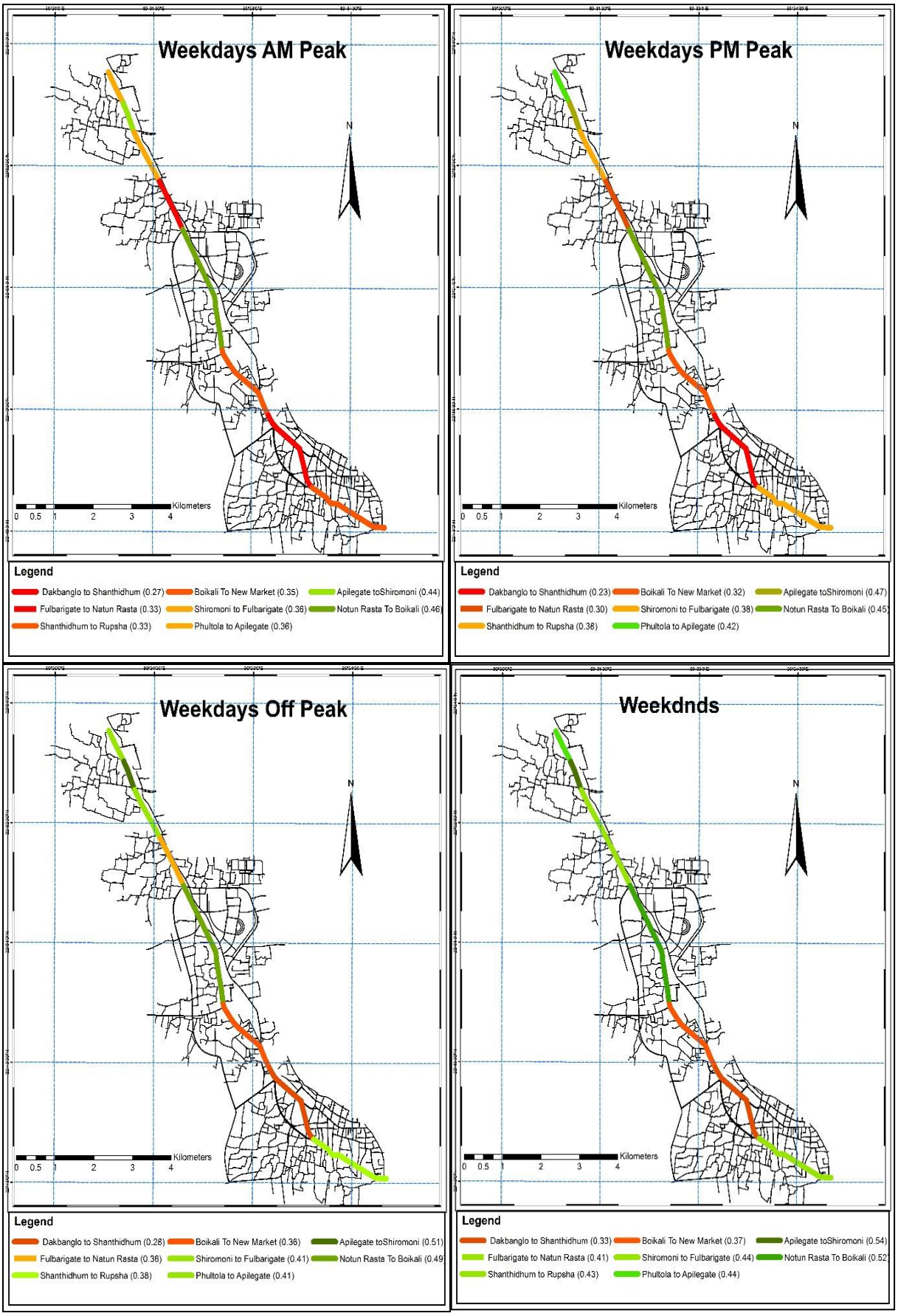

Figure 1. . Highway Segment Congestion Index using color variation (Source: Author's).

Table 2. Road Segment Congestion Index of Khulna-Jessore Highway (Source: Field Survey, 2016).

Location	Distance	Speed (km/hr)	Rv	R_{NC}	R_i
Fultala-Afil Gate	3.1	31	38.75	0.92	0.3565
Afil Gate-Shiromoni	3.5	38.04	47.55	0.92	0.43746
Shiromoni-Fulbarigate	2.6	31.33	39.1625	0.92	0.360295
Fulbarigate-Notun Rasta	4.4	29.33	36.6625	0.92	0.337295
Notun Rasta-Boikali	3	40	50	0.92	**0.46**
Boikali-New Market	2.5	30.12	37.65	0.92	0.34638
New Market-HadisPark	2.7	23.08	28.85	0.92	**0.26542**
Hadispark-Rupsha Gaht	2.9	29	36.25	0.92	0.3335
			Rv Bar =39.36		Ri Bar = 0.36

3.2 Network congestion assessment

The network congestion index shows the congestion at various times during the day. From analysis the peak hour and off peak hour network congestion index is 0.36 and 0.47 for per hour respectively. That means in the morning, the road network congestion continues to become worse, until the worst congestion (R=0.36). Again from the table no 3 it is observed that for the morning peak hour the Notun Rasta Baikali intersection is the smoothest drive way (R=0.46) and new market intersection is the most congested (R=0.27). The network congestion index for morning peak hour is given in table no. 3.

Table 3. Network congestion assessment of Khulna-Jessore Highway.

Location	Ri	Li (km)	Ri Li	R
Fultala-Afil Gate	0.36	3.1	1.116	0.36
Afil Gate-Shiromoni	0.44	3.5	1.54	
Shiromoni-Fulbarigate	0.36	2.6	0.936	
Fulbarigate-Notunrasta	0.33	4.4	1.452	
Notun-Rasta-Boikali	0.46	3	1.38	
Boikali-New Market	0.35	2.5	0.875	
New Market-HadisPark	0.27	2.7	0.729	
Hadispark-Rupsha Gaht	0.33	2.9	0.957	
Total Length		**24.7**	8.985	

3.3 Overall Speed Range, Frequency and Central Tendency of Speed Data

In order to take decisions like vehicles of which speed can be introduced to ensure maximum potentiality, mean speed plays important role. In study area for both directions the mean speed 29.2 km/hr which indicates that the vehicles within this speed can provide efficiency for reducing uninterrupted traffic flow. From modal speed it can be concluded that maximum numbers of vehicles in our study area have speed of 37.5 km/hr. Figure no. 3 shows the percentile spot speed in Phultala to Rupsha. It shows that the 85^{th} percentile speed is 35 km/hr which means that 85% vehicles are moving at or below 35 km/hr and rest 15% vehicles are moving above 65 km/hr speed in Fultala to Rupsha. On the other hand, 15^{th} percentile speed is 17 km/hr which means that 15% vehicles are moving at or below 17km/hr and rest 85% vehicles are moving above 17 km/hr speed in that direction.

3.4 Speed Fluctuation over the Study Area

The speed study shows that speed of different vehicles fluctuates at different segments due to variation of traffic volume, funneling effect, on street parking, horizontal curve and other factors. The survey data shows that the mean speed is about 29.2 km/hr and the modal speed is 37.5 km/hr. In Phultala vehicular speed remains in between the mean and modal speed and it rises in Shiromoni. The main reason behind it is low vehicular volume (about 525/hr in avg.) in Phultala to Shiromoni. The speed falls to 10 to 15 km/hr because funneling effect is caused here due to uncontrolled on street parking. Two or more bays of parked three wheelers reduce the effective road width here causing funneling effect. Moreover, heavy pedestrian movement and unsystematic pedestrian crossing and increased number of slow moving vehicles also interrupts vehicular speed. A huge number of trips are generated because Khulna-Jessore highway occupies 43.4% commercial land use and 41.56

% residential land use within 100m buffer along the roadway in both side *(Field study, 2016)*. All the vehicles speed drops down to 10-15 km/hr. in average at fulbarigate segment. A rail crossing in this Fulbarigate segment also reduce the vehicular speed as 17 passenger trains cross this segment every day *(Field study,2016)*. Speed rises again in New-market but not as Shiromoni. New market area is less congested than Fulbarigate or Daulatpur. Less residential trips are generated to New- market from Baikali and Boira as they are mainly administrative area.

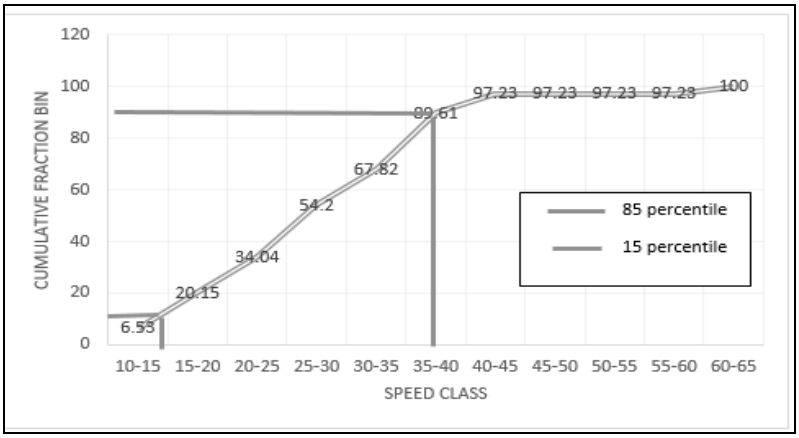

Figure 2. Percentile Speed of Khulna-Jessore Highway.

Moreover, New-market has 14.46% residential land use and commercial land use is 28.64% *(Field study,2016)*. These types of land use attract more private cars and three wheelers so there is less chances for speed interruption by slow moving vehicle. New-market to Shantidham-mor is mainly commercial area (85%) where different types of vehicles both slow and fast moving vehicles are attracted *(Field study,2016)*. These commercial activities cause heavy pedestrian flow and speed falls in this segment. The survey data shows that vehicular speed is lower in morning hour (8.00 AM-9.00AM) because a significant number of home based work trips are generated. This is the peak hour for passengers as the office, school and college start at this time occupying heavy traffic volume. At 10.00AM -11.00AM the speed vehicular volume decreases but it again goes up at 12.00PM-13.00PM because of the ending period of school, colleges which causes further reduction in speed. At 15.00PM-16.00PM the vehicular volume decreases as this is an off-peak hour. The closing hour (17.00PM-18.00PM) of offices enhance the traffic movement. Moreover, many home based other and non-home based trips take place in this time which makes the vehicular and pedestrian movement increased. And as result vehicular speed falls again. These three peak hours (8.00AM-9.00AM, 12.00PM-13.00PM, 17.00PM-18.00PM) causes congestion and passenger's inconvenience. Space occupied for a long duration by the vehicles also reduces the highway efficiency.

3.5 Variation of Delay Time in Khulna-Jessore Highway

Some congestion points were identified from moving average method by car from Rupsha to Phultala. In Shiromonibajar, the road gets a little congested which causes slowing down of car. In Fulbarigate the road width narrows down for on street parking and heavy pedestrian movement which cause one minutes or more to slow down the car and sometimes to stop. This intersection plays significant role in delay time as it has a rail crossing. Seventeen passenger trains cross this road causing 5 minutes' delay in the signal. There was heavy traffic in Daulatpur which causes 1 to 1.5 min of congestion. Due to merging and diverging of vehicles in Notun Rastar mor, there the normal speed of the car slows down. In Baikali to Boira the interruption in speed is negligible. But the car slows down in New-market due to its busy traffic behavior and in Shibbarimor the car has to be stopped due to congestion at signal. In Ferri-ghat there is similar scenario of congestion as a lot of vehicle take U-turns and merge and diverge. Another reason is there is a parking place for bus which causes congestion due to park and unparks of vehicles. In Tut para intersection there was a little congestion. But it gets bigger scenario in road toward Rupsha as a huge no. of trucks stand there and three wheelers park on street. Rupsha bazar also has a great impact on the traffic behavior causing on street business and huge pedestrian movement.

In case of applying moving average method by bus, the same points cause traffic congestion but additional delay time is required because of passenger boarding and lighting. Between Phultala and Rupsha buses stop at thirty point for passenger boarding and alighting. About 13 minutes 54 seconds is delayed for this purpose. More delay time is required in Daulatpur, Ferry-ghat mor and Rupsha traffic mor due to heavy passenger volume and existing traffic congestion at these points.The running speed and journey speed is 33.87 and 30.78 km/hr.

respectively considering 4 min 15 seconds of delay time all the way through. The congestion occurs due to unauthorized parking, frequent pedestrian movement and high density of slow moving vehicles. These reduces the highway performance of Khulna-Jessore highway.

4 Concluding Remarks

Under the above circumstances, it is concluded that the overall highway performance is in average condition. But to meet the future demand it is a matter of great thought that whether it would be good enough to support the future condition or not. This study will be helpful to identify the congested or problematic areas where caution needs to be taken such as New market intersection, Fulbari intersection. Based on the traffic state classification standards, this study proposed the road network congestion index and the road network congestion index to measure the congestion degree of road segment and road network respectively in Khulna-Jessore highway. One can have an accurately and clearly grasping of network traffic operation status which provides important information for future traffic management in Khulna city.

References

Hansen Ingo Determination and Evaluation of Traffic Congestion Costs [Journal] // EJTIR. - 2001. - 1 : Vol. 1. - pp. 61 - 72.

M.Zainora Asmawi [et al.] SUSTAINABLE GOVERNANCE IN RELATION TO THE FINANCIAL ASPECT IN MANAGING COASTAL AREAS:MALAYSIAN EXPERIENCE [Journal] // Urban Planning and Local Governance. - 2014. - Vol. 3. - pp. 15-26.

Takyi Harriet, Kofi Poku and Anin Kwabena Emmanuel An Assessment of Traffic Congestion and Its Effect on Productivity in Urban Ghana [Journal] // International Journal of Business and Social Science. - March 2013. - 3 : Vol. 4.