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Assessment of Operational Performance of Unsignalized Intersection using Microsimulation: A Case Study of Intersection at Pepsicola, Kathmandu

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Abstract

The intersection at Pepsicola, Kathmandu is a three legged unsignalized intersection. Three approach roads from Jadibuti, Kadaghari and Sanothimi merge at Pepsicola, Kathmandu to form the intersection. The study aims to assess the existing operational scenario of the intersection. The data collected is used to replicate the actual condition of the intersection in PTV VISSIM 2023 after sufficient calibration and validation. VISSIM was preferred over other simulation softwares due to its easiness in use and flexibility. The performance of the intersection is evaluated in terms of Level of Service and Queue length. During the peak hour i.e. 9:00 AM to 10:00 AM the intersection accommodates 3759 vehicular traffic and during the same hour the intersection serves 318 pedestrians. At present condition the Level of Service of the intersection is C with average total delay of 18.62 Sec.

Keywords: Operational Performance, VISSIM, Level of Service, Delay, Queue Length

1. Background

An intersection is the junction of two or more roads either merging or crossing. It plays a vital role in any road network as it helps in providing the access to any road or getting off of the road sections. Intersections can either be controlled by a traffic light or manually by the traffic police. If an intersection is controlled by a traffic light it is known as signalized intersection and if not, or being controlled by a traffic police, it is known as unsignalized intersection. [6]

Intersections in urban areas can often cause significant traffic delays due to the multiple directions of traffic flow [17]. The centralization of the Kathmandu Valley has contributed to a gradual rise in population thus impacting the efficiency of the traffic management system. There is a need for targeted measures to address the challenges posed by congestion and enhance the efficiency of traffic management at the intersections for smooth traffic flow [8]. Pepsicola intersection is a unsignalized intersection formed by merging of roads from Kadaghari, Sanothimi and Jadibuti. The intersection accommodates large volume of traffic as well as pedestrians daily. Speed and volume are often considered as the major contributor of road accidents and conclusion can be drawn that crashes are influence to quite reasonable extent by speed, traffic volume at the locality and percentage of two wheelers [16]. T Traffic congestion can be observed during the morning and evening hours in Pepsicola intersection. Thus, evaluation of operational performance of the intersection is necessary to implement necessary measures to improve the performance.

2. Objective

The objective of this study was to evaluate the operational performance of the intersection at Pepsicola. The study area was modelled in VISSIM after collection and analysis of primary as well as secondary data. The objective was achieved after analysis of adequately calibrated and validated model.

3. Literature Review

Different studies have been reviewed for the evaluation of the operational performance of the unsignalized intersection. Tiwari and Marsani: [18] calibrated model can be used for predicting the future scenario of speed and density with anticipated change in traffic volume and Level of Service. The research is an initiation for calibration of traffic flow models for Nepalese roads which suggests use of various simulation models in context of Nepal rather than conventional ones.

Pokhrel et al; [10] provided an overview of the current situation of signalized intersections in Jay Nepal Hall. The performance of the intersection was assessed based on the LOS, Average Delay and Queue length and is followed by the implementation of the performance enhancement strategies.

Prajapati et al; [11] determined that microscopic simulation such as VISSIM has more individualistic approach such as interaction of the driver to the environment and other vehicles, individual link behavior or behavior of the driver class, etc.

Pandey and Shrestha [9] analyzed the impact of lane use restrictions on traffic flow at New Baneshwor intersection. 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.

Ragab and El Nagae [12] evaluated the impact of different improvement measures on traffic operations at signalized intersections in urban areas based on field data and microsimulation models. The micro-simulation models were developed for the selected intersections using VISSIM software. Then, they were calibrated and validated using the collected data. The developed models were used to evaluate two different improvement measures.

Shrestha and Marsani [13] identified that the main cause of the traffic congestion problems that occurred in the area of New-Baneshwor was due to heavy traffic volumes which exceed the capacity of the intersection. The study used VISSIM to simulate the traffic and signal timing of the intersection on present condition. The study suggests alternatives for improvement of performance in the intersection.

Ishaque & Noland [5] provided a method for including pedestrians in a vehicle microsimulation model, specifically the VISSIM model. VISSIM provides a default mechanism for simulating pedestrian movements; however, this does not adequately replicate pedestrian behavior. Instead pedestrians can be defined as vehicles and calibrate various parameters within VISSIM so that pedestrian behavior is calibrated with pedestrian speed-flow models.

Luitel et al; [7] studied to enhance the traffic flow at the Buspark intersection in Birgunj Metropolitan City. 72 hours traffic volume data and geometrical characteristics of the intersection were collected and an existing model of the intersection was developed in software 'SIDRA Intersection 8.0' The validation of the model involved assessing both observed and simulated queue lengths for each approach, and an assessment of the current performance of the intersections was conducted.

A study by Tiwari et al; [17] showed that coordinating the signal systems between intersections at Kanti Children's Hospital and Shital Niwas significantly reduced the average delay time and maximum queue length at both intersections. The study included survey to collect morning peak hour traffic volume and geometrical features of the two intersections and developed a signalized intersection model in SIDRA software. The model was validated based on observed and modelled queue lengths for each approach, and the existing performance of the intersections was evaluated.

Dhakal et al; [3] provided an overview of the current situation of signalized intersections in Satdobato. The environment and traffic flow parameters were modeled in a microsimulation software 'SIDRA Intersection 8.0'. The calibration and validation of the intersection model in the software were performed using field data. The performance of the intersection was evaluated based on the LOS, and delay, and back of the queue.

Zainuddin et al; [19] studied the application of VISSIM microsimulation model to assess and compare the operational performance at the two T-Leg intersection of Pengkalan Weld Road, Malaysia. In this study T-leg Intersection was upgraded into roundabout and comparative study was carried out between operational performance of existing and improved roundabout.

Sun et al; [14] found out that for the large intersection and high volume of traffic, VISSIM is more appropriate simulation software than CORSIM. Furthermore, VISSIM also more appropriate than CORSIM to calculate the average control delay at the intersection

4. Study Area

The unsignalized intersection at Pepsicola, Kathmandu was chosen for this study. The intersection has four legs but the road on west part of the intersection has very small volume of traffic and its effect is minimum compared to the other legs, thus is ignored in this study. Jadibuti and Sanothimi legs have total width of 14m and Kadaghari leg has width of 12m. The width of footpath in the intersection varies from 1.7m to 3m. Old Sinamangal Mandir is located at edge of the intersection in North leg towards Kadaghari.

Figure 1 Pepsicola Intersection

5. Methodology

The intersection is uncontrolled three-legged intersection without any traffic police control or signals. The movement of vehicles occurs spontaneously with short queue length. The study area was selected after studying and analyzing research articles related to topic. Traffic volume was extracted from videographic survey that was carried out for three days in May 9,10 and 11 from 8:00 AM-10:30 AM and 4:00 PM- 6:30 PM. Peak hour was determined after classified vehicle count of the vehicles. Pedestrian count was carried out for the determined vehicular peak hour. Geometry of the intersection was determined after field measurements. Speed survey using radar gun was done to determine speed of vehicles and pedestrians.

Based on the real-world traffic data, evaluation of result of SIDRA and VISSIM have been analyzed in terms of simplicity and output error. Results conclude that VISSIM is more accurate and error free simulation software than SIDRA [14]. The data were then used to develop traffic model in PTV VISSIM-2023. Furthermore, the model was calibrated using two days traffic data of speed and volume. After the data was sufficiently calibrated, validation was done using third day volume and speed data. GEH statistic was used to validate volume and RMNSE value was used to validate speed. Finally, operational performance of the intersection was analyzed using three-day data after adequate calibration and validation. The operational performance of the intersection after 5 years was also evaluated by forecasting traffic and pedestrian volume.

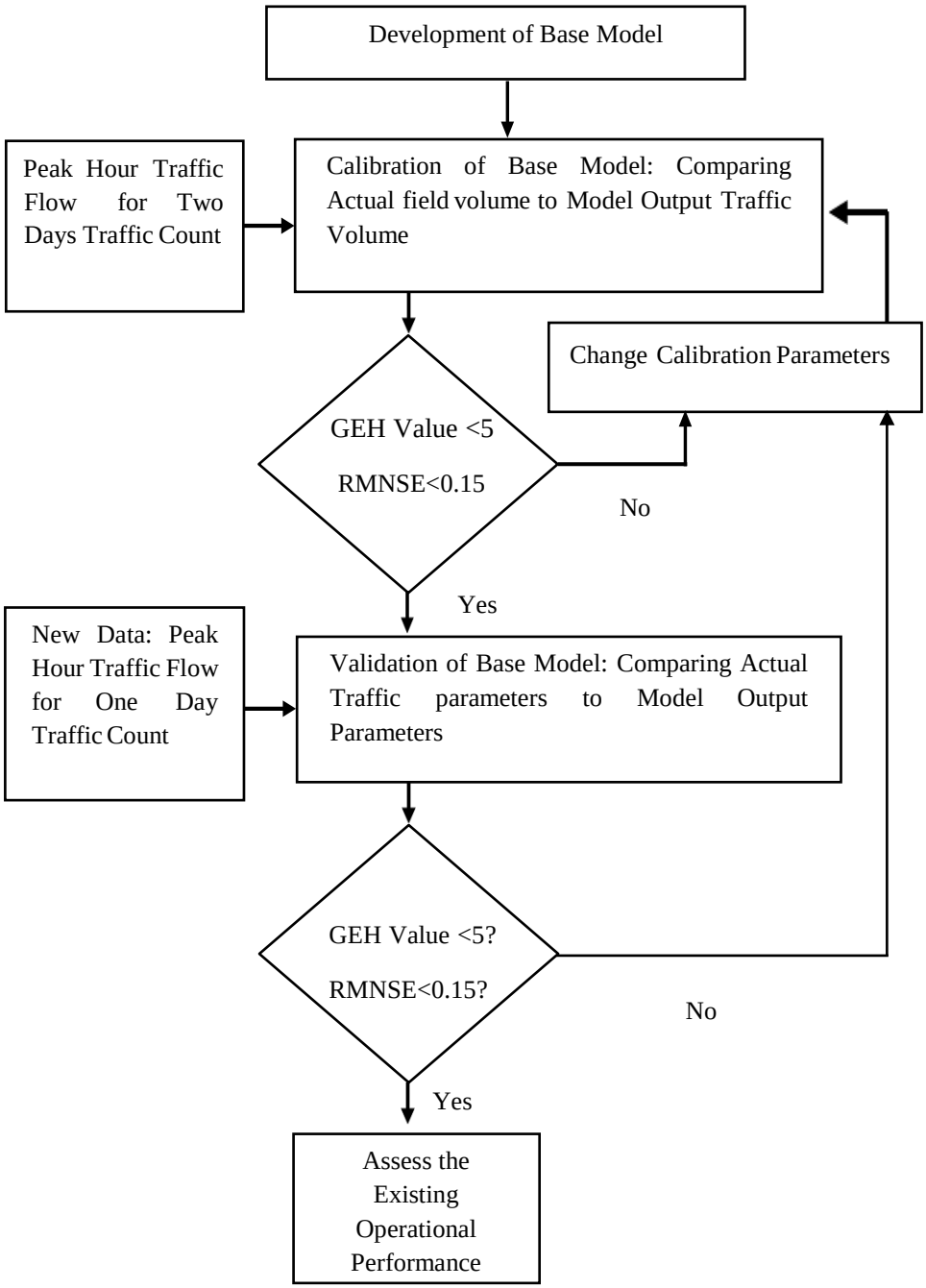

Figure 2 Flowchart for evaluation of operational performance of the unsignalized intersection

6. Data Analysis and Results

6.1 Hourly Traffic Volume

Three-day traffic count was done to determine the peak hour of the traffic in the intersection. The peak hour of the intersection was identified to be 9:00 AM to 10:00 AM in which 3758 vehicles (average of three-day count) cleared the intersection. Similarly, during the same period 318 pedestrians crossed the intersection.

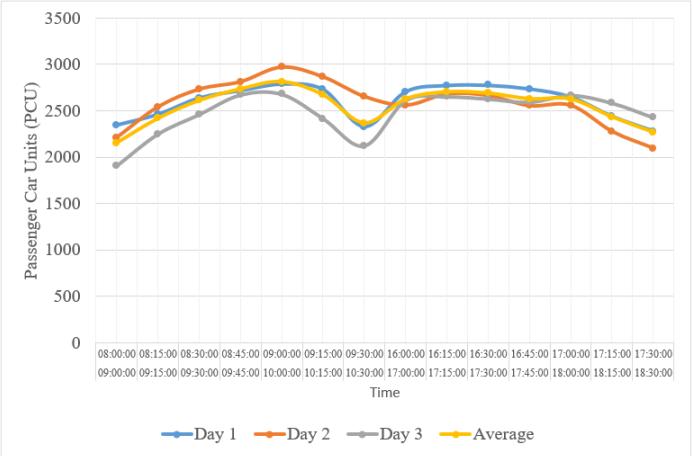

Figure 3 Hourly traffic volume

6.2 Directional Volume

The directional traffic volume of each leg was counted using videographic survey. The count was carried out for three days. During the peak hour there were 3713 vehicles in Day 1, 4005 vehicles in day 2 and 3555 vehicles in day 3 in the intersection.

Table 1. Directional Volume

	Sanothimi		Jadibuti		Kadaghari		Total
Day	Jadibuti	Kadaghari	Sanothimi	Kadaghari	Sanothimi	Jadibuti	
Day 1	830	463	404	648	238	1130	3713
Day 2	721	465	395	623	286	1515	4005
Day 3	638	406	334	627	254	1296	3555

6.3 Speed Distribution

Speed of vehicles was determined using radar gun and speed of pedestrian was determined from videographic survey. Fifty samples (Edwing, 1999) of each vehicle type and pedestrians was surveyed to determine the average, minimum and maximum speed. Spot speed survey of the vehicles was also carried out. The 50th percentile speed was found to be 22.6 Kmph and 85th percentile speed was 30.5 Kmph.

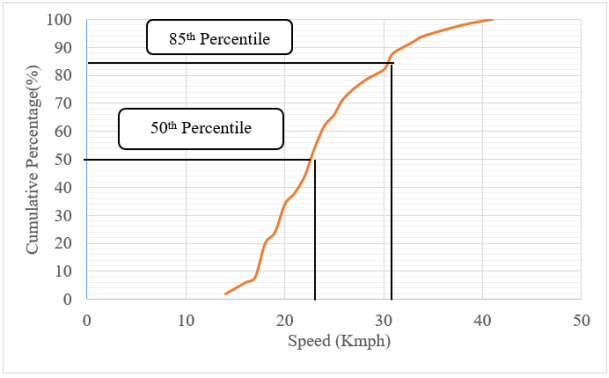

Figure 4 Speed distribution of vehicles

6.4 Development of Base Model

Base model is prepared in VISSIM to replicate the existing geometry of the intersection that comprises of different elements such as links, connectors of various shapes and measurements. Using data from videographic Survey, vehicle and pedestrian volume input of peak hour 9:00 AM to 10: 00 AM was fed to VISSIM. The composition of the traffic was also used as input during this process. The directional split of the vehicles obtained from Videographic survey was fed to the VISSIM model. The speed distribution of each types of vehicles and pedestrians from spot sped survey was also used. The developed base model was then calibrated and validated.

6.5 Calibration of Model

Calibration has been done for volume, average speed and queue length. Two-day data has been used for calibration of the model. GEH statistics and RMNSE values has been checked for calibration of model. Trial and error method have been adopted for calibration of the model.

Table 2. Calibration of volume

SN	From	To	Simulated Volume	Actual Volume in Field	GEH Statistics
1	Sanothimi	Jadibuti	785	776	0.32
2	Sanothimi	Kadaghari	478	464	0.64
3	Jadibuti	Sanothimi	379	400	0.83
4	Jadibuti	Kadaghari	622	636	0.55
5	Kadaghari	Sanothimi	255	262	0.43
6	Kadaghari	Jadibuti	1256	1323	1.86

Table 3. Calibration of speed

SN	Category	Average Speed in Field (Kmph)	Average Speed in model (Kmph)	RMNSE
1	Two-Wheeler (Motor Cycle)	27.64	27.44	0.03
2	Pedestrian	4.18	4.18	0
3	Four-Wheeler Light (Jeep, Car)	24.02	23.26	0.11
4	Four-Wheeler Heavy (Truck, Bus)	20.68	20.18	0.1

Table 4. Calibration of Queue Length

SN	Leg of Intersection	Queue length in VISSIM model	Actual queue length in Field	RMNSE
1	Sanothimi Leg	15.28	15	0.07
2	Kadaghari Leg	12.36	12	0.1
3	Jadibuti Leg	16.32	16	0.08

6.6 Validation of model

After the model was adequately calibrated, validation of model was done by checking the model for Day 3 traffic (Third day volume). The GEH statistics and RMNSE statistic was calculated for Day 3 traffic by following process similar to calibration.

Table 5. Validation of volume

SN	Movement	Volume in VISSIM model	Actual Volume in Field	GEH Statistics
1	Sanothimi to Jadibuti	617	638	0.83
2	Sanothimi to Kadaghari	412	406	0.28
3	Jadibuti to Sanothimi	314	334	1.1
4	Jadibuti to Kadaghari	600	627	1.08
5	Kadaghari to Sanothimi	245	254	0.56
6	Kadaghari to Jadibuti	1229	1296	1.88

Table 6. Validation of speed

SN	Category	Average Speed in Field (Kmph)	Average Speed in VISSIM (Kmph)	RMNSE
1	Two-Wheeler (Motor Cycle)	27.64	27.44	0.03
2	Pedestrian	4.18	4.18	0
3	Four-Wheeler Light (Jeep, Car)	24.02	23.26	0.11
4	Four-Wheeler Heavy (Truck, Bus)	20.68	20.18	0.1

Table 7. Validation of speed

SN	Leg of Intersection	Queue length in VISSIM model	Actual queue length in Field	RMNSE
1	Sanothimi Leg	15.21	15	0.05
2	Kadaghari Leg	13.14	13	0.04
3	Jadibuti Leg	15.42	15	0.1

6.7 Operational Performance

After the VISSIM model of the intersection was adequately calibrated and validated, the operational performance of the intersection was determined using delay and level of service. The overall Level of service of the intersection was C and average delay was measured to be 18.62 Seconds. The maximum queue length in the intersection was 16.55m.

Table 8. Operational Performance

SN	Movement	Level of Service	Delay (Sec)	Maximum Queue Length(m)
1	Sanothimi to Jadibuti	C	17.95	15.33
2	Sanothimi to Kadaghari	C	18.78	15.33
3	Jadibuti to Sanothimi	B	12.93	16.55
4	Jadibuti to Kadaghari	C	17.31	16.55
5	Kadaghari to Sanothimi	C	19.1	12.76
6	Kadaghari to Jadibuti	C	21.12	12.76
7	Overall	C	18.62	16.55

7.Discussion

The study evaluated the operational performance of the intersection at Pepsicola by using simulation software VISSIM. The model replicated the present scenario of operation of the intersection. The intersection doesn't suffer much congestion compared to other busier intersection in Kathmandu valley which is also evident from its LOS C. Thus, no immediate measures for improvement of operation is required for the intersection.

8. Conclusion

The study focused on the evaluation of the operational performance of the intersection at Pepsicola. At present condition the Level of Service of the intersection is C with average total delay of 18.62 Sec. The movement from Jadibuti to Sanothimi has better level of service with LOS B among other movements in the intersection. The maximum queue length in the intersection is 16.32m. Signal phase design or coordination with other intersection nearby could be done to improve the performance of the intersection. [15]

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