Performance evaluation of Jatrabari-Gulistan Flyover (Mayor Mohammad Hanif Flyover) constructed over rail-road level crossing in Dhaka

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Abstract

So far eight flyovers have been constructed in Dhaka city with an aim to mitigate traffic congestion, enhance mobility and ensure a reliable transportation system. Although, full grade separation has the potential to eliminate conflicts between rail-road traffic and thereby can reduce both congestion and accidents, out of the eight flyovers, six of them are partially grade separated flyovers. This study is being carried out in an effort to assess how far these objectives have been met through the construction of these partially grade-separated flyovers on a particular focus on Jatrabari-Gulistan Flyover. Methodological survey and extensive analyses were performed incorporating temporal variation (weekday, day; weekday, night; weekend, day; weekend, night) of traffic flow, travel speed and delay to assess the relative level of usage, mobility and congestion level of the studied flyover. 29% vehicles are still exposed to rail-road conflict and although flyover shares a significant space with public bus, no facility has been provided to non-motorized vehicles (99.76 % travelling at-grade). Also, travel speed along the flyover corridor is found unsatisfactory (11.925 km/h at-grade and 30.46 km/h above-grade). Significant delays along with high congestion level increasing rate (168\%) have faded the potentiality of this flyover.

1. Introduction

With the prodigious increase in world population, cities are growing through rapid and uncontrolled growth. Past 200 years, world population has increased 6 times, whereas, it is 100 times in cities [1]. Constant population growth and urbanization will bring additional 2.9 billion vehicles on road by 2050 [2]. With these rapid urbanization and limited road networks, traffic congestion is reported to be as the most worsening, serious and pressing infrastructural problems in almost all the megacities around the world. In addition to that, it is a major contributor to environmental degradation, climate change, energy depletion, visual intrusion, lack of accessibility, economic loses, frustration among city dwellers and vice versa [2-6]. City dwellers of the second worst city in the world, Dhaka, the capital of Bangladesh are facing this worsening problem tremendously. They are compelled to undergo physical stress and suffer financial losses in terms of

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man-hours lost on working days [7]. Between 2010 and 2016, the population of Dhaka city, the capital of Bangladesh, has escalated by around 20%, while for the same period the vehicle fleet has grown by about 60% to approximately 950,000 vehicles, reflecting on the enormity of this bustling city [8,9]. The media, both print and electronic, have been constantly highlighting the sufferings of the commuters in Dhaka city because of the nagging traffic problem. Yet no solution to the problem, apparently, is in sight, at least, in the short and medium terms, though a lot has been said and a large program been undertaken with the assistance from a multilateral lender to improve the traffic situation of the capital city in recent years [7]. As most of Dhaka city is built-up area [10], there is little provision for at-grade expansion of existing roadway [7]. Hence a presumptive reliance based local knowledge has been shifted to flyovers to mitigate traffic congestion. Consequently, several flyovers have been built in Dhaka City to improve safety and mobility of at-grade traffic conditions [11-12]. Detailed observations have shown that of the 8 flyovers constructed in Dhaka city, 6 of them are partially grade separated from rail traffic and abject at-grade traffic conditions, Jatrabari-Gulistan Flyover is one of them. Rail-road traffic conflict is prevailing in the developing in countries and its’ negative consequences are increasing prodigiously. Rail covers a length of 2,877.10 route kilometers including 2,541 rail-road crossings across the country. Among them, 51 (Fifty one) railway level crossings are in Dhaka city, out of them 37 authorized and 14 unauthorized [13]. Unfortunately, eighty-five per cent of the railroad crossings are in a dangerous state as there is no lookout at 2,170 rail crossings. More than 2000 rail crossings have no traffic control devices. Lack of safety devices in level crossings have made them potential hotspots for accidents. Most victims of train accidents are pedestrians. On average, 12 people are killed in the accidents per month [14]. In addition, the accidents that occurred in level crossing is 53% of all rail related accidents in Dhaka city [15]. To resolve this rail-road problem, a simple thought that came into the mind of policy-makers and decision-makers is to construct flyovers. This study was carried out in an effort to assess how far the objectives have been met through the construction of these flyovers. The present study will focus particularly on the largest flyover, Jatrabari-Gulistan Flyover (Mayor Mohammad Hanif Flyover), which has been constructed over Saidabad rail-road level crossing in Dhaka city to mitigate traffic congestion, enhance mobility, ensure safety and provide a sustainable smooth flow along the flyover corridor of Saidabad-Jatrabari-Gulistan area.

2. Literature review

In 2008, prior to the construction of Jatrabari-Gulistan Flyover, Bureau of Research Testing and Consultation (BRTC) identified problems associated with Jatrabari and Saidabad intersection and tried to offer rational solutions to those problems [16]. The study identified various forms of side
frictions from which the corridor was seriously suffering from significant loss of effective width of carriageway and productivity. It diagnosed ill maintained untreated Jatrabari, Gulapbag and Saidabad intersections those were contributing traffic problems along the most critical section of this corridor. The study proposed various traditional low cost but very effective traffic control and roadway capacity augmentation measures to restore level of service (LOS) as well as functionality of this corridor before advocating any expensive measure including construction of flyover. The study also gave a warning by stating that flyover is constructed without understanding the root causes of the problem, there is a strong possibility that instead of solving the problem it might be a permanent hindrance for implementing future transportation projects along this corridor, and as the corridor has not been treated effectively by applying any low cost capacity augmentation measure yet, it would not be wise at all to construct capital intensive flyover type measure directly without implementing these cost effective precursor measures [16]. However, the government and policy-makers ignored this study outcomes and went for capital-intensive solution by constructing flyover in this corridor considering it as a solution to this perennial traffic flow interruption problem.

Hassan and Alam (2013) worked on Jatrabari-Gulistan flyover project. Main focus of their research was to record and analyze noise levels in major intersections located at surrounding the flyover as well as key entities, such as hospitals, educational institutions; religious institutions etc. for both day and night and seven days of a week. They compared the Jatrabari-Gulistan flyover noise level data with the Khilgaon and Kuril flyover data. They also performed Noise modelling for generator and wheel loader used in the construction site of flyover [17]. However, their study was far away from evaluating the performance of the Jatrabari-Gulistan flyover on the basis of speed, flow and queue length.

Hasnat, Hoque and Islam (2016) evaluated the economic, environmental and safety impact of at-grade railway crossings on Dhaka city. This study revealed the economic losses, environmental impact and safety hazard of the busiest 7.15 kilometer railway corridor which has six level crossings. It also calculated the delays and emission incurred by individual level-crossing and found that the yearly economic losses incurred by studied six level crossings was 32.95 million USD [18]. However, the study neither dealt with any particular flyovers nor evaluated their functional effectiveness.

Anwari, Hoque and Islam (2016) focused on operational effectiveness of the partially grade-separated flyovers built on level crossings in Dhaka city till February 2016. They considered six partially grade-separated flyovers in Dhaka including Jatrabari-Gulistan Flyover. The evaluation criteria used include assessment of vehicular as well as pedestrian safety at level crossings under
those flyovers, degree of congestion and speed characteristics. However, the study didn’t incorporate the variation of flow during different times of the day [11].

Anwari, Hoque and Islam (2016) further explored the reasons for poor traffic operation and railroad conflict at Shaheed Ahsanullah Master Flyover. The study was conducted to identify and evaluate the at-grade traffic movement at Tongi Level Crossing under the flyover. This paper shed light on the traffic problems prevailing at Tongi Railway Crossing. However, it is a fraction of the entire city and it didn’t cover the other flyovers in Dhaka city as a sum and assess the overall impact on mobility and accessibility in Dhaka city [12].

Miyauchi (2017), using cell phone data, analyzed how the opening of Jatrabari-Gulistan Flyover in October, 2013 has changed the urban trip patterns. The research found that about 23.8% more trips are generated on the routes that crosses over flyover relative to other routes. The study also mentioned a within-day variation in the generated trips; in the mornings more trips are generated from suburban area (Narayangonj area) toward the central business district (Motijheel area), and the other way around in the evenings [19]. However, the study did not deal comprehensively with the performance evaluation of this flyover.

No systematic analysis has yet been performed to evaluate the performance and effectiveness of Jatrabari-Gulistan Flyover constructed over rail-road level crossing in Dhaka city. The aforementioned literatures neither dealt comprehensively with the performance evaluation of Jatrabari-Gulistan Flyover nor did they quantify the identified problems. In addition to that, performance evaluation of this flyover incorporating temporal variation of traffic flow and volume along with pedestrian consideration are completely missing. In this backdrop, this research is an attempt to investigate how the partially grade separated Jatrabari-Gulistan Flyover constructed at the level crossings have facilitated city-dwellers in terms of mobility and accessibility

3. Study area

Jatrabari-Gulistan Flyover, also known as Mayor Mohammad Hanif Flyover, is an 11.8km-long flyover opened on October 11, 2013. It has 4 lane divided carriageway and consists of 13 entry and exit ramps at major junctions for smooth inflow and outflow of traffic [20]. It extends from Jatrabari to Sayedabad, Tikatuli, Joykali Mondir, Kaptanbazar and Gulistan. In particular, it serves as a connector to Central Business District (Motijheel area) and suburban area (Narayangonj area) [19]. In broader perspective, it is at the confluence point of three important national highways viz. Chittagong (N1), Sylhet (N2) and Mawa (N8) as well as Demra (old Chittagong) road. It is one of the major gateways to enter Dhaka City from at least 30 districts of Chittagong, Sylhet, Barisal and Khulna division, which essentially implies that Dhaka bound traffic stream from these three important national highways along with a large number of suburban city bound local traffic have to
enter through the only roadway link between Jatrabari and Saidabad [16]. The construction started on June 22, 2010 as the largest public-private partnership investment in Bangladesh [19]. The route of flyover is marked with red line in Fig. 1. It shows the route of the flyover starting from Chankhar-Pool and then pass through Bongo-Market, Gulistan, Tikatuli, Wari, Narinda, Swamibag, Saidabad, Jatrabari and ends at Kutubkhali.

![Figure 1. Connecting Area of Jatrabari-Gulistan Flyover. (Source: [21])]()

The details information about the Jatrabari-Gulistan Flyover has been shown in Table 1.

<table>
<thead>
<tr>
<th>Descriptive Characteristics</th>
<th>Corresponding Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade Separation Type</td>
<td>Partial</td>
</tr>
<tr>
<td>No. of Lanes</td>
<td>4 (Two in each Direction)</td>
</tr>
<tr>
<td>Length (km)</td>
<td>11.8</td>
</tr>
<tr>
<td>Construction Cost (crore Taka)</td>
<td>2300</td>
</tr>
<tr>
<td>Date of Commencement of Traffic Operations</td>
<td>11 October 2013</td>
</tr>
</tbody>
</table>

(source: [22-27])

Field study reveal that there is one rail-road conflicting point underneath this flyover and it is denoted as Saidabad Level Crossing in this study and shown in Fig. 2. The latitude and longitude of the Saidabad Level Crossing are 23.714322 N and 90.425341 E respectively.
4. Methodology

A reconnaissance survey was first conducted to assess level crossing adjacent land use and surrounding conditions. Video based short classified traffic count method (15 minutes) was adopted by Cordon count method identified from analysis of hourly traffic count over a period of 24 hours for the following four periods: weekend-day, weekend-night, weekday-day and weekday-night. Data for day was collected during the morning peak hour from 9:00 am to 10:00 am. Data for night was collected during from 8:00 pm to 9:00 pm. Vehicles were then counted after analysing video.

To assess the mobility conditions of vehicles, travel speed and free flow speed of each types of vehicles were measured at both at-grade and above-grade. Floating car method was used to assess travel speed at each direction of each flyover by recording the travel time (including motion time, segment delay and through vehicle delay) and dividing the segment length by the travel time. A permitted error of ± 1.0 miles/hour and 95% confidence interval was chosen to get speed difference (R) of 4 miles/hour between maximum and minimum value of travel times. As a result, a minimum of 10 test runs were required as per Manual of Transportation Engineering Studies [28]. Travel time measured using intra-frame scene capture based on superimposed image at free-flow conditions was used to determine space mean free flow speeds validated by radar gun spot-speed studies. The field survey works were undertaken between 6th October 2017 and 11th October 2017.

5. Analyses and results

After gathering data both manually and using video, comprehensive analyses of the collected data have been made and the findings are presented in the following sections.

5.1 Assessment of traffic flow

Classified traffic count was performed to assess the relative level of usage of road space under and over the flyover.
Since vehicles of various sizes and weights pass through the study area, it was requisite that their impact be judged using a common unit. Hence, the vehicle counts were converted to passenger car units, as depicted in Table 2, using the following passenger car equivalent (PCE) factors prescribed by the Ministry of Communication (2000): Rickshaw/Van: 2.00, Motorcycle: 0.75, Bicycle: 0.50, Car: 1.00, CNG: 0.75, Tempo: 0.75, Bus: 3.00, Utility: 1.00, Truck: 3.00, Bullock Carts: 4.00 [29]. Accordingly traffic flow in terms of PCUs were obtained multiplying vehicle count data by their corresponding PCE factors.

Table 2. Classified Traffic Count at Jatrabari-Gulistan Flyover (PCUs)

<table>
<thead>
<tr>
<th>Name of Flyover</th>
<th>Over/ Under</th>
<th>Rickshaw/Van</th>
<th>Motorcycle</th>
<th>Bicycle</th>
<th>Car/Jap/Microbus</th>
<th>CNG</th>
<th>Human Haulers</th>
<th>Bus</th>
<th>Utility</th>
<th>Truck</th>
<th>Total equivalent hourly flow (PCU)</th>
<th>Percentage of Total (%)</th>
<th>Ratio of Vehicles Passing over to those Under</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekend, Day</td>
<td>Over</td>
<td>0</td>
<td>941</td>
<td>0</td>
<td>1785</td>
<td>613</td>
<td>163</td>
<td>1932</td>
<td>199</td>
<td>0</td>
<td>5632</td>
<td>79.78</td>
<td>3.95:1</td>
</tr>
<tr>
<td></td>
<td>Under</td>
<td>957</td>
<td>58</td>
<td>13</td>
<td>26</td>
<td>14</td>
<td>0</td>
<td>342</td>
<td>18</td>
<td>0</td>
<td>1328</td>
<td>20.22</td>
<td></td>
</tr>
<tr>
<td>Weekend, Night</td>
<td>Over</td>
<td>15</td>
<td>903</td>
<td>4</td>
<td>2046</td>
<td>1391</td>
<td>588</td>
<td>1998</td>
<td>309</td>
<td>298</td>
<td>7551</td>
<td>74.13</td>
<td>2.87:1</td>
</tr>
<tr>
<td></td>
<td>Under</td>
<td>1906</td>
<td>72</td>
<td>20</td>
<td>33</td>
<td>33</td>
<td>0</td>
<td>563</td>
<td>7</td>
<td>0</td>
<td>2635</td>
<td>25.87</td>
<td></td>
</tr>
<tr>
<td>Weekday, Day</td>
<td>Over</td>
<td>0</td>
<td>991</td>
<td>0</td>
<td>986</td>
<td>185</td>
<td>182</td>
<td>5288</td>
<td>442</td>
<td>0</td>
<td>8074</td>
<td>68.51</td>
<td>2.16:1</td>
</tr>
<tr>
<td></td>
<td>Under</td>
<td>1259</td>
<td>55</td>
<td>6</td>
<td>416</td>
<td>58</td>
<td>66</td>
<td>1733</td>
<td>63</td>
<td>55</td>
<td>3710</td>
<td>31.49</td>
<td></td>
</tr>
<tr>
<td>Weekday, Night</td>
<td>Over</td>
<td>0</td>
<td>1322</td>
<td>0</td>
<td>1439</td>
<td>414</td>
<td>511</td>
<td>5829</td>
<td>666</td>
<td>0</td>
<td>10181</td>
<td>66.08</td>
<td>1.94:1</td>
</tr>
<tr>
<td></td>
<td>Under</td>
<td>2502</td>
<td>69</td>
<td>9</td>
<td>537</td>
<td>102</td>
<td>41</td>
<td>1833</td>
<td>99</td>
<td>33</td>
<td>5227</td>
<td>33.92</td>
<td></td>
</tr>
</tbody>
</table>

The total flow across different times of the day are compared in Figure 3.

Figure 3. Grade-wise and Temporal Comparison of Vehicle Flow at Jatrabari-Gulistan Flyover.

Table 2 and Figure 3 show that an overwhelming majority of vehicles are travelling through above-grade or using the flyover, hence, reducing the probability of rail-road traffic conflict in Saidabad Level Crossing. The last column of the Table 2 showing relative usage by vehicles of road space over and under the flyover clarifies this proposition. The greatest disparity in flows between different grades is at weekend, day, with 20.22 % vehicles travelling at grade and 79.78 % vehicles.
travelling above grade. This variance decreases to a minimum of 66.08 % and 33.92 % respectively at weekday, night. Overall, the ratio of above-grade to at-grade flow is only 2.42:1. From Figure 3 it is observed that the highest flow above grade (10180.72 PCU/hr) at weekday, night and at grade (5226.52 PCU/hr) also occurring at weekday, night. The rationale for this may be explained by the fact that people from sub-urban area like, Narayanganj, Bhulta, Munshipur, Fatullah, Munshiganj are come to capital for work purpose and leave Dhaka after their office. Another reason may be added to the previous one is that as house rent and life-expense is extremely high in Dhaka, People who work in capital with less salary prefer to live outside the main city to save their cost. Additional reason is that the communication between port city, Chittagong and the capital, Dhaka is established through this route, number freight flow (truck) is extremely increased in night time as this type of vehicular flow is limited in day time in capital. Hence, it has been seen that number of trucks has been increased to 501.82% at night time compared with day time. In addition to that, considering the combined situation, total night flow exceeded the day flow by 29.38 % above grade and 53.02 % at grade. On the other hand, total weekday flow exceeded weekend flow by 38.46 % above grade by 119.97% at grade. This justifies the rationale explained earlier for high flow at night time in weekday.

5.2. Comparison with previous data

A comparison has been drawn between the weekday, day data of Anwari, Hoque and Islam (2016) collected in 2015 with the present data set of this study to visualize the yearly variation of flow and also to observe whether the flyover is performing well than previous or not.

![Figure 4. Vehicle Flow Comparison on Yearly Basis at Jatrabari-Gulistan Flyover (Weekday, Day).](image)

Figure 4 shows that the vehicle flow has increased at both grades (from 333.04 PCU/hr to 8073.92 PCU/hr above grade, and from 2400.28 PCU/hr to 3710.36 PCU/hr at grade. The percentage increase in above grade and at grade are 2324.31 % and 54.58%. In addition to that statistics, the
above grade to at grade flow ratio has enormously increased from 0.138:1 to 2.176: 1, indicating a prodigious increasing trend for vehicles to move from at grade to above grade. Since at grade motor traffic make conflicts with the train movements at the level crossings at this site, it can be evidently concluded that this flyover is successful in fulfilling the objectives of segregating rail and road traffic and thereby successful in eliminating congestion as well as to improve safety issues.

5.3 Assessment of non-motorized vehicles

From Table 2, it is also found that Rickshaw is the overwhelming major transport used at grade (51%). Hence, a particular focus has been given on NMVs to assess how far they are benefitted through the construction of this flyover.

Table 3 shows the proportion of non-motorized vehicles (NMVs) travelling over and under flyover. NMVs refer to rickshaws/ vans and bicycles in this study.

<table>
<thead>
<tr>
<th>Time</th>
<th>Percentage of Rickshaws/Vans</th>
<th>Percentage of Bicycles</th>
<th>Percentage of NMVs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Above grade</td>
<td>At grade</td>
<td>Above grade</td>
</tr>
<tr>
<td>Weekend, Day</td>
<td>0.00</td>
<td>100.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Weekend, Night</td>
<td>0.77</td>
<td>99.23</td>
<td>15.38</td>
</tr>
<tr>
<td>Weekday, Day</td>
<td>0.00</td>
<td>100.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Weekday, Night</td>
<td>0.00</td>
<td>100.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

A negligible presence of NMVs (only 0.95% at weekend, night) travelling above grade can be attributed to the dimensions that the grades of the approach ramps of flyovers make it difficult for NMVs to get on the flyover. This means that a significant portion of traffic will always be forced to travel at-grade and come in conflict with rail, implying that there will always be conflict with rail at level crossings whether or not flyovers are present. Consequently, it can be concluded that it is never completely possible to eliminate conflicts at level crossings by continuing the design approaches adopted for flyover design in Bangladesh. Anwari, Hoque and Islam (2016) observed that nearly half of at-grade flow of all flyovers is attributed to NMVs. This implies that nearly 50% of existing vehicles will continue to come in conflict with rail. The present study reveals that 29.25% of total traffic will pass underneath the studied flyover. Among these at-grade traffic 51% are NMVs. In addition to that, 99.76% NMVs of total NMVs are forced to use at-grade road. Hence, it is clearly evident that NMVs are not the beneficiary of constructing this flyover. Rather, they are travelling through at-grade road, hindering flow of at-grade vehicles and consequently, making congestion prolonger. In addition to that, since most of the vehicles are still using at-grade road to collect passengers, these NMVs hinder the flow of these public bus, produce severe congestion and make bus unpopular to general people. Eventually, people will shift to private small sized vehicles.
to get relief from this intolerable traffic congestion. Thus construction of flyover will promote usage of small sized vehicles rather than public transit oriented development.

5.4 Assessment of road usage by public transport

Assessment of public transport was incorporated into the study to investigate how much public transport have benefitted through the construction of flyovers. Fig. 5 shows the temporal variation of different types of vehicles using the at-grade and above-grade road along the corridor of flyover. From Fig. 5 it is apprehended that Jatrabari-Gulistan Flyover is facilitating the public bus to a significant level. The analyses of the data reveal that during studied time period bus and car are the most beneficiaries of construction of flyovers. The percentage of bus and car during different time periods at above-grade level are as following: weekend, day, Bus (34%), Car (32%); weekend, night: Bus (27%), Car (27%); weekday, day: Bus (66%), Car (12%) and weekday, night: Bus (57%), Car (14%). That is definitely a good sign that construction of this flyover is significantly associating public bus to use flyover space. The rationale for such findings may be justified by the fact that this flyover is at the confluence point of three important national highways viz. Chittagong (N1), Sylhet (N2) and Mawa (N8) as well as Demra (old Chittagong) road. Interestingly, most of the buses using this flyover are highway and long route buses. The percentage of public bus to serve the city dweller for their internal-internal movement is very negligible. In addition to that, field investigation also reveals that the at-grade roadway capacity has been deducted significantly by the piers of the flyovers, hence, vehicles passing through this corridor are compelled to use the above-grade road along the flyover corridor. Despite this fact, still car is found to be the second-most dominating vehicle along the flyover corridor, implying an unprecedented rate of growth of private vehicles, which will definitely affect the future traffic management of Dhaka city.

5.5 Assessment of speed

Travel speed and free flow speed of each types of vehicles were measured at Jatrabari-Gulistan Flyover to assess the mobility conditions of vehicles both at-grade and above grade and also apprehend the subsequent segment delays along the flyover corridor. These speeds were measured incorporating temporal variation in weekday, Night; Weekday, Day; Weekend, Night and Weekend, Day and presented in Figure 5.
Figure 5. Temporal Comparison of Travel Speed at Jatrabari-Gulistan Flyover.

It is observed that the maximum travel speed was recorded in Jatrabari-Gulistan Flyover at above-grade during weekend, day (31.37 km/h) while the slowest was recorded in weekday, day (10.06 km/h) at-grade road of this flyover corridor. This implies that a better travel speed is observed in this flyover corridor during weekend, day time while the case becomes critical during weekdays and it becomes the worst at weekday, day time of the at-grade road of the flyover. Vehicle speed at above-grade varies from 31.37 km/h during weekend, day time to 29.49 km/h during weekend, night. While it varies from 13.41 km/h during weekend, day time to 10.06 km/h during weekday, day. Average vehicle speed at above-grade in this flyover corridor is 30.46 km/h while the average vehicle speed at at-grade is 12.03 km/h. Although on an average vehicles are travelling at above-grade 2.53 times faster compared to at-grade, average vehicle speeds both at-grade and above-grade are really very insignificant to maintain smooth flow in urban cities. Particularly, the case is severe in at-grade road, where the vehicle speed has dropped drastically.

It has been found that vehicles are operated at travel speed rather than free flow speed in field condition. Speed variation results into variation of travel time in a particular segment of road. Consequently, author has given an insight to investigate how much delay is commenced due to these speed variation in this flyover corridor during different periods of times i.e., weekday, day; weekday, night; weekend, day; weekend, night. Table 4 shows the delay occurred due to variation in travel speed and free flow speed.

<table>
<thead>
<tr>
<th>Jatrabari-Gulistan</th>
<th>Segment</th>
<th>Travel</th>
<th>Travel</th>
<th>Free Flow</th>
<th>Free Flow</th>
<th>Average Delay Per Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekend Day, Over</td>
<td>11.8</td>
<td>31.37</td>
<td>1354.16</td>
<td>560.35</td>
<td>793.81</td>
<td></td>
</tr>
<tr>
<td>Weekend Night, Over</td>
<td>11.8</td>
<td>29.49</td>
<td>1440.49</td>
<td>564.52</td>
<td>875.97</td>
<td></td>
</tr>
<tr>
<td>Weekday Day, Over</td>
<td>11.8</td>
<td>30.56</td>
<td>1390.05</td>
<td>488.28</td>
<td>901.78</td>
<td></td>
</tr>
<tr>
<td>Weekday Night, Over</td>
<td>11.8</td>
<td>30.41</td>
<td>1396.91</td>
<td>494.82</td>
<td>902.09</td>
<td></td>
</tr>
<tr>
<td>Weekend Day, Under</td>
<td>9.62</td>
<td>13.41</td>
<td>2582.55</td>
<td>531.08</td>
<td>2051.47</td>
<td></td>
</tr>
<tr>
<td>Weekend Night, Under</td>
<td>9.62</td>
<td>11</td>
<td>3148.36</td>
<td>437.66</td>
<td>2710.70</td>
<td></td>
</tr>
<tr>
<td>Weekday Day, Under</td>
<td>9.62</td>
<td>10.06</td>
<td>3442.54</td>
<td>424.83</td>
<td>3017.72</td>
<td></td>
</tr>
<tr>
<td>Weekday Night, Under</td>
<td>9.62</td>
<td>13.23</td>
<td>2617.69</td>
<td>483.42</td>
<td>2134.27</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Delay Due to Variation of Travel Speed and Free Flow Speed at Jatrabari-Gulistan Flyover
Table 5 shows that significant delay occurs at Jatrabari-Gulistan Flyover corridor in every considered time period. Maximum and minimum delay were found during weekday, day at the at-grade road (3017.72 sec/vehicle) and weekend, day at the above-grade road (793.81 sec/vehicle) correspondingly. This implies that severe delays occur both at-grade and above-grade road of the flyover and it becomes most critical during weekdays. Hence, it can be evidently concluded that construction of this flyover has failed to enhance the free flow mobility condition in this flyover corridor, rather becomes a source of severe delays.

6. Conclusion and recommendations

Analyses of traffic flow reveal that an overwhelming majority of vehicles are travelling through this flyover, hence, reducing the probability of rail-road traffic conflict. From this perspective, this flyover can be considered as successful to fulfil the current traffic demand. However, the prodigious traffic growth rate and no of trips form south-eastern districts to Dhaka will be accelerated enormously with the construction Padma Multipurpose Bridge. Hence, it can easily be predicted that this flyover will be inadequate to meet this enormous traffic. Assessment of NMVs shows that this flyover has provided no facility for NMVs rather these NMVs are travelling through at-grade road and creating congestion by hindering flow of public vehicles and also making public vehicles unpopular to general people and promoting the use of small sized private vehicles. Assessment of speed study reveals that vehicles are operated at very low speed both at-grade and above grade of the flyover, especially vehicles travel speed at above-grade road is very low during weekdays and there is trend to decrease travel speed both at-grade and above-grade and, this will remain to continue in future if no further proved traffic engineering measures have applied. Also significant delay occurs all the studied time especially, at at-grade road along the flyover corridor. Thus, it can be concluded traffic growth rate along with more induced traffic due to rural connectivity improvement will worsen the scenario and adversely impact on the mobility in this corridor. To this end, Jatrabari-Gulistan Flyover has failed to fulfil its’ overall objectives and can be rated as poorly performed. However, the study doesn’t consider the queue length and queue dissipation time assessment to estimate traffic congestion level. In addition to that, no assessment has been performed to observe the impact of this flyover to adjacent regions in perspective of mobility and safety. Also the study does not consider geometric flaws of the flyovers which were observed during conducting the study. All these features can be incorporated into the future studies.

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