Proceedings of 13th IOE Graduate Conference
Peer Reviewed
ISSN: 2350-8914 (Online), 2350-8906 (Print)
Year: 2023 Month: April Volume: 13

Analyzing the Impact of Lane Use Restrictions on Traffic Flow at Urban Intersection: A Case Study of New Baneshwor Intersection

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Abstract
New Baneshwor intersection is one of the busiest intersections inside Kathmandu valley. Flow of traffic occurs to and through this intersection as it houses major educational institutions, hospitals and business area. A huge traffic flow occurs through this intersection during morning and evening peak hours. Traffic congestion occurs during these hours so study had to be carried out to present an alternative. Field data were collected during the morning peak hours (9:00 – 11:00 AM) and evening peak hours (4:00 – 6:00 PM). Data were extracted from the video-graphic survey and fed to VISSIM to carry out the simulation. 4 Scenarios were prepared based on lane use plan to compare the traffic performance measures. Scenario 4 proved to be most effective in reducing the travel time and delay. Left turn vehicles from the main lane of major road were shifted to service lane and the left turn vehicles from minor road were restricted to main lane of major road. Travel time could be reduced by 15.11% and 5.39% for Maitighar Main lane and Tinkune Main lane respectively. Delay could be decreased by 18.63% and 7.05% for Maitighar Main lane and Tinkune Main lane respectively. In the evening peak hours, travel time decreased by 5% and 5.63% for Maitighar main lane and Tinkune main lane respectively. Delay decreased by 7.07% and 7.22% for Maitighar main lane and Tinkune main lane respectively..

Keywords
VISSIM, Vehicle Restriction, Urban Intersection, Simulation, Travel time, Delay

1. Introduction

1.1 Background

Time lost by a vehicle due to causes beyond the control of the driver while traversing the intersection is delay. Huge traffic volume moves through New Baneshwor intersection. Out of 2,783,428 vehicles registered till the fiscal year 2073/74, 1,042,856 were registered in Bagmati zone [1].

Travel Demand Management (TDM) need to be implemented to reduce congestion to some extent. Among the various TDMs vehicle restriction method are direct and most effective methods [2].

Field experiments are generally prevented due to legal and financial constraints while traffic simulation is a cost effective, objective and flexible approach to analyze and evaluate transportation system [3]. PTV VISSIM has been used as micro simulation software to simulate the flow in given different sets of conditions. The output from the simulation includes vehicle volume, travel time, Queue Length and Delay.

1.2 Research Objectives

The focus of this study is to determine the effect of the vehicular restriction policies on intersection performance using VISSIM as micro simulation software. The primary focus of this study can be listed as:

- To calibrate and validate VISSIM model for traffic volume and average queue length.
- To perform lane use restriction scenario analysis to find its effect on travel time, delay and queue.

2. Literature Review

Microsimulation tool used to carry out a study to determine the effect of truck lane use restriction on highway under a set of scenarios concluded there was a little difference in speed and Level of Service but effectively reduced lane changes [4].

Effects of heavy vehicle restriction in a section of Princes Highway in Melbourne, Australia were studied using microsimulation software. Heavy vehicles were categorized in to three classes Rigid, Heavy Combination and Multi Combination and four scenarios restrictions were applied. Average travel time and average speed were used to calibrate the model and average travel time, average speed and average delay were used as performance measures for comparison. Restriction of all heavy vehicles provided most efficient results [5].

Microsimulation was carried out to study the effects of two lane restriction strategies left lane and right lane truck restriction strategies. Density, lane change per vehicle and speed differential were used as traffic performance measures to evaluate the model. Two comparison scenarios in the study were no restriction against restriction of heavy trucks from left lane and no restriction against restriction from right lane. The study concluded not to restrict heavy vehicles from right lane due to increase in lane change causing safety concerns [6].

Microsimulation was carried out to evaluate the alternative scenarios introducing flyover and U-turn to relieve congestion at New Baneshwor Intersection. Among the scenarios three phases signal planning with flyover by providing U-turn could effectively decrease delay and travel time by 81.92% and 80.1% in morning and evening peak time respectively.Additionally, travel time and delay could be decreased by 60% in Maitighar, Tinkune, Old Baneshwor and Shankhamul in morning and evening peak hours [7].

License Plate Recognition data were used to study the effect of two restriction strategies Odd and Even (OAE) and One Day Per Week (ODPW) effective in Langfang. Volume of traffic decreased with shift from ODPW to OAE [8]. The shift of volume was not as expected due to the use of alternate vehicles, travel intensity and illegal travel [9].

From most of the literature reviewed it can be found that lane restriction and vehicle restriction strategies were studied for highways with homogeneous traffic for a certain span of road. This study focuses to find the result of restriction applied on urban intersection with heterogeneous traffic.

3. Methodology

3.1 Study Area Selection

In this study New Baneshwor intersection and the links connected to it are considered as it has high volume, is congested during the peak hours and causes delay.

3.2 Field Data Collection

3.2.1 Intersection and Road Geometry

Geometry of intersection and width of link roads were measured manually in the field using portable handheld laser distance measuring tool. Major road of length 1km and minor road of length 580m were taken for the study.

3.2.2 Video-graphic Survey

Wide angle video camera was used to collect video of movement of traffic at the intersection at two peak periods of day i.e. 9:00 – 11:00 AM and 4:00 – 6:00 PM. Video were taken for three days on Tuesday, Wednesday and Thursday.

3.3 Data Extraction

Collected videos were played multiple times in the computer and the following data were extracted from the video-graphic survey:

- Type of vehicles
- Classified vehicle count
- Directional movement of each vehicle
- Relative flows of individual vehicles
- Signal timing and phase data
- Computation of travel time

Classification of vehicles was considered as per Nepal Road Standard 2070 [10].

3.4 Microscopic Simulation Model Development

Model was developed using VISSIM as a microsimulation tool. The links in and out of the intersection were first drawn over the map in VISSIM. The links were then connected by the connector to make the flow of traffic as observed in the site. The maneuvers were depicted as per the field by aligning the connectors with the general curvature of the roadway. Separate right turn lanes were defined for traffic travelling from Maitighar to Shankhamul and Tinkune to Purano Baneshwor to avoid the blockage of through traffic by right turn traffic [11]. The extracted data were then fed into VISSIM for simulation.

Node was defined and Travel time measurement points were provided to measure travel time and delay. Queue counters were placed just before the signal head to obtain the queue count.

4. Calibration and Validation of the Model

4.1 Calibration of Driving Behavior

Field data from Wednesday and Thursday were used in calibration of model and field data from Tuesday was used in validation of model. Driving Behavior parameters were used in calibration of model and those parameters were altered until the output from simulation matched the field traffic volume. Driving behavior parameters used by Acharya and Marsani [11] were used in the model. Calibrated driving behaviour parameters have been presented in Table:1).

Table 1: Calibrated Driving Behavior Parameters

S.N.	Parameters	Calibrated values
1	Look ahead distance	30.00m
2	Look back distance	5.00m
3	Average standstill distance	0.30m
4	Min. headway (front/rear)	0.50m
5	Additive part of safety distance	0.19
6	Multiplicative part of safety distance	0.71

4.2 Calibration and Validation of Model for Traffic Volume

Traffic Volume from Wednesday and Thursday (9:00 – 11:00 AM and 4:00 – 6:00 PM) were used to calibrate the model. Simulations were run in VISSIM and the output volume and input volume were compared using the Geoffrey E. Havers (GEH) formula. Value of (GEH) was obtained less than 5, which indicates the acceptable fit. Calibration and Validation of VISSIM Model for Traffic Volume are presented in fig:1 and 2. R squared value after calibration was found to be 0.9999. It indicates that 99.99 percent of variance of the field data is explained by the variance of the VISSIM output. Regression equation is:

$$VISSIMoutputexpectedVolume = 0.9758 * FieldVolume \quad (1)$$

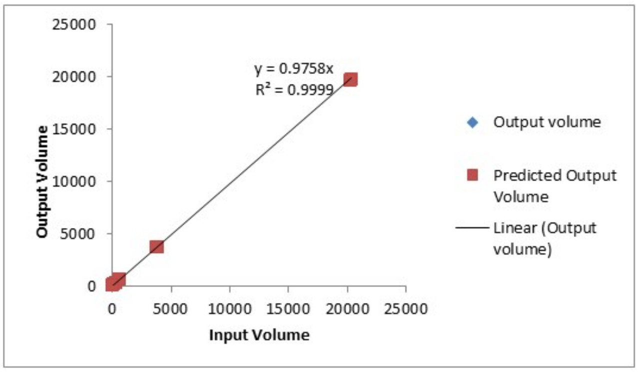

Figure 1: Calibration of VISSIM Model for Traffic Volume

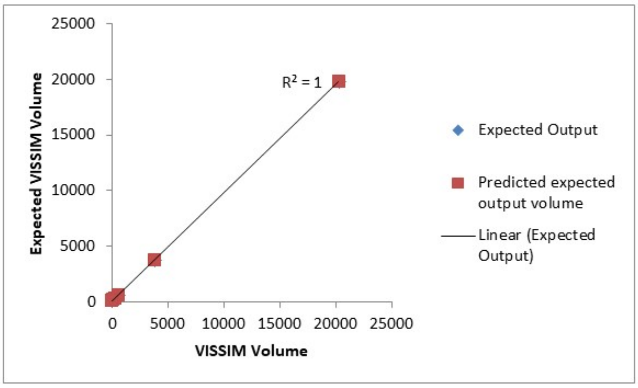

Figure 2: Validation of VISSIM Model for Traffic Volume

4.3 Calibration and Validation of Model for Queue Length

The average queue length and VISSIM queue length were compared by carrying out the regression analysis. R-squared value after calibration was found to be 0.9238. It indicates 92.38 percent of variance of the field data is explained by the variance of the VISSIM Output. Calibration and Validation of VISSIM model for Queue length are presented in fig:3 and 4 respectively. The relationship between the field queue length and VISSIM queue length was obtained as:

$$VISSIMQueueLength = 0.9741 * FieldQueueLength \quad (2)$$

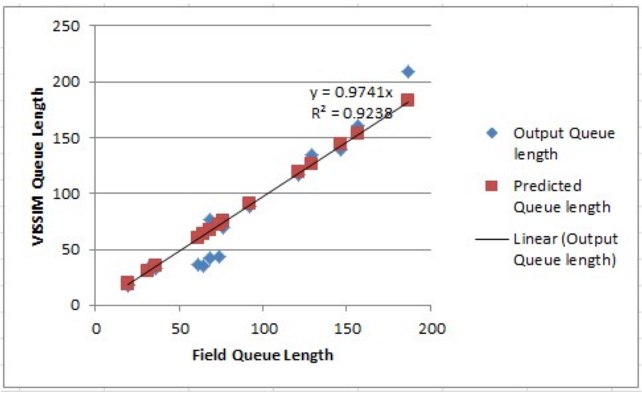

Figure 3: Calibration of VISSIM Model for Queue Length

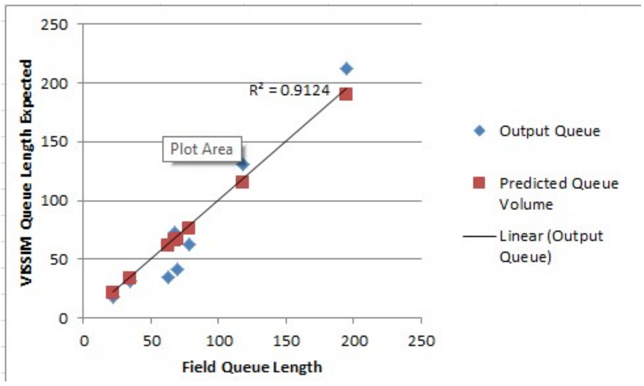

Figure 4: Validation of VISSIM Model for Queue Length

5. Data Analysis and Results

5.1 Traffic Volume and Traffic Composition

Total volume from Tinkune is more compared to the volume from other legs during the morning peak hour and total volume from Maitighar is more compared to others during the evening peak hours. This is due to the location of major business areas around Maitighar, Sundhara, Ratnapark, Pulchowk, Putalisadak and Thapathali. The heavy traffic flow during the peak hour from Tinkune is due to movement of traffic to business area in morning and heavy traffic in Maitighar is due to departure from the business area during evening peak hours. The directional movement of traffic volumes during morning and evening peak hours in a single day in PCU is presented in fig:5 and 6 respectively.

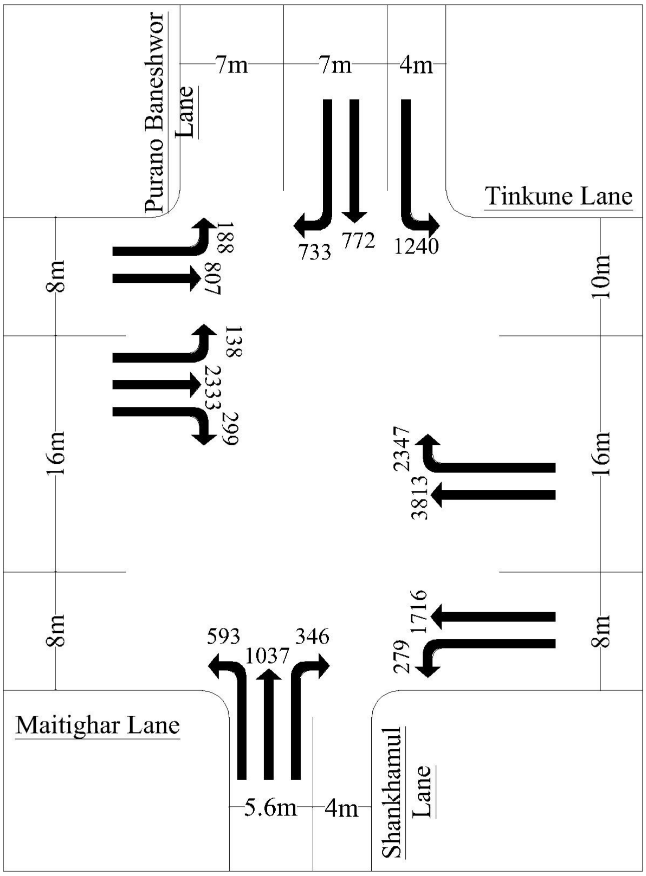

Figure 5: Directional movement in PCU (9:00 - 11:00 AM)

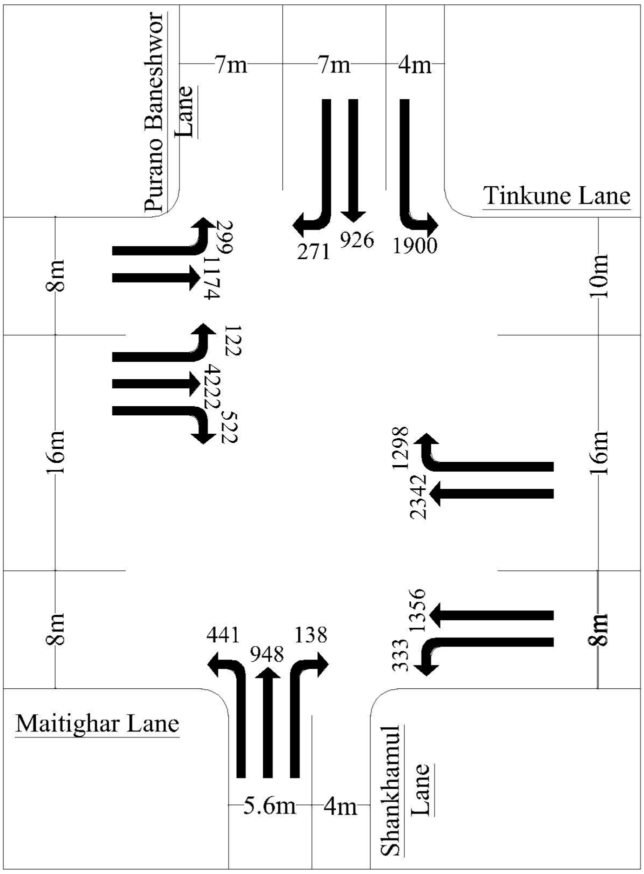

Figure 6: Directional movement in PCU (4:00 - 6:00 PM

5.2 Relative Flows

Traffic movements depicted from the site were split accordingly. Total volume from Purano Baneshwor was split towards Tinkune (Service Lane and Main Lane), Shankhamul and Maitighar (Service Lane and Main Lane).Traffic movements from other links were also split according to the site observations and the relative flow were calculated. It was observed from the survey that, there was little to no movement of traffic from Tinkune Main Lane to Shankhamul. A sample of relative flow of motorcycles from Purano Baneshwor to respective lanes is shown in fig:7.

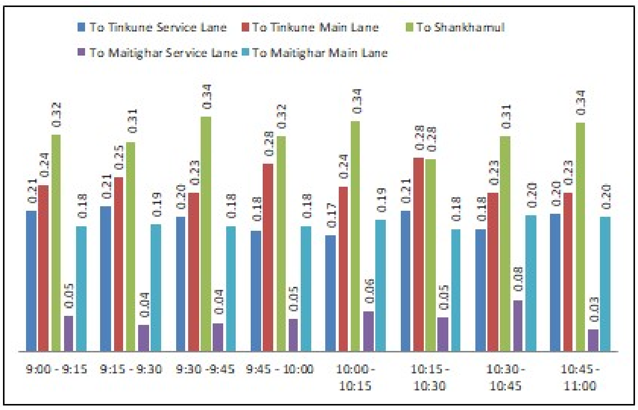

Figure 7: Relative Flow: Purano Baneshwor to Respective Lanes

5.3 Comparison of result for scenarios

5.3.1 Scenarios

Lane use scenarios were simulated in VISSIM and the 6 scenarios simulated are listed as:

Scenario 1:
Left turn vehicles from Minor roads (Purano Baneshwor and Shankhamul) were allowed only on Service Lane of Main road at intersection

Scenario 2:
Through traffic from service lane were restricted to enter the main lane of Main road at intersection

Scenario 3:
Left turn traffic from Main lane were relocated to Service lane in combination with Scenario1

Scenario 4:
Scenarios 2 and Scenario 3 were combined

5.3.2 Comparison of traffic performance measures

Comparison of Travel time, Queue and Delay for Morning and Evening peak hours under four scenarios simulated in VISSIM is presented in fig:8 to 13. All the scenarios are based on lane use of vehicles in main lane and service lane so significant differences in traffic performance measures can be seen for Major road through traffic. However, as the minor road is not distinguished as main lane and service lane significant changes in traffic performance measures cannot be seen for minor road. Scenarios 1 and 2 do not show significant change in traffic performance measures. Changes can be visible with Scenarios 3 and 4; significant change can be seen in Scenario 4. With the application of scenario 4 for morning peak hours, Queue obviously decreases for main lane and increases for service lane. As a result, travel time decreases by 15.11% for Maitighar main lane and 5.39% for Tinkune main lane. Delay decrease by 18.63% for Maitighar main lane and 7.05% for Tinkune main lane. There is no left turn movement of traffic from Tinkune main lane so there is significant change in travel time and Delay for Maitighar main lane but comparatively low for Tinkune main lane. Although there is shift in traffic to service lanes, in most cases travel time and delay does not change significantly for service lane. There is decrease in travel time and delay by 0.60% and 0.39% respectively for Maitighar service lane, queue increases by 10.17%.

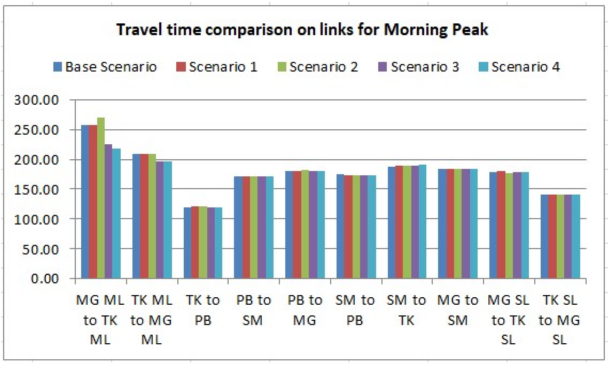

Figure 8: Comparison of travel time for different scenarios in morning peak hour

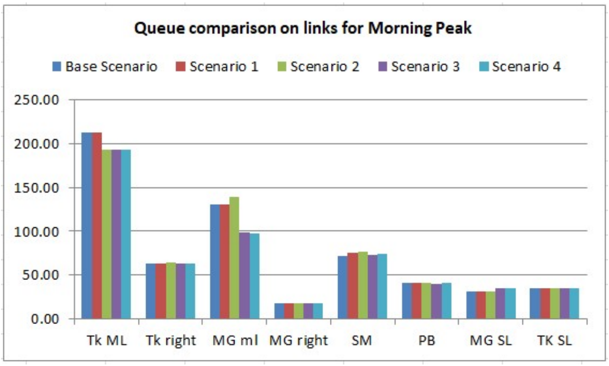

Figure 9: Comparison of queue for different scenarios in morning peak hour

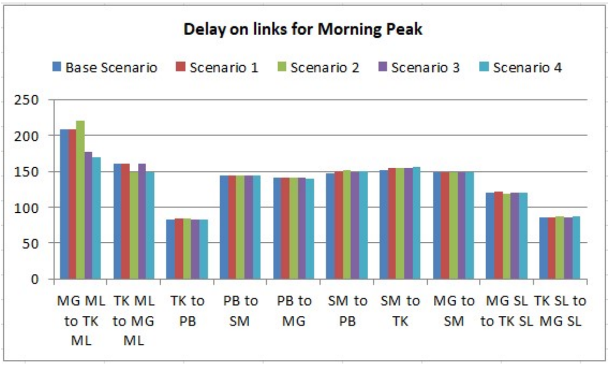

Figure 10: Comparison of delay for different scenarios in morning peak hour

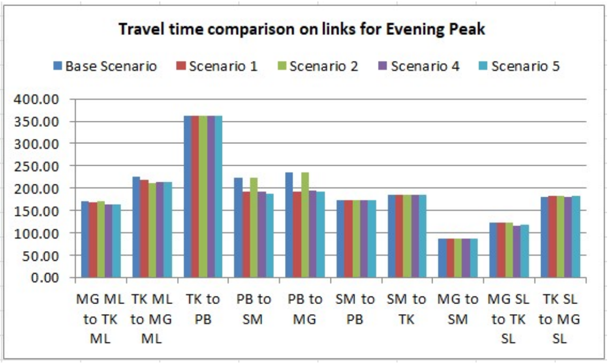

Figure 11: Comparison of travel time for different scenarios in evening peak hour

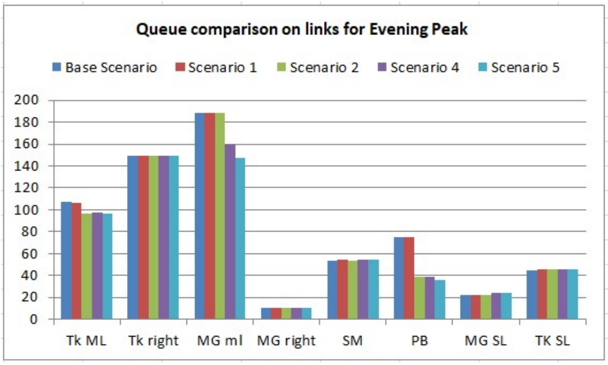

Figure 12: Comparison of queue for different scenarios in evening peak hour

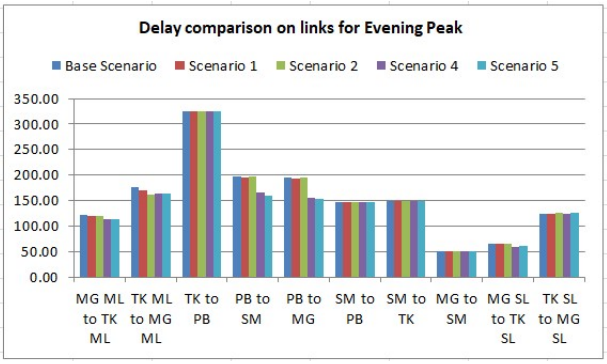

Figure 13: Comparison of delay for different scenarios in evening peak hour

6. Conclusion

It was found that the lane use plan can be an effective tool to relieve traffic congestion in an urban intersection. Shifting movement of vehicles to keep the minimum conflict at intersection reduced the travel time and delay of vehicles. Repositioning of left turn traffic from the main lane to service lane and restricting left turn traffic from minor roads (Purano Baneshwor and Shankhamul) to Main lanes of main road was found to be most efficient in reducing traffic congestion. Travel time could be reduced by 15.11% and 5.39% for Maitighar Main lane and Tinkune Main lane respectively. Delay could be decreased by 18.63% and 7.05% for Maitighar Main lane and Tinkune Main lane respectively. In the evening peak hours, travel time decreases by 5% and 5.63% for Maitighar main lane and Tinkune main lane respectively. Delay decreases by 7.07% and 7.22% for Maitighar main lane and Tinkune main lane respectively. Although there is shift in traffic to service lanes in most cases travel time and delay does not increase for service lane due to low volume in service lanes.

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