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IMPACT OF FOUR LANE BRIDGES ON MOBILITY OF TRAFFIC FLOW IN DHAKA-CHITTAGONG HIGHWAY

G. M. A. Mamun[1*], A. S. Hasan[2], K. Roksana[3] and A. Pervin[4]

[1] *Department of civil Engineering, Presidency University, Dhaka, email: sopnil@student.presidency.edu.bd*
[2] *Department of Civil & Environmental Engineering, Rowan University, Glassboro, New Jersey, email: hasana26@rowan.edu*
[3] *Department of Civil Engineering, Bangladesh University of Engineering & Technology, Dhaka, email: roksan75@rowan.edu*
[4]*Department of Civil Engineering, World university of Bangladesh, Dhaka, email: asmay7992@gmail.com*

***Corresponding Author**

ABSTRACT

The N1 or Dhaka-Chittagong highway is the main transportation artery in Bangladesh. This road is significant for the export-import process and tourism. So, the demand is to connect the capital with the port city in the shortest possible travel time. After two years of expanding N1 highway to four lanes from two lanes, narrowing of highway occurred at the vicinity of three major bridges namely Gumti, Meghna and Kanchpur. Due to the bottleneck of the bridges, chronic congestion was recorded multiple times during 2017-2019. It was until May 2019, when the encroachment of the highway was abolished by the construction of the 2nd bridges. Video data of the traffic flow were collected at peak hours and off-peak hours in both directions near the bridge and away from the bridge. Our results demonstrate that the flow and velocity decrease drastically at obstructed flow near the bridge than the free flow during the construction period of the 2nd bridge. After the 2nd bridges started operating, the mean traffic velocity and traffic flow highly increased near the bridge and the bottleneck was eventually removed. However, the issue of the overall mobility of the traffic due to high proportion of heavy vehicles still remains unsolved. Proper coordination of the concerned authorities to address the optimal traffic supply for the balance of traffic demand and supply should be a top priority in future days.

***Keywords**: N1; Dhaka-Chittagong highway; Four-lane bridge; Traffic condition.*

1. INTRODUCTION

The national highway N1 or Dhaka Chittagong highway is the most important economic corridor of Bangladesh as it connects the capital of Bangladesh, Dhaka, with the principal seaport Chittagong. The Kanchpur, Meghna, and Gumti bridges (KMG) on the Dhaka Chittagong highway have contributed to minimizing the route from Dhaka to Chittagong. These bridges were built with financial help from the Government of Japan and were opened to the public in the 1990s (JICA, 2015). After constructing a four-lane highway from two lanes, the movement of the vital road is hampered due to traffic congestion at highway merging or bottlenecks. Traffic congestion is one of the global urban problems that can lengthen journey time, increase energy consumption, aggravate environmental pollution, and result in traffic accidents (Ye, 2012). The aim of this this study is to address the traffic flow near the bridges with and without bottleneck situations. In other words, this study shows the change in traffic velocity and flow before and after the construction of the second bridges.

As the busiest economic corridor and connector of the industry and port, N1 is designed to accommodate most of the heavy vehicles of the country. Ullah et al., 2013 found that the share of trucks is almost one third in N1 highway (31%). Though individual years vary significantly, Truck and Buses

average growth factor is found 6.68% and 4.07% per annum, respectively (Ullah et al., 2016). The big share of trucks in highways contributes to the decrease in mean velocity and space management issues at toll plazas. This study evaluates the impact of heavy vehicles on the mean velocity of existing traffic under consideration.

Two recent studies showed the decrease of traffic flow and mean velocity near the bridges during a four lane highway with two lane bridge period (2015-2018). Hasan et al., 2019 found a mean decrease of 45% and 46% in traffic flow and mean traffic velocity respectively due to bottleneck near the Gumti bridge. Roksana et al., 2018 also found a decrease of 48% and 51% in traffic volume and mean traffic velocity respectively due to bottleneck near Meghna Bridge. Besides the highway merging, toll plazas are also responsible for the loss of traffic mobility near the bridges (Hasan et al., 2019; Roksana et al.,2018). Several long congestions were recorded near these two bridges over their construction phase (Dhaka Tribune, 2018). After a long wait for three years, the four lane bridge was ensured by the inauguration of second Meghna and Gomti bridges to traffic on May 25, 2019 (The Daily Star, 2019; BDnews24, 2019). The expectation from these 2nd bridges was to promote mobility in the traffic flow. Unfortunately, there were no previous studies that compared these two situations and found the contribution of the second bridges to save travel time on the busiest economic corridor of the nation.

This study has two objectives. First, this study demonstrates the impact of four-lane bridges (more specifically the impact of the construction of the second bridge) in the mobility of traffic flow in the N1 highway. Second, this study would find the impact of heavy vehicles on the traffic flow of the N1 highway.

2. METHODOLOGY

The bridge is located along the Dhaka–Chattogram Highway. The geographic coordinate of the Meghna Bridge is 23°36.162′N 90°36.991′E.

Figure 1: (a)Traffic congestion before Four Lane Bridge (Source: Dhaka Tribune, 2019)
(b) Four lane bridge (Source: BDnews24, 2019)

From the survey, it was observed that noticeable congestion was within the exit point of the bridge, near the toll collection system. Observers were positioned at the near four-lane bridge to get a clear view of traffic. Layout of the study area are given below,

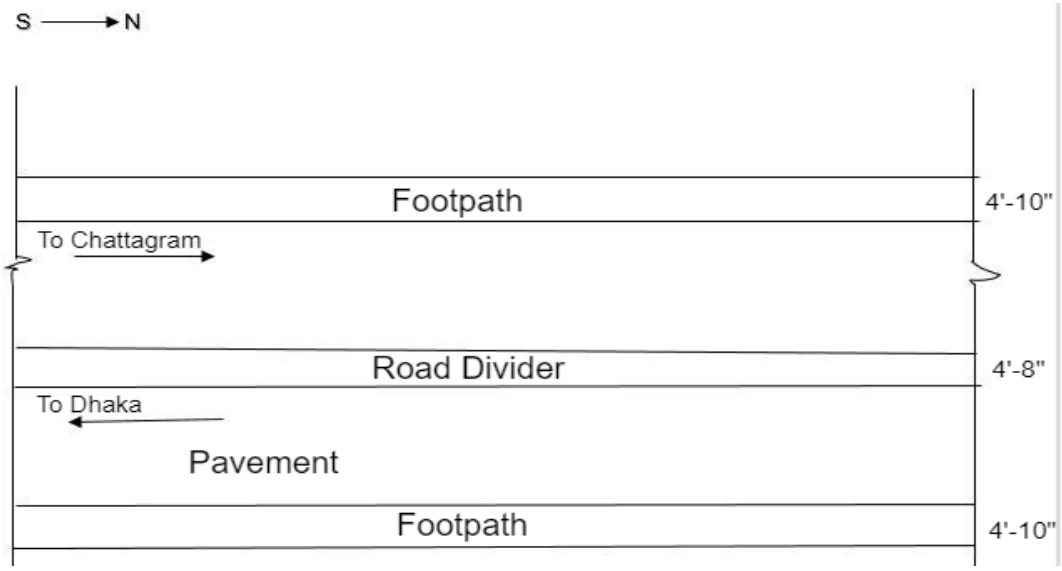

Figure 2: Layout of the study area

For this study, Traffic volumes were counted by viewing videotapes recorded with a camera at a collection site, and imperial data were collected for the study by sample survey method. Video is captured for one hour, and data is collected later by rewinding (Botswanq Guideline 9, 2004). The following PCU values are used for these studies which are adopted from the manual book of Geometric Design Standards for Roads & Highways Department (RHD Manual Book, 2000).

Speed is the distance travelled by vehicle during a unit time. i.e. rate of movement of traffic. It is measured in kilometre per hour or mile per hour (Raheem et al., 2015). Speed was determined by sampling a set of vehicles, noting their travel time (with the use of stopwatch) on a predetermined length of road along the case road.

Traffic flow is the quantity of vehicles in space measured in an interval of time. It is measured in vehicle per hour. The PCE factors utilized for traffic volume calculation are cited in table 1.

Table 1: Passenger Car Unit (PCU) values for different vehicles

Type of Vehicle	PCU
Bus	3
Truck	3
Micro	1.5
Pickup	1.5
Private car	1
Motorcycle	0.5
Lorry	3
Cover van	3

2.1 Mann-Whitney U test

To evaluate the statistical significance of the parameters, A Mann-Whitney U test is further implied on the velocities and PCU's near and away the bridges in the years of data collection. The Mann-Whitney U test is a nonparametric method for comparing the means of two independent samples. The test makes

no assumptions about how the scores will be distributed. The test was first designed for equal sample sizes, but it was later expanded to include unequal sample sizes. It should be observed that when the ranks of the two samples are taken from the same categories, implying that the null hypothesis is correct, the findings of both samples should have an equal mean rank. However, if the independent variable influences the sample outcome, it is likely that it will modify their rank order and even cause the mean ranks for the two samples to diverge, indicating that the null hypotheses are untrue (Patel, 2020). The Mann-Whitney test is calculated in the following way:

$$U_1 = R_1 - \frac{n_1 (n_1 + 1)}{2} \quad (1)$$

$$U_2 = R_2 - \frac{n_2 (n_2 + 1)}{2} \quad (2)$$

Where U_1 and U_2 are Mann-Whitney test results for two different data variants, n_1 and n_2 are the number of events for the variations, and R_1 and R_2 are the rank sums for the variations. The two samples are statistically significant when the U value is less than the critical value.

P-Value

To analyse the outcomes of the observed results, the level of significance must be determined. The significance level usually has a value between 0 and 1. It's worth noting that the most common significant values used by academics are 0.01, 0.05, and 0.10, which correspond to 99 percent, 95 percent, and 90 percent confidence levels, respectively. The p-value must be less than 0.05 for a change to be statistically significant at the 95 percent level (α= 0.05).

Effect size

The effect size for the sample data is calculated by dividing the absolute standardized test statistic, z, by the square root of the total sample size, n, as follows:

$$\text{Effect Size} = \frac{Z}{\sqrt{n}} \quad (3)$$

Cohen's classification of effect size is used to determine whether the changes are statistically significant. According to Cohen's classification, an effect size between 0.1 and 0.3 is considered to have a small effect, between 0.3 and 0.5 is considered to have a moderate effect, and 0.5 and above is considered to have a large effect (Patel, 2020)**.**

3. RESULTS AND DISCUSSIONS

This study conducted surveys in two different sections of the road- near the bridge and 1 Km away from the bridge. The velocity and traffic volume of the sections were taken at both peak and off-peak hours. For a standard comparison of the traffic conditions during two-lane bridge and four-lane bridge, the same time frame was selected for the data collection at the same place in the year 2018 and 2019. The comparison of the traffic flows is illustrated in figure 3.

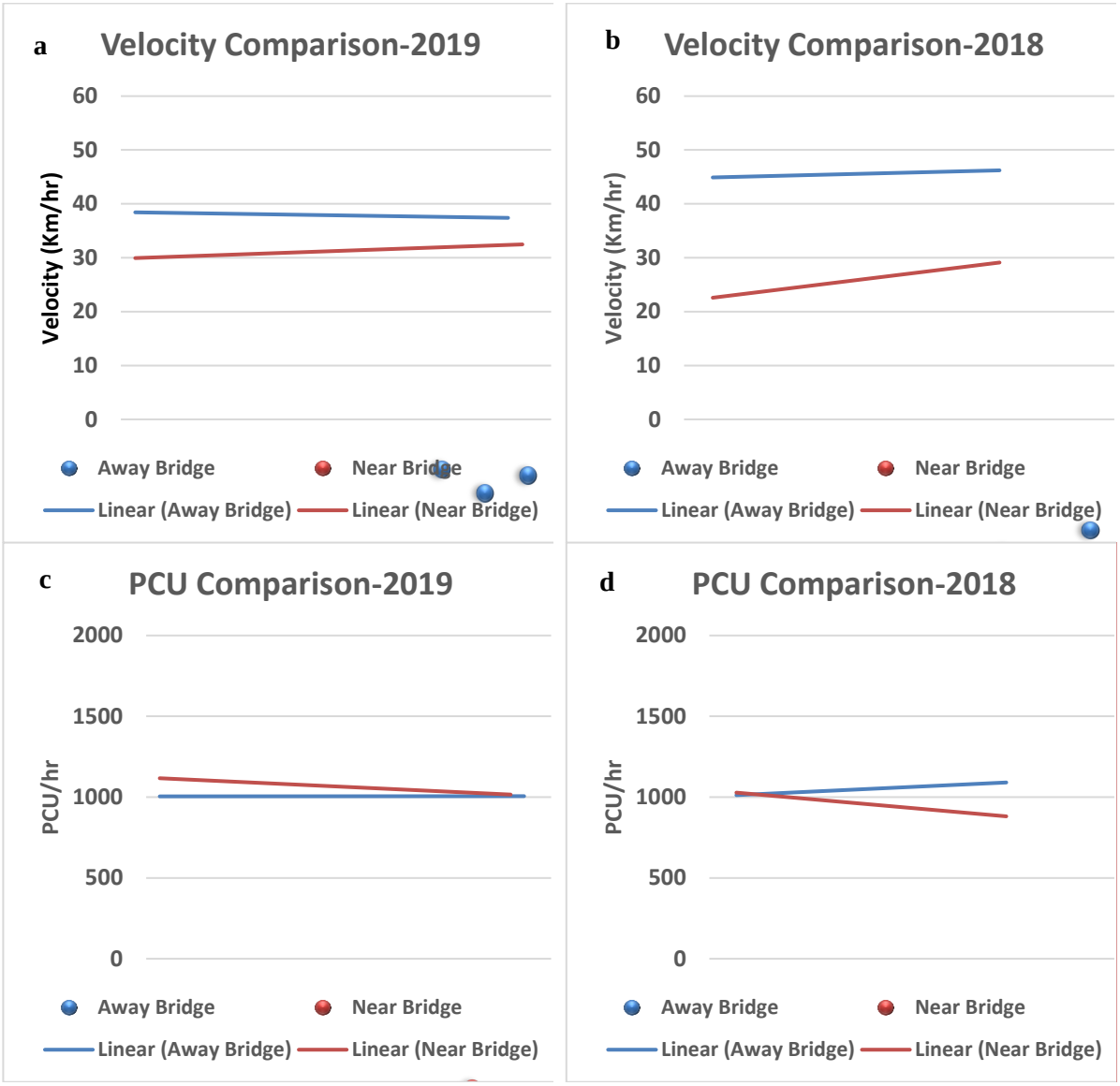

Figure 3: a) Velocity comparison of traffic between near bridge and away from bridge at 2019, b) Velocity comparison of traffic flow between near bridge and away from bridge at 2018, c) Traffic flow comparison between near bridge and away from bridge at 2019, d) Traffic flow comparison between near bridge and away from bridge at 2018

The results show a very significant change in the velocity and flow of the traffic at free flow and obstructed flow condition. In 2018 when there was only a two-lane bridge then the velocity range near the bridge was from 20-30 Kmph whereas it increased to 25-40 Kmph in four lane bridge. It also shows that the difference of near and away bridge was around 20 Kmph in 2018 when there was only a two-lane bridge. However, when both road and bridge were four lanes (after construction of the second bridge), the difference decreased significantly under 10 Kmph. Hence, the mobility of the traffic increased due to the operation of four lane bridges at Dhaka-Chittagong highway. The difference from near and away of bridge was around 100 PCU/hr during 2018 whereas the difference of flow near and away of the bridge almost merged in 2019.

3.1 Test of Significance of the parameters

A Mann Whitney U test gives the ordered rank of the variation of two data samples. The positional variation (near vs away), variation of time (2018 vs 2019). From table 2, it is evident that the mean rank of velocity near the bridge has increased significantly in 2019 compared to that in 2018 with a confidence level of 95%. Similarly, there is also significant increase in the velocity away from the bridge in 2019 compared to 2018. It is noteworthy that all the changes occurred with a large effect size. These findings are indicative that the velocity of the individual vehicles had improved once the bottleneck is relieved because of the four lane bridge.

Similarly, the mean rank of the PCU had also showed statistically significant rise in 2019 compared to that in 2018. The test results are also showing a large effect size. Hence, significant improvement in the flow of the traffic is also evident near and away of the bridge due to the full-fledged operation of the four lane bridges - Meghna and Gumti.

Table 2: Significance test of velocity and PCU for different scenarios

Driver Behavior	Mean Rank 2019	Mean Rank 2018	Delta Mean Rank	Mann-Whitney U	Z-score	P-Value	Effect Size
velocity near	34	14.5	-19.5	154	-4.790	< .00001	0.767
velocity away	6.55	24.78	-18.23	291	-4.570	< .00001	0.741
PCU near	33.82	14.57	-19.25	306	-4.728	< .00001	0.757
PCU away	31.45	14.63	-16.82	280	-4.216	< .00001	0.683
*** means statistically significant**							

3.2 Contribution of Heavy Vehicles

It is noted that the number of bus and pickup is more than that of the other vehicles. This indicates that the number of heavy vehicles is more than that of light vehicles like private cars or micro buses on the highway. The result from 2018 indicates that both the traffic near the bridge and away from bridge experiences huge congestion but in 2019 after the four-lane bridge, it decreased a lot. It was also found that a huge number of heavy vehicles move on this bridge. Heavy vehicle in 2018 was associated with low mobility and congestion for various records taken. However, as it can be seen in 2019, for heavy vehicles after the four lanes completed the congestion was removed which created for the bottleneck and then mobility increased and moved on freely without lose valuable time. Interestingly, percentage of heavy vehicles increased in 2019 compared to that of 2018. But, intuitively its heavy share decreased the velocity away from the bridge. On the contrary, the negative value of slope for velocity near the bridge in 2018 was minimized in 2019 with an increase of 5-10 Kmph in velocity due to four-lane bridge. A previous study on the toll plaza of Meghna bridge demonstrated that the heavy vehicles could impede the overall flow of the traffic because of longer processing time of toll payment (Sultana, 2010). Since, the number of heavy vehicles is increasing every year, strict rules and regulation should be imposed for the heavy vehicles near the bridges.

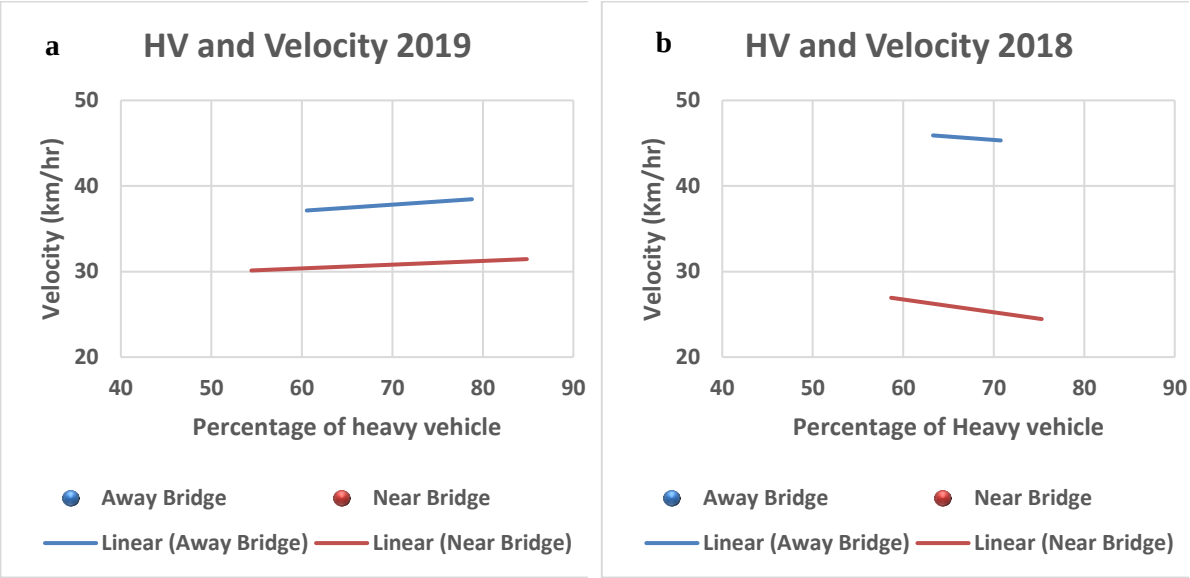

Figure 4: a) Variation of velocity vs. heavy vehicle percentage in 2019, b) Variation of velocity vs. heavy vehicle percentage in 2018

4. CONCLUSION AND RECOMMENDATION

Traffic congestion has become a critical issue for all urban cities recently. This paper mainly studied the impact on traffic flow mobility after the construction and operation of a four-lane bridge. From the outcomes, it is found that the flow, density, velocity increased in both directions. The result indicates that traffic volume is satisfactory with the highway Capacity, but some congestion created for the illegal loading-unloading, no additional lane for toll plaza, and heterogeneous traffic. This problem can be solved by creating an additional lane for the toll collection system, different lay bay for heavy traffic, clearing roadside shops and vendors etc. Most importantly, strict rules and regulations should be imposed for motorized and non-motorized vehicles.

Due to budget, resource constraints and time limitations, a particular time frame for peak and off-peak hours were taken over the last two days. The future work on collecting continuous data over the year can provide a better insight of the condition of highways near the bridges by providing seasonal and other varieties.

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AUTHOR BIOGRAPHIES

G M Al Mamun is a final year undergraduate student in Presidency University, Bangladesh. Ahmed Sajid Hasan is a graduate research assistant at Rowan University, New Jersey, USA. He has been pursuing his PhD in Transportation Engineering since September 2019. Kaniz Roksana is a graduate research assistant at Rowan University, New Jersey, USA. She has been pursuing her PhD in Geotechnical Engineering since January 2021. Asmay Pervin completed her BSc in Civil Engineering from World University of Bangladesh, she helped us with the data collection.