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Effectiveness of black spot treatments along Dhaka-Aricha highway

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Abstract

Dhaka-Aricha highway is one of the important national highways which connect the Northwestern and Northern region of Bangladesh with Dhaka. During 1990-2003, two major rehabilitation works were completed from Aricha to Savar and Aminbazar to Savar portion of this highway. Improvement of roadway safety was one of the major objectives. Besides three black spots were also improved namely Balitha area in Dhamrai upazilla, 2nd Golara bridge area and Golara area in Saturia upazilla under the Jamuna Bridge Access Road Project (JBARP). From the study it is seen that after the improvement work significant reduction of accidents took place in 2nd Golara bridge area and Balitha area but no tangible safety benefit was observed in Golara area. To this end, the effectiveness of the specific safety improvement measures that have been undertaken at these black spots by various methods is studied. Finally, recommendations are made for further improvement of these study sites and other similar black spots in Bangladesh.

Keywords: Black spots, safety treatments, before-after study, control site study.

1. Introduction

Dhaka-Aricha highway plays a vital role in inter-district and inter-regional transport as it connects the Northwestern and Northern region of Bangladesh with Dhaka, the national capital. It originates from Aminbazar Bridge and ends at Aricha Ghat covering a length of 75.4 km, encompassing six upazillas (UZ) namely, Savar, Dhamrai, Ghior, Saturia, Manikganj and Shibalaya. In this study, an attempt was made to evaluate the effectiveness of the safety measures undertaken during 1990 to 2003 along the three black spots in Dhaka-Aricha highway (Tender Document 1994, RMSS Bangladesh 1995).

In order to identify black spots along this highway, accident pin/dot diagrams were prepared by considering all geo-coded accident data and a location was considered as black spot if at least three fatal accidents are taken place during 3 year long observation period. In this study, the black spots are identified by using both per year accident rate as well as ranking methods. It is found from these maps that clustered type accident at the identified 41 locations accounts for 72.4% of total accidents and 72.2% of all fatal accidents occurred in the whole study area. It is learnt from Roads and Highways Departments (RHD) that during 1990 to 2003, two major rehabilitation works were completed from Aricha to Savar and Aminbazar to Savar segment of this highway, improvement of safety being one of the major objectives. Besides three black spots are also treated namely Balitha area (0.75 km segment) in Dhamrai UZ, 2nd Golara bridge area (0.50 km segment) and Golara area (0.50 km segment) in Saturia UZ (Contract Agreement Document 1997, RHD Report 1999). The authors tried to investigate the effectiveness of various safety measures undertaken at these black spots during the study period. To evaluate the performance of implemented safety schemes, various methods like before-after analysis, use of control sites and statistical tests were adopted to have a clear picture about the effectiveness of these safety measures in Bangladesh perspective, which may also be implemented on other similar high standard roads in Bangladesh.

2. Background of the study

Hoque (1991) conducted a comprehensive study of accidents on Dhaka-Aricha highway, which was of 81.4 km in length and encompassing six upazillas. He recommended various low cost safety measures including shoulder improvement, delineation, installation of guardrails, provision of overtaking lanes and improvement of narrow bridge approach. Unfortunately until very recently, road safety aspects could not attract as much the attention as it deserved, by concerned authorities, as such neither much effort nor resources were given for this critical issue. However, during 1995 to 1999 with the assistance of Denmark, a major rehabilitation work was completed from Aricha to Savar segment of the highway. In this major rehabilitation work accident reduction was one of the prime objectives. Besides, under JBARP a portion of this highway (Mirpur to Savar) was improved, through widening to dual carriageway with a median barrier to enhance road safety and also to accommodate increasing traffic. Again under the same project three black spots were improved on this highway. Different safety features were implemented under these projects, on the basis of the recommendations of various government and research organizations and more importantly by the donor agencies to improve the safety situation in this important inter-regional and inter-district major arterial highway. But neither any government nor donor agency has so far made any attempt to monitor or to evaluate the performance of these prescribed safety measures. The cost-benefit analyses of such works are yet to be conducted. The main reasons for not conducting such evaluation studies could be non-availability of relevant and detailed information over long period of time, especially the availability of detailed accident data, which could be amenable to scientific investigation. Moreover, as most of such projects are generally financed and implemented by donor agencies in Bangladesh, as they leave after the implementation of works hardly leaving behind any documents to be preserved by the users i.e. Roads and Highways Department (RHD) and other relevant agencies for identification and detailed effectiveness evaluation as follow up which are very important for a developing country like Bangladesh. As such, identification of details of such works become very difficult and strenuous task. In this study it was a big challenge to collect various types of data from RHD, consultants, donor agencies and contractors involved with the projects.

In this study, an attempt is made to depict the accident scenario and evaluate the performances of installed safety features in three black spots, along Dhaka-Aricha highway during 1990-2003. In order to study accident characteristics and to determine the effectiveness of different safety improvement measures, data were collected for both 'before' and 'after' implementation of these works. Accident data were directly retrieved from the Police records, Crime Index registrar as well as data is also collected from the hospital Road Traffic Accident (RTA) registrar and Road Safety Cell (RSC) for verification purposes. In order to supplement accident database, data also gathered from previous studies were considered as a secondary source. Inventories of different safety improvement measures undertaken at the locations of Dhaka-Aricha highway is collated getting information from the relevant parties, involved with the improvement works, such as RHD and consulting companies working in Bangladesh namely, SARM associates, SMEC, DDC and BCL. For detail analysis of accident data, site specific roadway geometric and operational inventories were also collected by field survey. The inventory data along with accident data can also be found elsewhere (Muniruzzaman 2004).

3. Description of the black spots

In 1999, nationwide 27 black spots were identified by RHD using accident data reported by Police, of which 10 were selected for immediate improvement (RHD Report 1999). Three of those are located along Dhaka-Aricha Highway, namely Balitha area that is also known as Bethuli bazar (km reference 50.7-52.0), 2nd Golara bridge Area (km reference 56.0-56.7) and Golara area (km reference 57.2-57.7) (RHD Report 2003, RHD Detailed Zonal Report Series 1998). It is to be mentioned here that Balitha is situated in Dhamrai UZ and other two black spots are in Saturia UZ and all these three spots are located in Section 2 of the Savar-Aricha highway. These black spots were improved through JBARP. The project commenced on 2001 and completed on June 2002 (RHD Status Report and Monthly Progress Report 2000). The treated locations are shown in Figure 1.

4. Before-after analysis of black spots

In this analysis while considering the before period, two sets of timings are used, one from the beginning of the study duration up to implementation of the projects (1990-2000) and the other considered by RHD while undertaking these projects (1996-1998). For after period one year data is considered. Before-after analysis of these improvement schemes is furnished in the subsequent Articles.

5. Improvement of Balitha area (km reference 50.7-52.0, Treated Site 1)

Site description: Balitha area, which is also known as Bethuli bazar and Ballya to the local people, is located on curve. It also includes a staggered-T type, unsignalized 3-legged intersection. The pavement in this section is single carriageway with 6.5 m width having smooth-non-skid surface. Embankment height varies from 5 to 12 ft (2-4 m). Average shoulder width varies from 2.5-5.0m paved and 2.0-2.5m earthen on each side. There are few big trees near the shoulder.

Improvement measures: Major improvement features include widening of pavement along with alignment correction, construction of separate bus bay, installation of warning gate with speed reducing sign on both entry and exit.

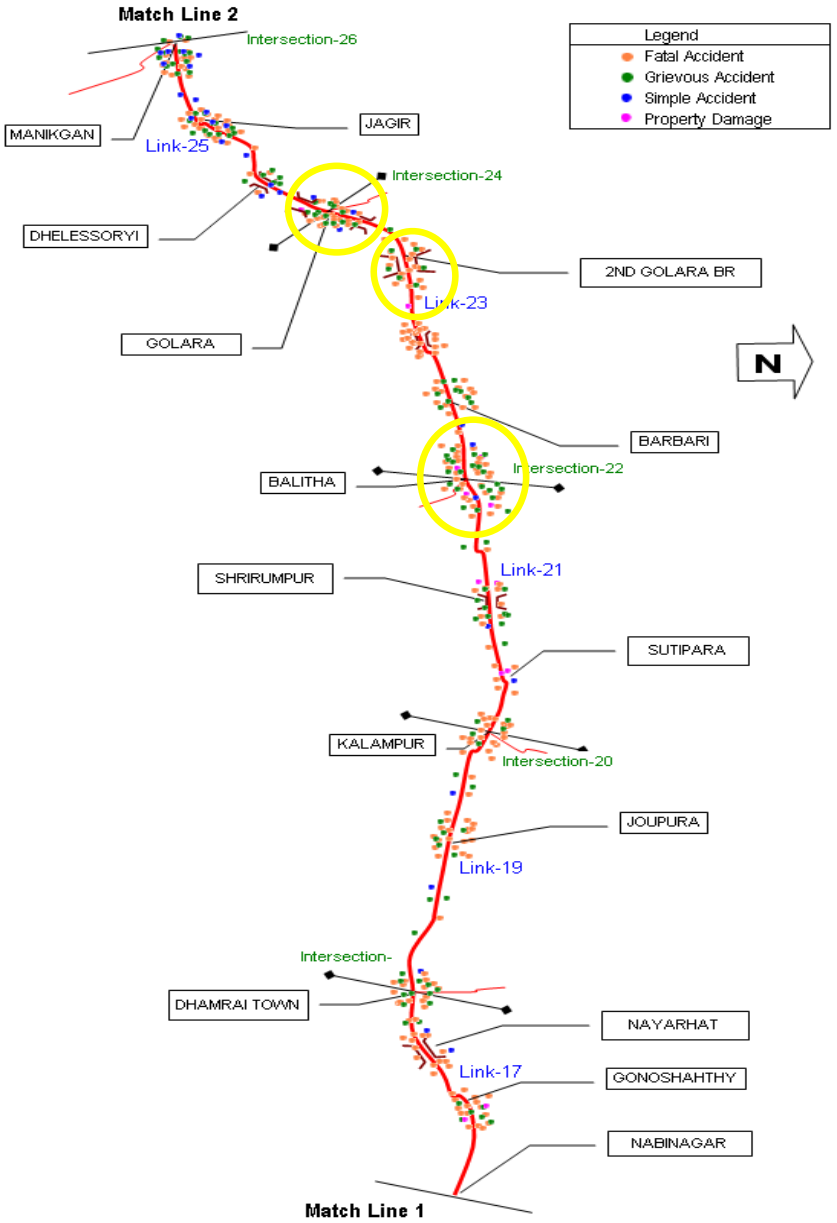

Fig. 1. Road alignment map showing the accident intensity and treated black spots

Observations: Table 1 presents the before-after analysis of Balitha area, (Treated Site 1), which reveals that in Balitha area significant improvement in accident reduction took place due to the improvement work. It can be seen from the Table 1 that in this area accident were reduced by 59% and 69% considering the 1990-2000 (the total period) and 1996-2000 (RHD period) as before periods. From the close observation of Table 1 it can also be seen that, grievous, Property Damage (PD) and simple accidents are eliminated and fatal accidents were reduced by 22% and 34% for total (1990-2000) and RHD (1996-2000) considered period.

As regards to accident pattern Table 1 discloses that head-on, hit object and rear end collisions are eliminated and pedestrian accidents were reduced by 22% and 25% for total and RHD period respectively. However, overturned accidents were increased by 50%. As only one year "after period" is considered in this analysis for definite conclusion continuous further monitoring is essential.

Table 1
Before-after analysis of Balitha / Bethuli area (50.7-52.0km) Treated Site 1

Basis of Before-After Comparison	Before Period				After period		Change of Accident (%)	
	Considering total period (1990-2000)		RHD Considered Period (1996-1998)		(Jun2002-Jun2003)			
	Total No	Avg/Year	Total No	Avg/Year	Total No	Avg/Year	Considering total period	Considering RHD period
Based on Severity								
Fatal	28	2.55	9	3.00	2	2	-21.43	-33.33
Grievous	18	1.64	7	2.33	0	0	-100.00	-100.00
Simple	2	0.18	1	0.33	0	0	-100.00	-100.00
Property Damage (PD)	6	0.55	2	0.67	0	0	-100.00	-100.00
Total	54	4.91	19	6.33	2	2	-59.26	-68.42
Based on Collision type								
Pedestrian	14	1.27	4	1.33	1	1	-21.43	-25.00
Head On	8	0.73	2	0.67	0	0	-100.00	-100.00
Hit Obi	8	0.73	3	1.00	0	0	-100.00	-100.00
Over T	7	0.64	2	0.67	1	1	57.14	50.00
Side Swipe		0.00	-	-	-	-		
Rear End	1	0.09	-	-	-	-	-100.00	
Doped from bus		0.00	-	-	-	-		
Unidentified	16	1.45	8	2.67	0	0	-100.00	-100.00
Total	54	4.91	19	6.33	2	2	-59.26	-68.42
Based on Casualty								
Killed	29	2.64	10	3.33	3	3	13.79	-10.00
Serious Injured	98	8.91	27	9.00	6	6	-32.65	-33.33
Total	127	11.55	37	12.33	9	9	-22.05	-27.03
Based on Time of Day								
Day	36	2.67	14	4.67	1	1	-62.50	-78.57
Night	18	1.33	5	1.67	1	1	-25.00	-40.00

6. Improvement of 2nd Golara bridge area (km reference 56.0-56.7 km, Treated Site 2)

Site description: The area includes a bridge with sharp bend and vertical curve. Sometimes, it is difficult to perceive the bend from both directions especially at night. The pavement in this section is of single carriageway with 6.5m width having smooth-non-skid surface. Embankment height varies from 3-5m. Average shoulder width varies from 1.5-2.5m paved and 1.0-1.5m earthen on each side. The bridge width is less than the approach width of pavement. There are few big trees near the shoulder. Vertical sight distance in the area is inadequate.

Improvement measures: Major improvement features include widening of pavement and embankment along with alignment correction; installation of marking, signs and guard post, improvement of bridge, which include construction of sub grade and rainwater drain.

Observations: Table 2 presents the before-after analysis of 2nd Golara bridge area (Treated Site 2). It can be seen from the Table that, significant improvement took place in accident reduction due to the improvement work. Table 2 reveals that, in 2nd Golara bridge area accident was reduced by 67% and 50% considering the 1990-2000 (the total period) and 1996-2000 (RHD period) as before periods. Close insight of Table 2 disclose that, grieves, PD and simple accident were eliminated and fatal accident was reduced by 27% and 63% for total (1990-2000) and RHD (1996-2000) analysis period. Regarding accident pattern Table 2 reveals that head on, hit object, overturned and unidentified collisions were eliminated and pedestrian accidents were reduced by 9% and 40% for total (1990-2000) and RHD (1996-2000) considered period.

7. Improvement of Golara area (km reference 57.2-57.7, Treated Site 3)

Site Description: Golara area is located on a sharp curve. The area includes a T-type unsignalized i.e. major/minor intersection. There are two bridges within this area on eastern and western side, at entry/exit to this section. The pavement in this section is single carriageway with 7.0m width having smooth-non-skid surface. Embankment height varies from 3-5m. Average shoulder width varies from 2.0-3.5m paved and 1.5 - 2.5m earthen on each side. There are few big trees near the shoulder. On the southern side there are deep ditches at a very steep slope.

Improvement measures: Major improvement features include widening of pavement and embankment along with correction of alignment, construction of retaining wall, bus bay, passenger shed, construction of separate lane for NMV and MV traffic on the bridge at eastern side, installation of marking, signs, improvement of intersection.

Observations: Table 3 presents the before-after accident analysis of Golara area (Treated Site 3). The Table reveals that in Golara area though fatal accidents were reduced by 36% and 58% for total (1990-2000) and RHD (1996-1998) considered period but grievous accidents were increased by five times causing an overall increase of accidents almost by two times. Regarding accident pattern Table 3 shows that hitting pedestrian and head on accidents were increased by more than two and three times respectively considering RHD period (1996-1998) but over turned, sideswipe and rear end collisions were eliminated. Table 3 discloses evolving a new accident type of dropping from the bus in this area.

As pedestrian and head on accidents were increased significantly, Zebra crossing for pedestrian may be installed, besides overtaking should be prohibited in this section and a divider may be constructed to eliminate head on accident. However as only one year “after period” is considered in this analysis for definite conclusion continuous further monitoring for next two years is essential.

8. Evaluation by using control sites

One of the popular and useful methods of evaluation is to compare the accidents of treated sites with other sites of similar geographic and traffic condition, where no improvement has taken place. In this study, three control sites are selected for analyzing

performance evaluation of treated sites namely Balitha, 2nd Golara and Golara area. Each site is tested against two adjacent control sites. For this study, Shrirampur area (Control-site-1), Barbaria (Control-site-2) and Jagir area (Control-site-3) are selected as control sites having similar traffic and geographic condition. Comparisons of accidents of these improved sites with treated sites are shown in Tables 4 to 6.

Table 2
Before-after analysis of 2nd Golara bridge area (56.0-56.7 km, Treated Site 2)

Basis of Before-After Comparison	Before Period				After period		Change of Accident (%)	
	Considering total period (1990-2000)		RHD Considered Period (1996-1998)		(Jun2002-Jun2003)			
	Total No	Avg/ Year	Total No	Avg/ Year	Total No	Avg/ Year	Considering total period	Considering RHD period
Based on Severity								
Fatal	15	1.36	8	2.67	1	1	-26.67	-62.5
Grievous	5	0.45	1	0.33	0	0	-100.00	-100.00
Simple	1	0.09			0	0	-100.00	0.00
Property Damage (PD)	1	0.09			0	0	-100.00	0.00
Total	22	2.00	9	3.00	1	1	-50.00	-66.67
Based on Collision type								
Pedestrian	12	1.09	5	1.67	1	1	-8.33	-40.00
Head On	2	0.18	1	0.33	0	0	-100.00	-100.00
Hit Object	3	0.27	2	0.67	0	0	-100.00	-100.00
Over T	1	0.09	1	0.33	0	0	-100.00	-100.00
Unidentified	4	0.36					-100.00	0.00
Total	22	2.00	9	3.00	1	1	-50.00	-66.67
Based on Casualty								
Killed	14	1.27	11	3.67	1	1	-21.43	-72.73
Serious Injured	29	2.64	23	7.67			-100.00	-100.00
Total	43	3.91	34	11.33	1	1	-74.42	-91.18
Based on Time of Day								
Day	13	1.18	4	1.33	1	1	-15.38	-25.00
Night	9	0.82	5	1.67			-100.00	-100.00

- Table 4 reveals that in Treated Site 1 both fatal and total accident are decreased by 22% and 60% considering total (1990-2000) period whereas in Control-site-1 and 2 fatal accidents are increased by 57.1% and 120% respectively. Total accidents in Control-site-2, are increased by 37.5% and in Control-site-1 though decreased by 35.29% but this decrease is much lower than the corresponding decrease in Treated Site (59.3%). Critical observation from Table 4 implies that safety improvements in Treated Site 1 are apparently very effective in reducing accident in comparison to untreated sites both in terms of frequency and severity.

- Table 5 shows that in Treated Site 2 total accidents are reduced by 50% considering total period (1990-2000) but corresponding figure for Control-site-2 are increased by 37.5% and in Control-site-3, decreased at a lower rate of 40%. It can be seen from

Table 5 that fatal accident in Treated Site 2 is decreased by 62.5% by considering RHD period (1996-1998) though corresponding figure for Control-site-2 is increased by 16.67% and in Control-site-3, decreased by 50%. This statistics implies that safety improvements in Treated Site 2, apparently prove to be effective in reducing accidents in comparison to untreated sites both in terms of frequency and severity.

Table 3
Before-after analysis Golara area (57.2-57.7 km, Treated Site 3)

Basis of Before-After Comparison	Before Period				After period		Change of Accident (%)	
	Considering total period (1990-2000)		RHD Considered Period (1996-1998)		(Jun2002-Jun2003)			
	Total No	Avg/ Year	Total No	Avg/ Year	Total No	Avg/ Year	Considering total period	Considering RHD period
Based on Severity								
Fatal	17	1.55	7	2.33	3	1	-35.29	-57.14
Gravies	7	0.64	2	0.67	4	4	528.57	500.00
Simple	3	0.27	1	0.33	0	0	-100.00	-100.00
Property Damage (PD)	1	0.09	-	-	0	0	-100.00	-
Total	28	2.55	10	3.33	7	7	175.00	110.00
Based on Collision Type								
Pedestrian	13	1.18	4	1.33	3	3	153.85	125.00
Head On	3	0.27	2	0.67	3	3	1000.00	350.00
Hit Object	1	0.09	-	-	0	0	-100.00	-100.00
Over Turn	4	0.36	1	0.33	0	0	-100.00	-100.00
Side Swipe	1	0.09	1	-	0	0	-100.00	0.00
Rear End	2	0.18	1	-	0	0	-100.00	0.00
Dropped from bus		0.00	-	-	1	1	0.00	0.00
Unidentified	4	0.36	1	0.33	-	-	-100.00	-100.00
Total	28	2.55	10	3.33	7	7	175.00	110.00
Based on Casualty								
Killed	23	2.09	13	4.33	4	4	91.30	-7.69
Serious Injured	51	4.64	16	5.33	22	22	374.51	312.50
Total	74	6.73	29	9.67	26	26	286.49	168.97
Based on Time Day								
Day	19	1.73	8	2.67	5	5	189.47	87.50
Night	9	0.82	2	0.67	2	2	144.44	200.00

- Table 6 discloses that in Treated Site 3 accidents are increased by 110% whereas in Control-site-1 and 3 accidents are decreased by 50% and 14% considering RHD period (1996-1998). Table 6 discloses that in Treated Site 3 fatal accidents are reduced by 57.1% considering RHD period (1996-1998), whereas corresponding figures for Control-site-2 is increased by 16.67% and for Control-site-3 decreased by 50%. A detail insight of Table 6 indicates that in Treated Site 3, total accidents are increased and though fatal accidents are reduced but the reduction is not significant in comparison to the control sites. This implies that safety measures in Treated Site 3 apparently do not indicate any significant improvement in relation to the untreated sites in the network.

- From the above discussion it is evident that in Treated Sites 1 and 2 accident reduction is very effective in comparison to Control sites but accident scenario in Treated Site 3 is not effective in comparison to control sites.

Table 4
Comparison of before-after results for Treated Site 1 using control sites

Accident Type	Treated Site 1 (%)		Control Site 1(%)		Control Site 2 (%)	
	Total period	RHD period	Total period	RHD period	Total period	RHD period
Fatal	-21.43	-33.33	57.14	-2500.00	120.00	16.67
Grievous	-100.00	-100.00	-100.00	-100.00	-100.00	-100.00
Simple	-100.00	-100.00	-100.00	0.00	0.00	0.00
PD	-100.00	-100.00	-100.00	-100.00	0.00	0.00
Total	-59.26	-68.42	-35.29	-50.00	37.50	-50.00

Table 5
Comparison of before-after results for Treated Site 2 using control sites

Accident Type	Treated Site 2 (%)		Control Site 2(%)		Control Site 3(%)	
	Total period	RHD period	Total period	RHD period	Total period	RHD period
Fatal	-26.67	-62.50	120.00	16.67	-47.62	-50.00
Grievous	-100.00	-100.00	-100.00	-100.00	0.00	200.00
Simple	-100.00		0.00	0.00	-100.00	0.00
PD	-100.00	0.00	0.00	0.00	0.00	0.00
Total	-50.00	-66.67	37.50	-50.00	-40.54	-14.29

Table 6
Comparison of Before-After Results for Treated Site 3 Using Control Sites

Accident Type	Treated Site 3 (%)		Control Site 2 (%)		Control Site 3 (%)	
	Total period	RHD period	Total period	RHD period	Total period	RHD period
Fatal	-35.29	-57.14	120.00	16.67	-47.62	-50.00
Grievous	-100.00	-100.00	-100.00	-100.00	0.00	200.00
Simple	-100.00	-100.00	0.00	0.00	-100.00	0.00
PD	0.00	0.00	0.00	0.00	0.00	0.00
Total	175.00	110.00	37.50	-50.00	-40.54	-14.29

9. Evaluation by using statistical chi-square method

The Chi-square test is frequently conducted to check whether the adopted counter measures are really effective in reducing the number of accidents or the desired parameters intended to reduce by comparing before-after data. In this analysis it actually tests if sample means observed over two different intervals of time period is from the same population or not. Here, the Chi-Square values for different measures of indices (MOE) like total accident, fatal accident, predominant type of accident etc. are estimated, to test the effectiveness of the adopted safety measures at three treated sites. In this before-after statistical analysis two-analysis periods are used, one from the beginning of the study (1990-200) and another period (1996-1998) that is considered by RHD.

Table 7 shows the estimated Chi-Square values for total accidents, accident severity, different types of accidents, etc. for three treated black spots. Table 7 reveals that in Balitha area (Treated Site 1), there is strong evidence that the improvement at this black spot is significant and that the reduction of total number of accidents is not merely due to chance only, considering the RHD (1996-1998) period, at 10% LOS with 1 DOF. Other improvements during this period in these areas might have arisen due to chance only except grievous accident which is also significant at 10% LOS. Table 7 reveals that, in 2nd Golara area (Treated Site 2), as regards to head-on collision; there is strong evidence that the improvement at this black spot is significant considering the RHD (1996-1998) period, at 5% LOS with 1 DOF. Statistics results for this treated site shows that other improvements during this period are not significant and might have arisen naturally. Table 7 further discloses that, in Golara area (Treated Site 3) there is strong evidence that the improvement at this black spot is significant and that the reduction of total number of accidents is not merely due to chance only, considering the RHD (1996-1998) period, at 10% LOS. The other improvements in terms of significant reduction of head-on collision and pedestrian casualties are also evident considering both total and RHD period.

Table 7
Evaluation of black spot improvement works by using chi-square method

Basis of Evaluation	Chi-square (est) for Balitha Area				Chi-square (est) for 2nd Golara Bridge				Chi-square (est) for Golara Area			
	Total period	Remarks	RHD period	Remarks	Total period	Remarks	RHD period	Remarks	Total period	Remarks	RHD period	Remarks
Based on Type of Accident												
Total accident	1.79	Not Significant	3.72	Significant at 10% LOS	0.52	Not Significant	1.68	Not Significant	2.50	Significant at 10% LOS	1.60	Not Significant
Fatal Accident	0.17	Not Significant	0.48	Not Significant	0.13	Not Significant	1.24	Not Significant	0.38	Not Significant	0.90	Not Significant
Grievous Accident	1.69	Not Significant	2.58	Significant at 10% LOS	0.46	Not Significant	0.36	Not Significant	1.68	Not Significant	1.47	Not Significant
Predominant Accident Type												
Pedestrian	0.10	Not Significant	0.14	Not Significant	0.28	Not Significant	0.36	Not Significant	2.30	Significant at 10% LOS	1.68	Not Significant
Head On	0.79	Not Significant	0.72	Not Significant	3.31	Significant at 5% LOS	0.36	Not Significant	24.97	Significant at 0.1% LOS	7.10	Significant at 1% LOS
Hit Object	0.79	Not Significant	1.09	Not Significant	0.10	Not Significant	0.72	Not Significant	-	-	-	-
Over Turn	0.14	Not Significant	0.10	Not Significant	-	-	-	-	0.40	Not Significant	0.36	Not Significant

Note: Critical values of Chi-Square are: 2.7 at 10% LOS, 3.84 at 5% LOS, 5.02 at 2.5% LOS, 6.63 at 1% LOS, 7.88 at 0.5% LOS and 10.8 at 0.1% LOS

Obtaining ‘not significant’ at many occasions might be due to lack of data. In this study the statistical Chi-Square test is performed considering only one-year period after the implementation of the road safety improvement project. Theoretically, at least 3 years monitoring of after result is needed for any decisive conclusion regarding the performance of a particular counter measure.

10. Conclusions

Accident data were analyzed both at macro and micro level as well as qualitatively by observing data and field conditions critically. Performance evaluation of safety measures is made by applying before-after technique, control-site method and standard statistical chi-square method. Based on these, the summary of findings of this study, conclusions and understanding of the factors contributing to the frequent occurrence of accidents which may lead to better design of safer highway for the future are presented in the following articles.

10.1 Balitha area

From before-after analysis of accident data it is found that in Balitha site safety situation was improved significantly. The total and fatal accidents are reduced by 69% and 34% respectively. Before-after study of accident pattern shows that head-on, hit object, rear-end collisions are eliminated and hitting pedestrian accidents are reduced by 25%. It is worth mentioning here that in this analysis only one year is considered as 'after' observation period. Moreover, detail geometric changes of the roadway segment could not be studied due to unavailability of previous drawings.

- From the field observation, it is found that though the speed limit signs are installed but these are frequently violated especially by the through traffic. Moreover, in most of the cases bus drivers do not use the properly designed bus-bay and perform passenger picking and dropping operation on the main carriageway endangering road users' safety, which suggests that effective enforcement is warranted in order to further improvement of safety situation at this site.

10.2 2nd Golara bridge area

In 2nd Golara Bridge area significant reduction of accidents took place after the implementation of improvement works. Fatal and total accidents are reduced by 63% and 67% respectively. Head-on, hit object, overturned and unidentified collisions are eliminated and pedestrian accidents are reduced by 40%. At this location, significant reduction of accidents implies that widening of carriageway at bend, alignment correction and installation of guard posts with retro-reflecting markings are very effective measures and have the potential to improve safety situation.

- During field visit it is found that still there is a lot of scopes to improve the roadway operating conditions by dividing the bridge and if possible with special provision of separate NMV lane and more importantly by introducing effective enforcement measures with the of highway patrol police.

10.3 Golara area

Before-After analysis of accident data shows that in Golara area though fatal accidents are reduced by 36% but grievous accidents are increased by five times resulting an overall increase of accidents by almost two times. Looking at the accident patterns, it is observed that on one hand overturn and rear-end type collisions are eliminated, on the other hand, hitting pedestrian and head-on type accidents are increased by two and three times respectively.

- From the above findings it is revealed that though a large number of countermeasures are implemented in this section, they could not improve the situation expectedly. It also tentatively appears that though in this site number of accident considerably increased during the one year 'after' observation period, most importantly severity of accidents is reduced substantially.
- During field visits it is learnt from the local people that previously most of the accidents occurred on and around the bridges which are now shifted to the middle portion of the section, where intensity of pedestrian activities particularly where crossing activities of school going children are high. This implies that separation of NMV on the bridge is working properly and appears to be very effective in reducing accidents.

Both 'before-after' and 'control-site' methods of analyses revealed that the limited site-specific safety improvement measures undertaken along the Dhaka-Aricha highway are very effective in reducing the frequency as well as the severity of the accidents, though in a few instances the implemented accident preventive countermeasures could not produce the expected good results. For statistical test only, one-year time has elapsed after the implementation of the project. So at least 3 years monitoring of after result is needed, for any concrete decision about their performance. Field surveys disclosed that the presence of intense roadside non-motorized activities such as roadside hawking, conflicting use of road marginal areas for drying paddy, etc. in conjunction with the absence of the needed enforcement measures through strict highway patrolling loom as the underlying reasons for not getting the expected benefits from the safety improvement investment. Besides, considering the grime findings of on-going significant economic losses resulting from recurring accidents as well as evidence of significant improvement from investment related to the safety improvement measures which were undertaken at the selected black-spot areas of this corridor, it can be said emphatically that if improvements measures are undertaken for other black-spot areas of the national highways network and side by side if effective enforcement is put in practice it shall bring considerable economical benefits to the nation and the national exchequer.

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