Proceedings of IOE Graduate Conference, 2017
Volume: 5 ISSN: 2350-8914 (Online), 2350-8906 (Print)

Performance Improvement of a Signalized Intersection (A Case Study of New Baneshwor Intersection)

Sakar Shrestha [a], Anil Marsani [b]

[a, b] *Transportation Engineering Program, Department of Civil Engineering, Pulchowk Campus, IOE, TU, Nepal*
Corresponding Email: [a] sakar.330@gmail.com

Abstract
New-Baneshwor is one of the major junctions and also known as the heart of the Kathmandu Valley. This place consists of all the major educational institution, hospitals, a wide range of market, and most important "constitutional assembly" of the country. So it is one of the busiest places of Kathmandu Valley with high density traffic. The main cause of the problems that occurred in the area of New-Baneshwor is due to heavy traffic volumes which exceed the capacity of the intersection. In view of the above, it was necessary to analyze the existing conditions and proffers some alternative solutions. Before carrying out an analysis, a field surveys at peak hours, for example, in the morning (09:20 to 11:05 am) and evening (05:20 to 06:50 pm) was conducted. The number of vehicles was counted manually with "video graphic survey" according to types of vehicles. From the analysis study, it was found that the Level of Service (LOS) was F during morning as well as evening peak hours. This means that the capacity of the existing road is no longer able to accommodate the traffic flow. One of the alternative solutions for the congestion that occurs at the intersection of New-Baneshwor is to apply the efficiency of the intersection that is not provided with the Four phases signal planning, Three phases signal planning by providing U-Turn, Fly over with existing scenario, Four phases signal planning with flyover, Three phases signal planning with flyover by providing U-Turn verifying queue pocket area for U-Turn. Based on the travel time and delay reduction with 5 comparative modeling it shows that the three phases signal planning with flyover by providing U-Turn effectively decreases delay and travel time by 81.92% and 80.1% in morning and evening peak time respectively maintaining Level of Service C, in addition, Maitighar, Tinkune, Old Baneshwor as well as Sankhamul lane is found to have decreased by minimum 60% in the morning and evening which was found to be the most technically efficient to be applied.

Keywords
Intersection, VISSIM, Level of Service

1. Introduction

Traffic congestion is a condition on transport networks that occurs as use increases, and is characterized by slower speeds, longer travel times, and increased vehicular queuing. The most common example is the physical use of roads by vehicles. When traffic demand is great enough than the interaction between vehicles slows the speed of the traffic stream, this results in some congestion. Most of the transportation engineers believe that congestion will stay and we have to live with it. Limited financial resources and restricted right of way makes it truer for developing countries.

An Intersection is the junction of two or more roads either meeting or crossing at same or different level and is the main reason for the congestion. An intersection has always played its role by controlling the conflict and merging stream of traffic so that delay that happened can be reduced or minimized. Normally geometric parameter is the one that control and regulate the vehicle path through intersection [1]. Not only that assessment process can be done as to determine the traffic flow and turning movement at the selected intersection. This can lead to determining whether the traffic flow exceeds the capacity of the intersection can sustain or not. If there is no overcapacity experienced then the intersection cab be considered operate well below its capacity and smooth traffic going on. On the other hand if there is overcapacity that happened then there should be inclusion of travel time and delay for the assessment of the intersection. Delay that happens at intersection has been a major problem in the analysis of congestion [2]. The intersection delay study is valuable in evaluating the efficiency of effectiveness of a traffic control method.

VISSIM is a microscopic, discrete traffic simulation system modeling motorway traffic as well as urban traffic operations. Based on several mathematical models, the position of each vehicle is recalculated every 0.1–1 s. The system can be used to investigate private and public transport. In order to simulate multi-modal traffic flows, technical features of pedestrians, bicyclists, motorcycles, cars, trucks, buses, trams, light (LRT), and heavy rail are provided with options of customization [3].

2. Literature Review

Study on ”Estimation of delay at signalized intersections for mixed traffic conditions of a developing country” was conducted from which various problems associated with delay estimation under mixed traffic conditions in a developing country (India) and the methods to overcome them were discussed and an attempt was made to improve the accuracy estimating the same. Five isolated signalized intersections from a fast developing industrial city located in Tamil Nadu, India were chosen for the study. Site specific PCU values were developed considering the static and dynamic characteristics of vehicles. Saturation flow was also directly measured in the field for the prevailing roadway, traffic and signalized conditions and expressed in PCU/h. Control delay was also measured following HCM (2000) guidelines. Later, this was compared with that estimated from the theoretical delay model. Even after taking several measures, good correlation between observed and predicted delay could not be obtained. Therefore, in the present scenario field measured control delay was taken into account to define LOS [4].

Study about the performance of the flyover upgraded intersection was conducted and points out the remaining problems including long delays under the flyover and found that about 35-40% of the total traffic volume diverted to the flyover, and despite an increase in traffic volume of +29.46%, at the intersection, the vehicle delays were reduced by 30.41% over the same period; the saving in travel time and vehicle operating costs amounted to 421.65 Million Baht [5].

It was found out that the degree of saturation (DS) was 1.61 between Teuku Umar and Setia Budi road during the morning peak hours and 1.56 during the afternoon peak hours which means that the capacity of the existing road is no longer able to accommodate the traffic flow and compared alternative solutions for the congestion that occurs at the intersection of Jatingaleh by applying a Fly over, Underpass and the combination of Fly Over-Underpass. Based on the flow reduction calculation with 3 comparative modeling it show that the Fly Over is the most technically efficient to be applied in his research following the flow of traffic can be reduced by 93.42% (morning)and 93.59%(afternoon) while after the underpass in the form only able to reduce 25.24% (morning)and 14.28%(afternoon) [6].

Studies of flyover for improvement of intersection were done suggesting in order to reduce traffic congestion at-grade intersection near a big city, one method is construction of flyover bridge at the old junction in two directions on one of the main highways. The flyover facilitates the traffic flow in the directions of the bridge, but the infrastructure cannot fully solve all of the problems especially on the secondary road. Under the bridge, although it relieves the traffic congestion at the intersection; the traffic signal still uses the same control as the “before” situation, that is the fixed time control 13 plan. With the flyover bridge in place, it was found that about 30-35% of all traffic volumes diverted to the bridges, and time delay reduced by 30% over the same period. This paper provides suggestions to increase the benefits of the flyover such as creating a new cycle and phase times and improving the physical area under the bridge [7].

Evaluation of indirect right turn treatment to reduce conflicts and congestion at signalized intersections in urban areas was conducted. Volume and travel time studies were conducted at three signalized intersections in Islamabad where indirect right turn treatments were applied. Travel time study was done using GPS device. To monitor the traffic flow and driver behavior video recordings were also done on each intersection during the peak hours. Microscopic simulation model VISSIM and field travel time runs were used to evaluate before and after scenarios. It is found that at some locations, application of indirect right turn reduce travel time and increase the vehicle output. However, at one intersection the implementation of indirect right turn treatment resulted in increased travel times and reduced vehicle output. This is because of the number of vehicles affected by the closure of intersection are higher and also the movement of vehicles at the U-turns was effected by on-street parking [8].

It was proposed right turn lane design with sufficient lengths to improve the safety and operation of intersections by providing space for deceleration and storage of right-turn vehicles. On the other side, insufficient length of right-turn lane will result in the right turn lane over flow and the blockage of right-turn lane entrance by through traffics, which were referred toas right-turn overflow and blockage problems. [9]

Study on comparative study of VISSIM and SIDRA on signalized intersection was performed. Due to increasing volume of traffic intersection jam happens constantly. An effective way to solve the problem is to seek appropriate control mechanisms with the help of traffic simulation software. Based on the real world traffic data takes from the West Wenhua Road and Changchun Road of Xian yang City, their features and evaluation results of signalized intersections have been analyzed from the perspective of operation simplicity and the output error. Results show that SIDRA operation is easier while VISSIM output is more accurate. This study can provide references for simulation software selection[10].

3. The Need and the Objective of the Study

3.1 The Need of the Study

According to the transportation professionals' concern the increase in urban traffic congestion has become a serious matter. In urban road networks, the intersections are very large and very close to each other. Due to which more traffic congestion is observed especially during peak hours. Researchers are making efforts for obtaining rational quantification of congestion and formulating appropriate measures for mitigation of congestion for urban roads, also efforts to improve the traffic operations at urban intersection are made. In fact, in urban areas evidencing exciting roads or the scope of improvement of intersection at-grade are very limited. So, due to the unavailability of land and to achieve fast and safe movement of vehicle various alternatives must be analyzed at New-Baneshwor intersection.

3.2 The Objective of the Study

The overall objective of this study is to make comparison of probable congestion reduction approaches at New Baneshwor intersection with the help of micro-simulation model via VISSIM. Specific objective:-

- to identify the current level of service at New-Baneshwor intersection
- to calibrate and validate micro-simulation model to evaluate the travel time and delay of vehicles at existing scenario
- to establish probable alternatives to reduce the congestion problem at New-Baneshwor intersection
- to compare the travel time and the delay after application of different probable approaches

4. Methodology

4.1 Field Data Collection

Video cameras were used as a field data collection tool to record the footage of traffic flow at the New-Baneshwor intersection. Following data were collected in the field:

- Intersection geometry, including lane usage and link distances
- Existing Intersection Turning Movement Counts
- AM and PM peak hour observation (2 hours @ 15 minute periods) for four days
- Classified count of vehicles
- Field studies including travel time runs and approach delay studies. These data were useful for the calibration of the computer model and for comparison to corresponding data in and after condition

- Currently functioning Signal Timing and Phasing Data
- Additional data (as required

4.2 Data Extraction & Preparation of Input Parameters for Microscopic Simulation Model

The videos recorded at the site were played back on a computer to extract the required data. From the videos, following data were extracted:

- Classified vehicle count
- Directional movement of each vehicle
- Relative flow
- Signal Timing and phasing data
- Size of vehicles for modelling in VISSIM
- Analytical Computation of Delay and Travel time

4.3 Development of Model in VISSIM

Links were created using connector to represent road segments that carry them through movements and general curvature of the roadway. A connector is a type of link used to join two areas of a single link or to join two areas of two links which have additional characteristics that affect driver behavior, specifically lane changing, so it is important when coding to take this into consideration and eliminate the excessive use of connectors. They are the blue print for creating a new traffic network. They were imported from aerial photograph. Aerial image was acquired from a virtual map tool such as Google earth.

5. Calibration & Validation of model

5.1 Calibration of model

Calibration was performed using driving behaviour parameters in Vissim. The field data of Day 1, Day 2 & Day 3 were used to Vissim as inputs. Simulation runs were performed for those inputs. Observations were made to see if the simulation matches the corresponding field values of delay, travel time & traffic volume which is shown in figure1.

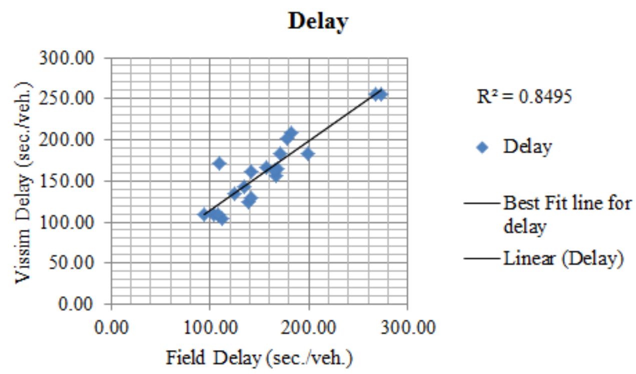

Figure 1: Sample of calibration of Old Baneshwor lane for delay

R squared = 0.8495 (i.e. 84.95 percent of variance of field data is explained by the variance of Vissim output

Regression equation: VISSIM OUTPUT EXPECTED= 0.8424 * FIELD + 29.683

5.2 Validation of model

The model was compared between Vissim output expected and Vissim output for Day4 collected at the same site under similar conditions and was performed for validation which is shown in figure 2.

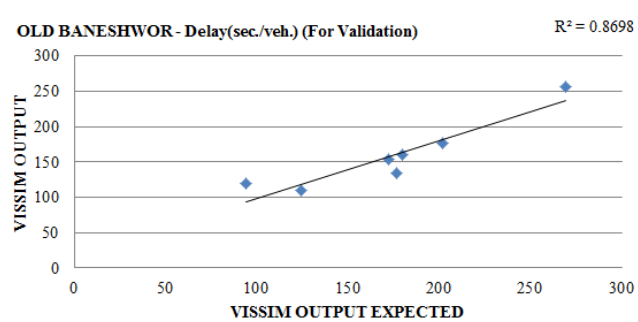

Figure 2: Sample of validation of Old Baneshwor lane for delay

6. Data Analysis and Results

6.1 Traffic Volume

Traffic survey showed that during the morning peak hour, there are more traffic demand flow from Tinkune as compared to the Maitighar, Old Baneshwor and Sankhamul i.e. from Tinkune to Maitighar at New-Baneshwor Intersection. This happens due to the arrival at the offices and business center of Kathmandu valley which are located around the Ratnapark, Pulchowk, Kupandole, etc. area. Total traffic volume at New-Baneshwor intersection is 14,876 PCU from 9:20 A.M. to 11:05 A.M for DAY 4. Similarly for DAY 4, total traffic volume at Tinkune is 7127 PCU which is more than minimum twice than that of Maitighar (3205 PCU), Old Baneshwor (2461 PCU) and Sankhamul (2084 PCU) which is shown in figure 3.

It was also observed that during the evening peak hour, there are more traffic demand flow from Maitighar as compared to the Tinkune, Old Baneshwor and Sankhamul i.e. from Maitighar to Tinkune at New-Baneshwor Intersection. This happens due to the departure from the offices and business center of Kathmandu valley. Total traffic volume at New-Baneshwor intersection is 12,056 PCU from 5:20 P.M. to 6:50 P.M for DAY 4. Similarly for DAY 4, total traffic volume at Maitighar is 4646 PCU which is more than minimum 1.25 than that of Tinkune (3694 PCU), Old Baneshwor (2136 PCU) and Sankhamul (1578 PCU) which is shown in figure 4.

Table 3 shows the total traffic volume of morning and evening peak time in terms of PCU which was carried out for 105 minutes and 90 minutes respectively.

6.2 Vehicle Composition

Traffic survey showed that motorcycle was found to be one of the major modes of transportation.Typically at New-Baneshwor intersection motorcycle/Bicycle was found to be 77 %, car/Jeep/Van/Pick up/Light Van/Micro Bus 18 %, Mini Bus/Truck/Bus 4 % and Tempo 1 % in composition.

6.3 Traffic Police Signal Data

In the Existing scenario, during morning peak time it is seen that traffic volume of Tinkune Lane is higher when compared with any other lane and hence 23 cycles for Tinkune lane(47.91 % of total traffic volume), 15 cycles for Maitighar lane, 16 cycles for Sankhamul lane, 15 cycles for Old Baneshwor lane is found out maintaining demand of each lane by traffic police when analyzed for 1 hour and 45 minutes.

Similarly, during evening peak time it is seen that traffic volume of Maitighar Lane is higher when compared with any other lane and hence 20 cycles for Tinkune lane, 20 cycles for Maitighar lane(38.5 % of total traffic volume), 19 cycles for Sankhamul lane, 18 cycles for Old Baneshwor lane is found out maintaining demand of each lane by traffic police when analyzed for 1 hour and 30 minutes.

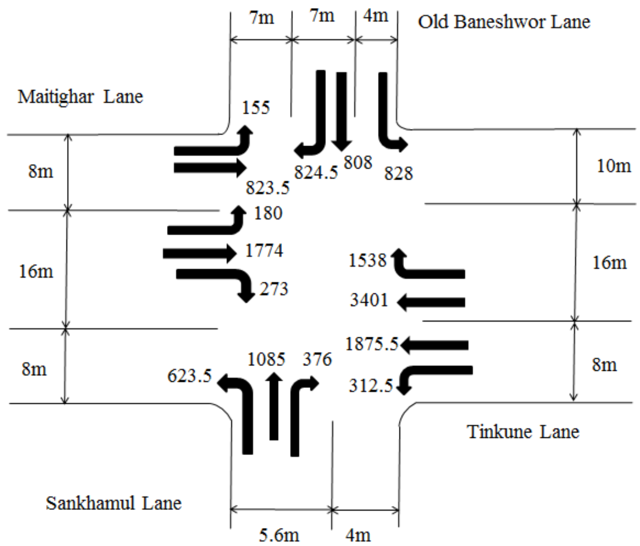

Figure 3: Directional movement (Morning Peak)

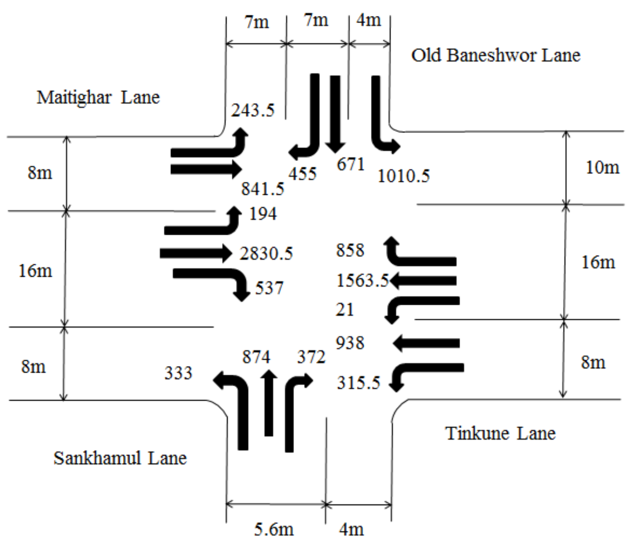

Figure 4: Directional movement (Evening Peak)

6.4 Level of Service (LOS)

Level of Service for both morning and evening peak are found to be F which were calculated using HIGHWAY CAPACITY MANUAL [11] for which passenger car unit for different vehicles were adopted from Nepal Road Standard 2070 [12].

6.5 Evaluation of results for different alternatives

6.5.1 Different Alternatives Solutions

Total 5 alternative solutions options were performed on Vissim which are liste

Option 1: Four-Phases Signal Planning on Existing Scenario of fixed timing signal 80, 120, 150 & 200 sec. [13]

Option 2: Three phases signal planning of 120 sec by providing U-Turn at 150, 200, 300 & 400m verifying queue pocket area for U-Turn [13]

Option 3: Fly over with existing scenario[6] [13] [14]

Option 4: Four phases signal planning with flyover of 120 sec.[6] [13] [14]

Option 5: Three phases signal planning with flyover by providing U-Turn at 150, 200, 300 & 400m verifying queue pocket area for U-Turn [13] [14]

Comparsion chart of option 2 & 5 with existing scenario is presented in Figure5, Figure6, Figure7 & Figure8.

From the above Option 1 & 2, it is observed that the overall delay for Three phases signal planning of 120 sec by providing U-Turn at 300m is effectively decreased by 69.93% and 78.9% in morning and evening peak time respectively maintaining Level of Service D, in addition, each lane of Maitighar,Tinkune, Old Baneshwor & Sankhamul are found to have delay and travel time decreased by minimum 30% in the morning and evening peak time.The best signal planning for option 2 that was adopted in Vissim is listed in Table 1.

Table 1: Adopted Signal Planning for Option 2

Priority	Time (sec.)
Maitighar & Tinkune	70
Old Baneshwor	15
Sankhamul	35

Similarly, after protecting the right turning traffic of Maitighar and Tinkune by providing U-turn at 300 m it is checked for delay and traffic volume at U-turn section due to the probability of increment or decrement of delay and traffic volume at U-turn section of existing scenario respectively. It is seen that after providing U-turnat 300m, there is no any huge variation on delay as well as traffic volume with respect to existing scenario which are listed Table.

Again from the above option 2, 3 & 5, it is observed that the overall delay for Three phases signal planning with flyover by providing U-Turn at 300m is effectively decreased by 81.92% and 80.1% in morning and evening peak time respectively maintaining Level of Service C, in addition, each lane of Maitighar,Tinkune, Old Baneshwor & Sankhamul are found to have delay and travel time decreased by minimum 60% in the morning and evening peak time. Thus, among all the above options, option 5 is the most effective in the reduction in congestion. The best signal planning for option 5 that was adopted in Vissim is listed in Table 2

Table 2: Adopted Signal Planning for Option 5

Priority	Time (sec.)
Maitighar & Tinkune	50
Old Baneshwor	35
Sankhamul	35

Table 3: Traffic Volume of morning and evening days interms of PCU

Peak Time	Date	Day	Total
Morning	2073 -3-22	Wednesday	12483
Morning	2073 -5-12	Sunday	13741
Morning	2073 -7-05	Friday	13988
Morning	2073 -7-09	Tuesday	14876
Evening	2073 -9-08	Sunday	10923
Evening	2073 -9-10	Tuesday	10947
Evening	2073 -9-11	Wednesday	11460
Evening	2073 -9-13	Friday	12056

6.5.2 Comparison chart

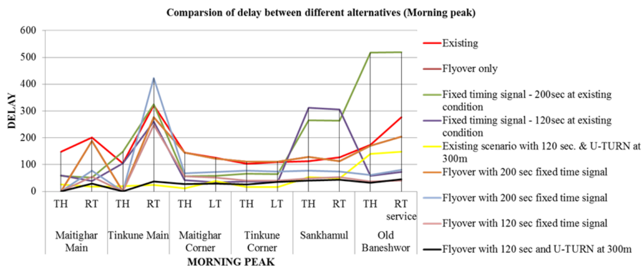

Figure 5: Comparsion of delay between different alternatives (Morning peak)

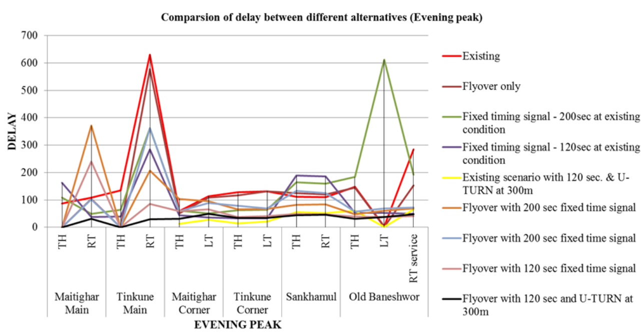

Figure 6: Comparsion of delay between different alternatives (Evening peak)

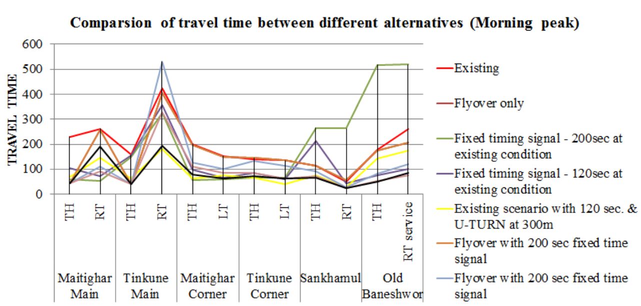

Figure 7: Comparsion of travel time between different alternatives (Morning peak)

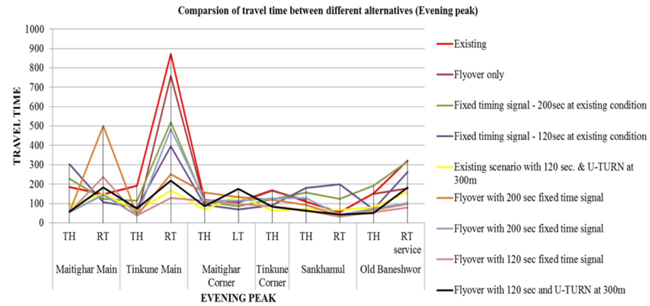

Figure 8: Comparsion of travel time between different alternatives (Evening peak)

6.5.3 Verifying Queue Storage Length

Maximum queue length for storage legth that must be provided (L1) = 91.7m

Comfortable Deceleration Length (L2) = 55m (F0r Design Speed 60km/hr.)

Minimum Total Length for U-Turn that ust be provided = L1 + L2 = 91.7 + 55 = 146.7m less than 300m (O.K.)

7. Conclusion

It was found that the Level of Service for both morning and evening peak are found to be F.

Four phases signal planning effectively decreases delay and travel time by 2.0254% and 9.76% in morning and evening peak time respectively, however, Maitighar main is found to increase by minimum 60% in the evening peak time and Sankhamul during morning and evening peak and are observed to be non-effective in the reduction in congestion.

After applying three phases signal planning by providing U-Turn at 300m, it was observed that the overall delay and travel time was effectively decreased by 69.93% and 78.9% in morning and evening peak time respectively maintaining Level of Service D, in addition, each lane is found to decreased by minimum 30% in the morning and evening peak and later checked for the traffic volume and delay at U-turn and found that there is no any huge variation on delay as well as traffic volume with respect to existing scenario.

Four phases signal planning with flyover observed that the overall delay and travel time was effectively decreased by 59.37% and 69.06% in morning and evening peak time respectively maintaining Level of

Service D, in addition, each lane is found to have decreased by minimum 20% in the morning and evening peak.

Finally after applying three phases signal planning with flyover by providing U-Turn at 300m, it was observed that the overall delay and travel time was effectively decreased by 81.92% and 80.1% in morning and evening peak time respectively maintaining Level of Service C, in addition, each lane was found to have decreased by minimum 60% in the morning and evening peak time. Thus three phases signal planning with flyover by providing U-Turn at 300m was most effective in the reduction in congestion.

8. Recommendation

Based on the analysis, congestion at New-Baneshwor intersections, it is an extremely difficult task to cover all aspects of a topic in a limited time frame. Following tasks are recommended for future studies in a similar topic:

- The vehicular volumes considered in this study were based on the present data collected on field. It is suggested to accurately forecast the future traffic volumes and attempt three phases signal planning with flyover by providing U-Turn, underpass too for the stability over time in year.
- While conducting the traffic signal of New-Baneshwor intersection on VISSIM that was controlled by traffic police manually, it seems that the fixed timing signal plan on VISSIM were limited to 125 signal combination which restricted the analysis period up to 1 hr. and 45 minutes for which 15 minutes were taken for seeding period and results total up to 1.5 hrs. analysis period. So it can be conducted by using other traffic flow simulation software's such as SimTraffic, Sidra Intersection, CORSIM ,etc. and compare the results with each output.

Acknowledgments

The authors are grateful to every single person who contributed directly or indirectly in the research.

References

[1] Bernard Enright Martin Rogers. *Highway Engineering*. WILEY Blackwell, 3rd edition, 2016.

[2] Wolfgang S. Homburger and James H.Kell. *Fundamentals of traffic engineering*. Berkeley, Calif. Institute of Transportation Studies, University of California, 9th edition, 1977.

[3] Jaume Barceló. *Fundamentals of traffic engineering*. Springer-Verlag New York, 1st edition, 2010.

[4] G. Dhinakaran R. Prasanna Kumar1. Estimation of delay at signalized intersections for mixed traffic conditions of a developing country. 2012.

[5] Auttakorn SALA. Assessment of traffic flow benefits of flyovers:a case study. 2013.

[6] Rahmat Mudiono. Research of flyover as a solution to congestion of intersection junction a case study: Jalan jatingaleh semarang. 2015.

[7] Narabodee Salatoom1 and Pichai Taneerananon. A study of a flyover-bridge - improved intersection. 2015.

[8] Kamran Ahmed. Evaluation of low cost technique "indirect right turn" to reduce congestion at urbanized signalized intersection in developing countries. 2011.

[9] Yi Qi Lei Yu. Left turn lane design and operation. 2007.

[10] YANG Hongxuc CHEN Tianzi, JIN Shaochenb. Comparative study of vissim and sidra on signalized intersection. 2013.

[11] USA: Transportation Research Board (TRB). *Highway Capacity Manual 2000*. National Research Council, 2000.

[12] *Nepal Road Standard 2070*. Department of Road.

[13] Suresh Nama Avijit Maji, Akhilesh Kumar Maurya. Performance-based intersection layout under a flyover for heterogeneous traffic. 2015.

[14] Joni Arliansyah Rhaptyalyani H. Della, Hanafiah. Traffic performance analysis of u-turn and fly over u-turn scenario;a case study at soekarno hatta road, palembang, indonesia. 2015.