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Evaluating U-Turn Capacity with Modified Geometry Designs and Various Conflicting Traffic Flows: A Traffic Microsimulation Approach

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Abstract

Factors such as U-turn geometric and conflicting traffic volume often play a key role on U-turn capacity and safety. Evaluating U-turn capacity under modified geometric designs and various conflicting traffic flow conditions thus is essential to improving traffic flow and safety. This paper analysis U-turn capacity under various conflicting traffic conditions and propose the U-turn geometry modifications to improve capacity. A microsimulation model using PTV VISSIM is developed, and the results is compared with conventional analytical method to highlight the advantages of using traffic microsimulation approach in such analyses. The results show that U-turn capacity is significantly affected by conflicting traffic flow that in turn affecting headway time, and service time for various vehicle type. Among the geometric modifications tested, channelization designs showed significant increase in capacity whilst roundabout and indirect right-side design give mixed results depending on the composition of vehicles performing U-turns.

INTRODUCTION

U-turn maneuvers are among high risk and complex vehicle maneuvers at road links and intersections. Unlike other maneuvers, U-turns requires drivers to merge into conflicting traffic which often operates at highers speeds and volumes. One of important indicators to evaluate U-turn performances is capacity. U-turn capacity refers to the number of vehicles that can pass the U-turn section in one hour considering the available gap in conflicting traffic [1]. Several studies have explored this issues using analytical methods based on the Highway Capacity Manual (see for example [2-4]). However, this method generaly is limited to specific facility type and cannot take into account varying traffic conditions which are important for traffic operation analysis. Analytical methods also cannot adequately address changes in U-turn geometric designs or variation in conflicting traffic necessitating other approaches that can better capture these factors.

One method that overcomes the limitations of analytical methods is microsimulation modeling [5]. This method has the advantage of representing vehicle movements at the individual level, meaning each vehicles is treated as separate entity. This allows simulation model to account for variability in individual driver behaviour and preference which conventional methods often overlook. This paper utilize PTV VISSIM, a microsimulation tool capable of modelling

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detailed driving behaviours and geometric configurations including U-turn facilities. Previous studies on U-turn facilities analysis have demonstrated the effectiveness of PTV VISSIM as a tool to analyze U-turn performance [6-8]. However, these studies have not explicitly address the impact of geometric modifications on U-turn and the variablity of conflicting traffic flow on U-Turn capacity.

This paper aims to investigate and analyze the impact of modified U-turn and various conflicting traffic flow variations on U-turn capacity using traffic simulation modeling. A simulation model within PTV VISSIM framework is developed. The model is capable of analyzing the interactive effects of different U-turn designs and conflicting traffic demand variation. Field data are collected through surveys and capture key U-turn parameters such as U-trun speed, travel time and critical gap. Once validated, the model is used to asess different U-turn geometric design and various conflicting traffic flow providing insights into their sensitivity to U-turn capacity. Two case studies are presented in this paper, each representing different U-turn conditions in terms of existing geometric of U-turn operning and traffic demand. The first case study – Juanda – focuses on U-turn facility without a dedicated lane and is dominated by car traffic. The second case – Cikapayang – examines U-turn with dedicated U-turn lanes and with high proportion of motorcycle users.

The structure of this paper is as follows: Section 2 reviews previous studies on U-turn capacity analysis and identifies the research gap. Section 3 outlines the methodology, followed by the case study, results, and discussion in Sections 4 and 5. Finally, Section 6 presents the conclusion and suggestions for future research on U-turn analysis using traffic microsimulation.

Literature Review

The geometric design of U-turn openings plays crucial role in determining U-turn capacity. Previous studies have primarily relied on analytical models based on gap-acceptance methods firstly proposed by [9]. In this approach, conflicting flow rate, critical gap, and follow-up time are key parameters used to determine capacity. Conflicting flow rate refers to the traffic flow from conflicting direction into which U-turn vehicles want to merge. The critical gap is defined as the minimum time interval in the conflicting traffic stream that allows U-turn vehicles to proceed safely. Follow-up time is defined as the time between the movement of the first U-turn vehicle and the next U-turn vehicle in a continuous flow. While analytical approaches have been successfully applied to analyse U-turn capacity, they possess significant drawbacks. Most of these models assume homogenous traffic conditions where most vehicles are cars or light vehicles with similar driving behaviour. This condition often does not reflect real world traffic conditions which can include a mix of vehicle types and varying degrees of driving behaviours.

In contrast to analytical approach, [10] propose a method to calculate U-turn capacity based on field survey data. By using empirical data, this approach provides more realistic and practical understanding of U-turn capacity under varying traffic condition. This approach utilizes two key parameters obtained from on field survey: service time and follow up time. Service time refers to the time required for a vehicle to merge during the U-turn movement. Follow-up time is the duration from when the previous U-turn vehicle leaves the stop line until the next waiting vehicle reaches the stop line. These parameters can be directly measured in the field as will explained in next section. Field based approach have several advantages. First, it can consider the impact of different vehicle types on capacity calculation [11]. Second, and perhaps more importantly it can incorporate various conflicting traffic flow condition which are critical on U-turn capacity calculation [4].

Another significant advantage of using field-based calculations is the ability to utilize microsimulation model. Research on microsimulation modeling for U-turns has been widely conducted to understand U-turn capacity and operations and its impact on road link operations. For instance, [7] and [8] investigate the effecs U-turn location and geometric on incoming and conflicting traffic using micro simulation, focusing on Indonesian context. They note that a key distinction in Indonesia's traffic conditions is the high prevelance of motorcycle which greatly infuence the traffic dynamics. However they are not explicitly focus on U-turn capacity. In contrast, [6] explore U-turn microsimulation modelling using PTV VISSIM to estimate U-turn actual capacity. However, their research primarity anlyzed mixed traffic common in developed country in which car and light vehicles dominate traffic composition.

This paper utilizes traffic microsimulation to analyze U-turn capacity using on field data approach. Specifically, this paper employs microsimulation to investigate the impact of different U-turn geometric designs and varying conflicting traffic flow rates on U-turn capacity. This analysis in conducted in the context of mixed traffic conditions where motor cycle are prevalent – a scenario that has not been extensively explored in previous study.

METHOD

This study is carried out in four main steps: (1) On field traffic survey (2) Developing micro simulation model (3) U-turn capacity calculation using both analytical and on field based approaches, and (4) performing U-turn capacity sensitivity analysis on different U-turn geometric and various conflicting traffic flow. Figure 1 shows the overall methodology used in this paper.

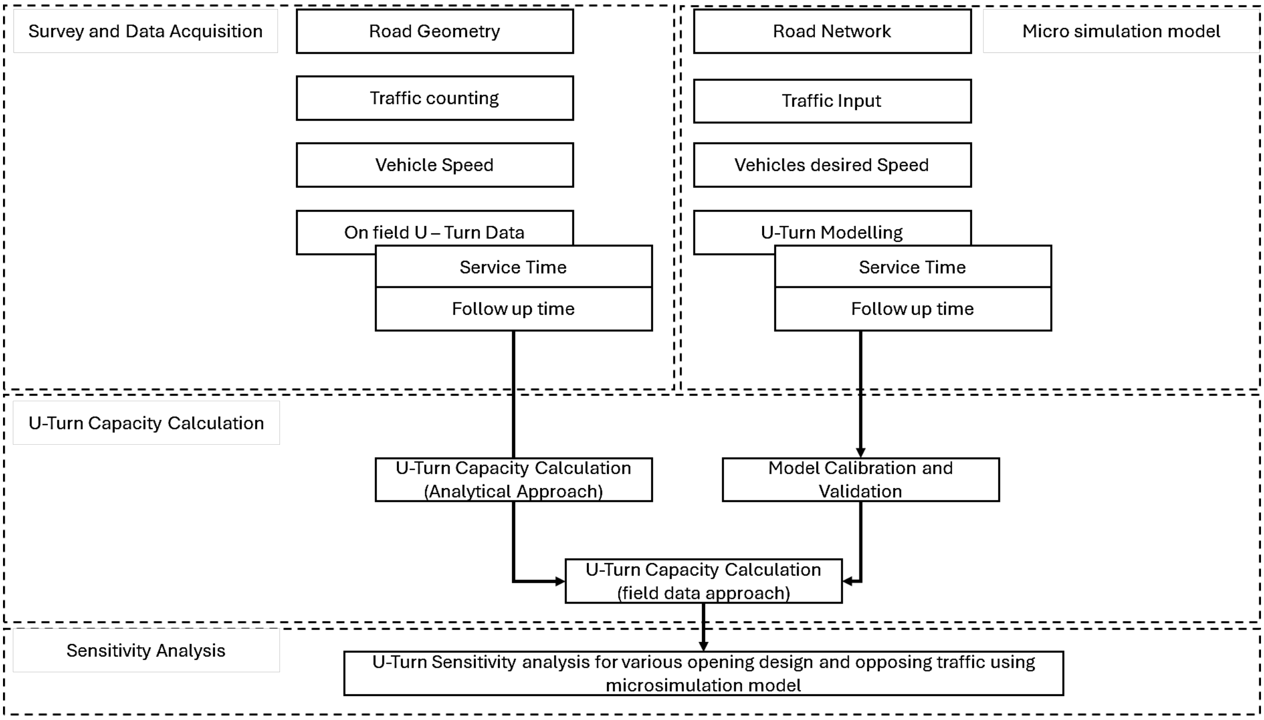


Figure 1. Data Acquisition and Modelling Framework

Primary data collection was conducted through traffic surveys on U-turn facility. The survey encompasses for main component (1) road geometry survey, (2) traffic counting survey, (3) vehicle speed survey, and (4) U-turn movement survey. The road geometry survey includes measurements of traffic lane width, and U-turn opening dimensions. The traffic counting survey was conducted over three-hour period with vehicle categorized and counted accordingly. To capture the distribution of vehicle arrival, counts was recorded at five-minute intervals throughout the survey period. The U-turn movement survey focuses on observing vehicle travel time under three specific conditions during U-turn maneuver. Data for U-turn maneuver are collected using video recordings and the travel times are measured based on imaginary reference lines marked in the video. Figure 2 illustrates the imaginary reference lines used to measure travel times for U-turn maneuver.

(a) (b)

Figure 2. (a) U-turn Line Detector Scheme, (b) U-turn Movement Survey Example

Using the reference lines, we can then define several travel time components during U-turn maneuver. t_0 is entering time refers to the time when vehicle's font bumper enters 'line detector a', t_1 is the time when vehicle's font bumper entering U-turn 'line detector b'. By defining t_0 *and* t_1 for each vehicle i we can then define service time and follow-up time for each vehicle i as follows:

$$t_{s(i)} = t_{1(i)} - t_{0(i)} \quad (1)$$

$$tf_{(i)} = t_{1(i)} - t_{0(i-1)} \quad (2)$$

Where:
t_0 : Entering time
t_1 : Stop line time
i : nth vehicles performing U-turn
t_s : Service time
t_f : Follow-up time

Next, this paper develops microsimulation model to simulate U-turn maneuver within PTV VISSIM platform. In general, traffic microsimulation needs four main inputs: (1) Road network (2) traffic demand (3) Driving Behaviour (4) Simulation parameter. Readers can refer to PTV VISSIM manual and pervious research on how to set up the micro simulation traffic model within PTV VISSIM framework (see for example [8], [12], [13]). This section explains in more detail the U-turn movement modelling.

The U-turn movement is modelled with this recurring steps : A vehicle arrive at the beginning of road segment, and then decides whether to perform a u-turn or not. If the vehicle chooses to make a u-turn, it approaches the median u-turn opening segment and then briefly stops at the temporary stop point to wait for the conflicting traffic. Once a sufficient gap is available for the U-turn maneuver, the vehicle will perform the u-turn i.e. the vehicle merge with conflicting traffic causing the vehicles in the conflicting traffic to reduce their speed to allow the vehicle to complete the U-turn. This process repeats with different arrival rates and driving behavior for each vehicle entity in both the incoming traffic and the conflicting traffic, based on field observation data.

To ensure the critical gap is addresses properly and the model closely replicate real world condition, this paper utilze priority rules module in PTV VISSIM. This is achieved by configuring driving behavior parameters such as turning speed, and gap parameters within priority rules module to match observed field conditions. To ensure that the parameters settings in priority rules module are correcly configured properly set up, the service time parameter is used to validate the simulation results. This step is important to ensure the U-turn maneuver is modelled accurately. To estimate the U-turn capacity this paper uses two approaches. First, we use analytical capacity by [1] adopted from [9] as follows:

$$C_p = V_c \times \frac{e^{-V_c \times \frac{t_c}{3600}}}{1 - e^{-V_c \times \frac{\overline{t_f}}{3600}}} \tag{3}$$

Where:
C_p: U-turn Capacity (vehicles per hour)
V_c: Conflicting traffic flow rate (vehicles per hour)
t_c: Critical gap for U-turn (seconds)
$\overline{t_f}$: Average Follow-up time U-turn (seconds)

As for field based capacity, we use formula by [10] The equation is as follows

$$C_f = \frac{3600}{\overline{t_s} + \overline{t_f}} \tag{4}$$

Where:
C_f: On field U-turn capacity (vehicles per hour)
$\overline{t_s}$: Average service time (seconds)
$\overline{t_f}$: Average follow-up time (seconds)

This equation is based on average service time and average follow-up time. Service time refers to the travel time required for a vehicle to merge to conflicting traffic during the U-turn movement. Follow-up time, on the other hand, is defined as the time interval between the departure U-turn vehicle from the stop line and the arrival U of the next waiting vehicle at the stop line. Note that the capacity calculation above assume hat the traffic flow consists of a single vehicle type. To account for mixed traffic with varying vehicle proportions, the following equation by [11] is used:

$$\frac{100}{Q_m} = \sum_i \frac{P_i}{C_i} \tag{5}$$

Where:
Q_m: Total potential capacity (vehicles/hour)
P_i: Proportion of vehicle type i
C_i: Capacity of vehicle type i (vehicles/hour)

Case Study and Model Development

This paper uses two U-turn locations as case studies: Juanda and Cikapayang in Bandung, Indonesia. These two locations have two distinct U-turn traffic characteristics and geometric designs. U-turn at Juanda has a conventional U-turn geometry with no dedicated lane for U-turn vehicles whereas U-turn at Cikapayang has dedicated lane U-turn Lane. Further investigation through traffic survey reveals that car or light vehicle dominates U-turn movement at Juanda, whereas motorcycle dominate U-turn movement at Cikapayang (see Figure 3).

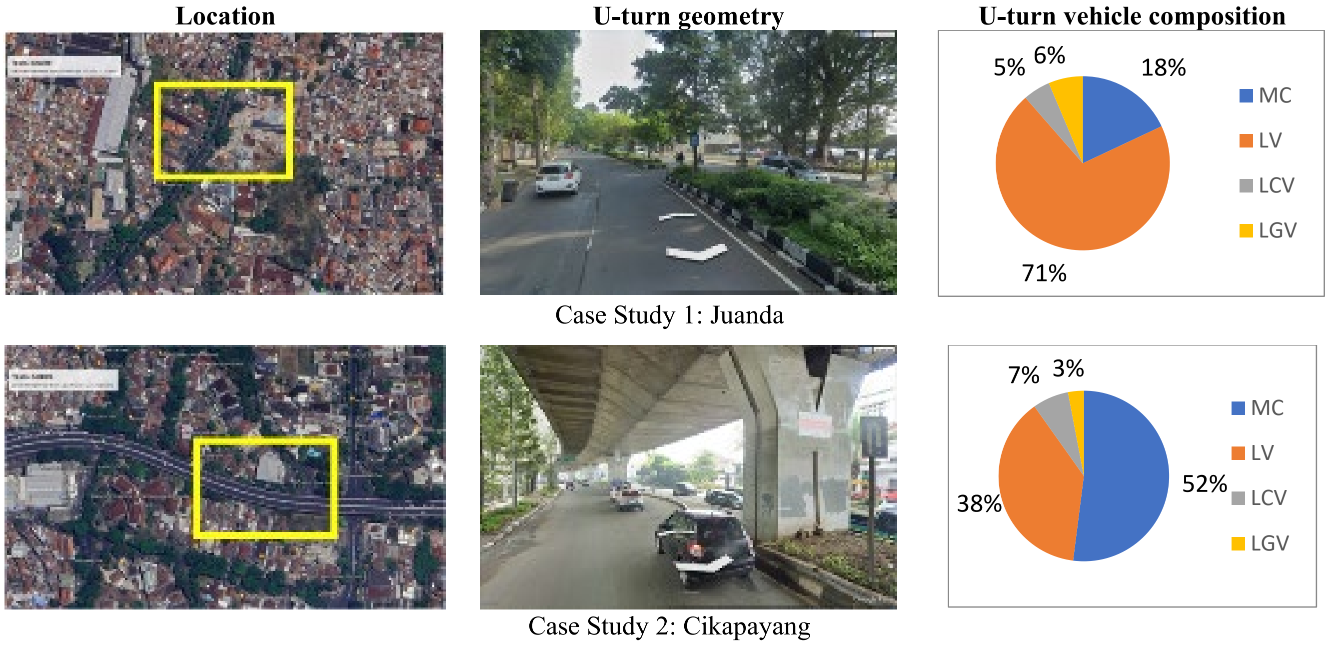


Figure 3. Case Studies Location, U-turn Geometry, and Traffic Characteristics

The data collected and processed in this paper consists of primary and secondary data. Primary data was collected directly from field observation and traffic surveys while secondary data is obtained from previous studies. Field surveys were conducted in two case studies location on typical weekday between 1:00 PM and 2:20 PM. This period is selected because it is the time in which the traffic condition for both incoming and conflicting traffic in U-turn facilities are non-saturated which is the focus on this study. Summary of survey and data collection process can be seen in Table 1.

Table 1. Survey and Data Collection

Data Type	Data	Survey / Data Collection
Road / U-turn Geometry	Road Geometry including number of lane and lane width	Road Geometric Survey
	U-turn Geometry including U-turn width, median width, U-turn, and length of dedicated lane (if any)	Road Geometric Survey
Traffic Volume data Data	Traffic volume for each vehicles category with 10 minutes time frame observation	Traffic Survey: Video Tapping
	Vehicles desired speed for each vehicles category	Traffic Survey: Video Tapping
U-turn movement	U-turn movement gap time, service time	Traffic Survey: Video Tapping
	Turning Speed	Secondary data from [6]
Driving Behavior Parameter	*car following*, *lane change* and *lateral distance*	Secondary data from previous study ([7],[10],[11])

This study categorizes vehicles type into four categories namely: (1) motorcycle (MC), (2) Car or light vehicle (LV), (3) Lights commercial vehicles (LCV) and (4) Large goods vehicle (LGV). The distinction between LV, LGV and HGV is mainly on vehicles dimensions. Specifically, LVs are defined as vehicles with length less than 5 m, LGVs are commercial or goods vehicles with a length between 5 and 6 m, and HGVs are vehicles that have length more than 6 m including Bus. To validate these categories a significance test (t-test) on service time data obtained from the survey. The analysis is done step-wise, testing the data in following sequence: MC vs Non MC, LV vs Non LV, and LCV vs Non-LGV. The results reveal that there is significance different in the mean service time across the categories confirming that four vehicle categories can be effectively used to analyze U-turn capacity on both location. Table 1 presents the results of significance test.

Table 2. Vehicle Category Significance Test

Pair Data	Significance (t-test)
MC vs non-MC (LV, LCV, LGV)	11.16
LV vs non-LV (LCV and LGV)	3.74
LCV vs non-LGV	3.15

The general steps involve in modelling U-turn using PTV VISSIM have been describe in previous section. However, for the specific case studies the setup of simulation and driving parameters as part of calibration process requires further discussion. The simulation parameters include the simulation period, number of runs, and random seed and increment. Simulation period is set up to be 4200 seconds with initial 600 seconds act as warm up period. Hence the observation period spans from 600 to 4200 seconds. To reduce the effect of data deviations caused by simulation randomness, multiple simulation runs are needed. This paper uses twelve simulation repetitions based on allowable deviation calculation obtained from piloting run. The final simulation results are obtained based on averaging these repetitions. Lastly, this study use PTV VISSIM default number of random seed and increment.

Table 3. Driving Behaviour and Priority Rules Parameter

No	Parameter	Unit	VISSIM Default	[11]	[7]	[12]	Calibrated Value	
							Juanda	Cikapayang
1	**Following**							
	a. Look Ahead Distance Minimum	m	0	0	0	0	0	0
	b. Look Ahead Distance Maximum	m	250	150	250	250	150	150
	c. Number of Interaction Object		4	4	2	4	4	4
	d. Look Back Distance Minimum	m	0	0	0	0	0	0
	e. Look Back Distance Maximum	m	150	100	150	150	100	100
2	**Car Following Model Wiedemann 74**							
	Average Standstill Distance	m	2	2	2	0.5	0.5	0.5
	Additive part of Safety Distance		3	3	2	0.8	0.5	0.5
	Multiplicative Part of Safety Distance		3	3	3	1	1	1
3	**Lane Change**							
	a. Waiting time before diffusion	sec	60	60	60	60	60	60
	b. Minimum headway	m	0.5	0.5	0.5	0.5	0.5	0.5
4	**Lateral**							
	a. Consider next turning direction		No	No	No	Yes	Yes	Yes
	b. Desired Position at free flow		Middle	Any	Any	Any	Any	Any
	c. Overtake on same lane : on left & on right		No	On	On	On	On	On
	d. Min. lateral Distance at 0 & 50 kmph	m	0.2 & 1.0	0.2 & 0.5	0.7 & 1.0	0.1 & 0.3	0.2 & 0.5	0.2 & 0.5
	e. Collision time gain All Vehicle	sec	2 & 2	2 & 2	2 & 2	0.5 & 1.0	2 & 2	2 & 2
5	**Priority Rules**							
	Minimum Gap Time	sec	3	3	3	3	1	0.6
	Minimum Clearance	m	5	5	5	5	5	6.5
	Maximum Speed	km/h	180	180	180	180	60	60

Validation process is performed concurrently with callibration process. Calibration focuses on determining parameter values for driving behaviour and priority rules module. Initial driving behaviour parameters value were set based on previous research. Then parameter values are modified as part of calibration process. Validation is done by evaluate each simulation model with spesifics simuation parameter values. The results of subsequent simulation is compared with field survey results to ensure alignment. Table 3 shows the calibrated parameter values used in this study.

Next, we discuss validation results. Frislty, traffic flow results are validated using the Mean Absolute Percentage Error (MAPE). The traffic flow being validated are incoming vehicle volumes in both parallel and opposite direction of U-turn movement as well as the volume of vehicles performing U-turn. The results show that the MAPE value is between 2% and 6% indicating that the simulation accurately repilicate field observations (See Table 4).

Table 4. MAPE Value for Traffic Flow Validation

Traffic Flow	Juanda	Cikapayang
Parallel Traffic Flow	0.02	0.02
Opposite Flow	0.02	0.02
U-Turn	0.06	0.05

The next parameter validated is service time. The results show the means of observed and modelled data are not significantly different suggesting the model effectiveness on replicating the observed data. However, the f-test results show a significant difference in service time variance between observed and modelled data. The result implies that the service time variance producing in simulation is much wider than the service time from observed field data. This discrepancy happens because the observed data is based on a limited sample size while the model calculates service time variance from the population generated from simulation. The complete statistic results are presented in Table 5.

Table 5. Statistics for Service Time Validation

Parameters	Juanda		Cikapayang	
	Observed Data	Modelled Data	Observed Data	Modelled Data
Mean	6.36	6.18	5.54	5.56
Variance	4.67	8.87	5.06	7.43
Std. Dev	2.16	2.98	2.25	2.73
Sample Size	379	3322	551	5560
F-test	1.867*		1.469*	
T-Test	1.43**		0.23**	

*Significantly different at 95% significant level **not significantly different at 95% significant level

RESULTS AND DISCUSSION

This section discusses the results of U-turn capacity analysis. Frist, we conduct a U-turn capacity analysis using two approaches : analytical based and field based. The aim is to compare the results from these different method for U-turn capacity calculation.

The data collected from the survey reveals that U-turn movements at the two locations are typically congested with queues consistenly forming at the U-turn facility over one hour period. Subsequently, by counting the number of vehicles performing U-turn during this period, the U-turn capacity based on observed data can be determined. Comparing this observed data with capacity analysis shows that the field based approach produces more accurate results thatn the analytical method. For example, at Juanda, the field-based approach estimates U-turn capacity at 269 vehicles per hour, which closely aligns with the observed capacity of 275 vehicles per hour. In contrast, the analytical method significantly underestimates capacity, yielding only 112 vehicles per hour. This discrepancy highlights the limitations of the analytical approach in capturing real-world conditions, particularly in scenarios with various vehicle types performing U-turn movements.

Figure 4 presents the results for U-turn capacity calculation for both Juanda and Cikapayang using field based approach and analytical approach. Notably, at Juanda, the analytical capacity is significantly lower (59% less) than the field capacity, whereas at Cikapayang, the difference is smaller (10% less). This arises because analytical capacity relies on simpler gap acceptance by calculating a single value of critical gap for a specific vehicle type. The effect of this simpler gap acceptance is more apparent scenarios where a single vehicle type dominates U-turn movements, as it it does not take into account variability of driver behaviour within the same vehicle category.

The remaining analysis utiize U-turn capacity using field calculation approach based on Kyte's formulation. We examinde the sensitivity of U-turn capacity to conflicting traffic flow. Figure 5 shows the relationship between the model capacity and the conflict flow variations at each location. It is evident that changes in conflict flow significantly affect the U-turn capacity. At both locations, capacity tends to decrease as the conflicting flow increases. This occurs because, with higher conflicting flow, U-turn vehicles have to wait longer to find acceptable gap i.e. the gaps between vehicles are tighter, reducing the number of vehicles able to complete the U-turn. In contrast, under low conflicting flow condition, U-turn vehicles encounters more sufficient gaps, allowing a greater number of vehicles to make the U-turn.

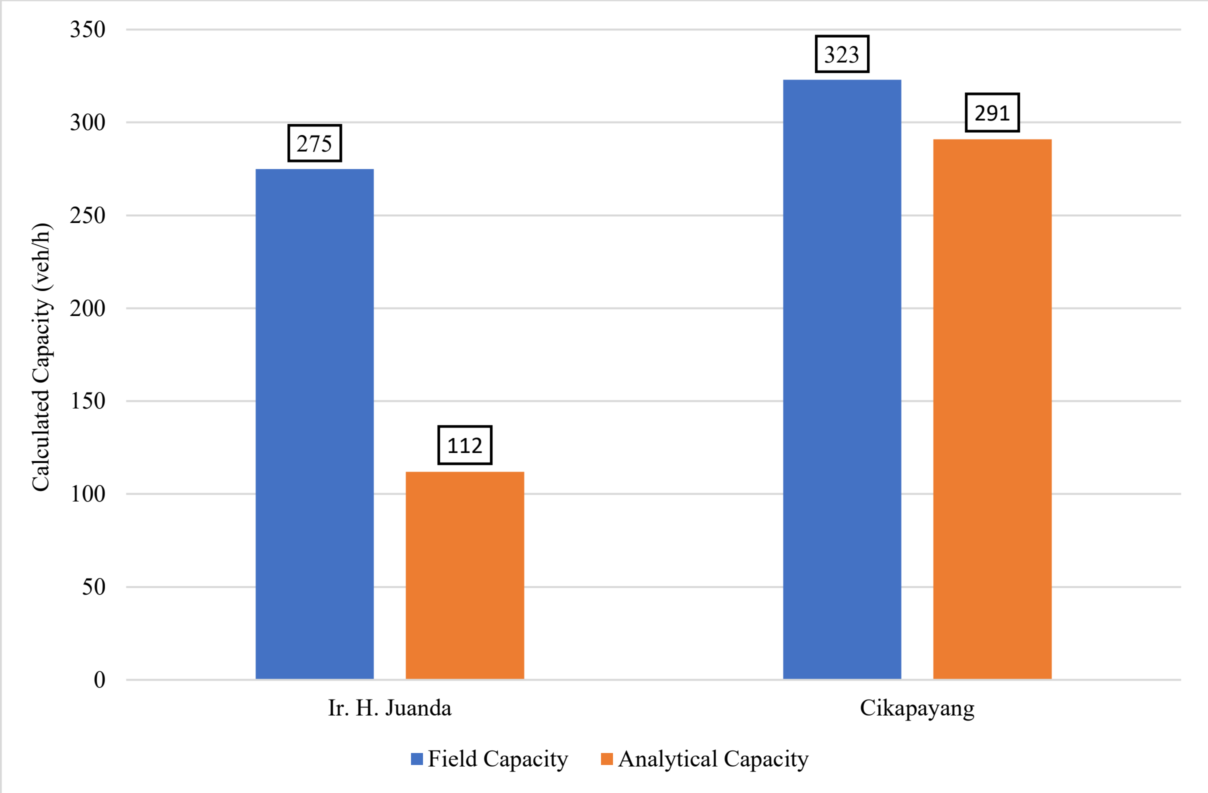
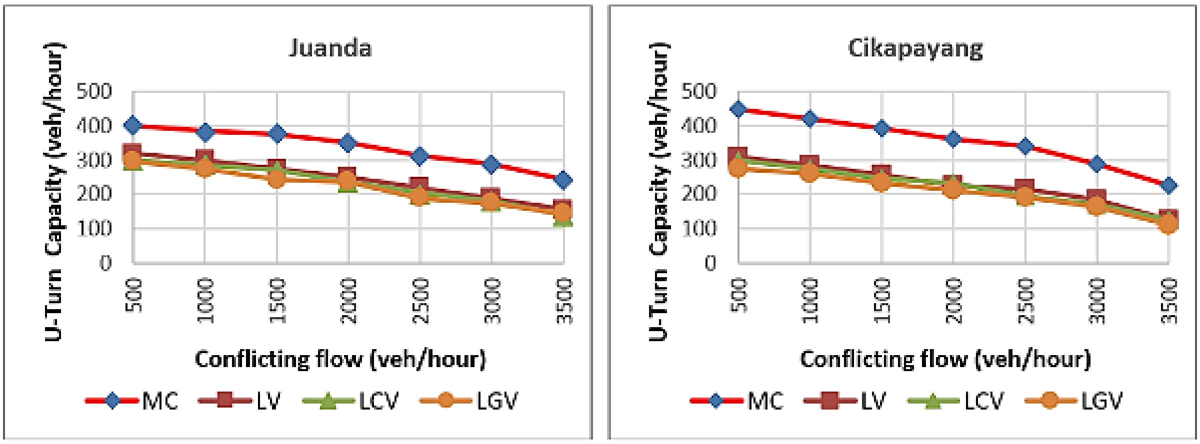
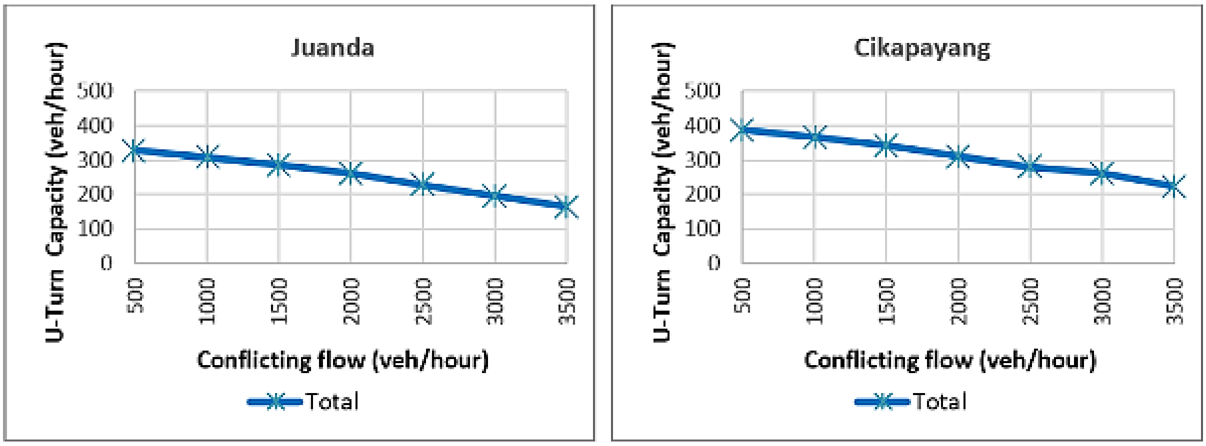


Figure 4. Calculated U-turn Capacity based on Analytical and Field Method

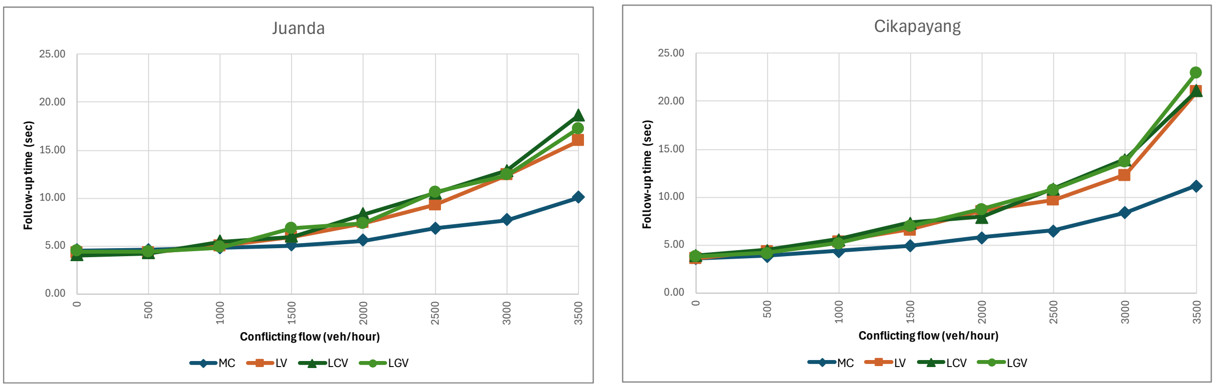


(a)

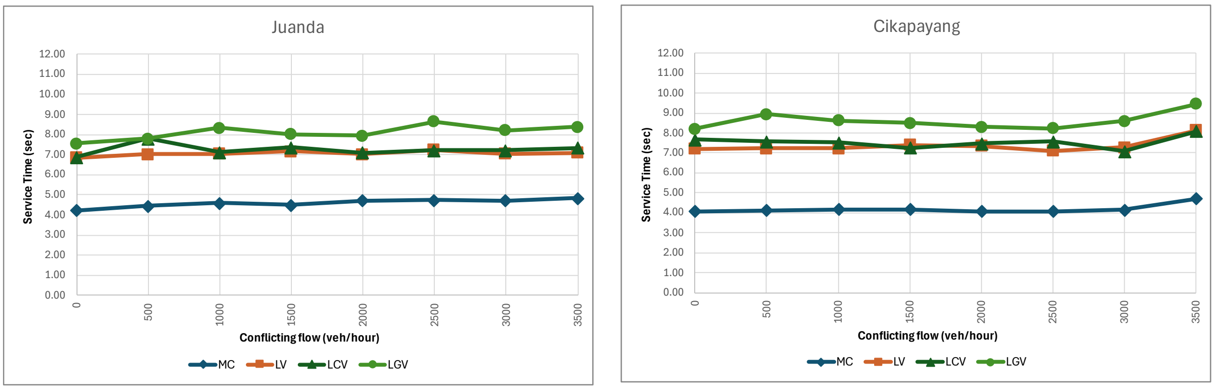


(b)

Figure 5. The relationship between (a) Model's Capacity and Changes in Conflicting Flow for Each Vehicle Type, and (b) Under Mixed Traffic Conditions



(a)



(b)

Figure 6. (a) The Follow-up vs. Conflicting Flow, and (b) Service Time vs Conflicting Flow

Another parameter influenced by conflicting flow is U-turn travel time which is divided into two components: follow up time and service time. The results reveal that follow up time is more sensitive to conflicting flow variations compared to service time. This occurs because service time is largerly dependent on gap acceptance behaviour where as follow up time is directly influenced by conflicting flow. As conflicting flow increases, follow up time also increases because the next vehicle in U-turn queue requires more time to find acceptable gap to perform U-turn movement. In contrast, service time is primarily determined by driver's gap acceptance tolerance rather than conflicting flow. An aggressive driver tend to accept smaller gap resulting in shorter service time. When comparing different vehicles it is evident that motorcycles have the smallest service time implying they they require smaller gap to perform u-turn movement compared to other vehicle. The relationship between follow up time, service time, and conflicting flow can be seen Figure 6.

The next analysis involves developing alternative scenario by modify the geometric design of the U-turn facility. The designs considered in these alternative scenario are channelization, roundabouts, and indirect right-side U-turns (see Figure 7).These alternatives are taken from U-turn design code in Indonesia [14]. The analysis is conducted by varying the the geometric design of the U-turn while keeping other parameters _ such as incoming traffic, U-turn vehicles proportion, and simulation parameters - constant. Capacity calculations for these scenarios are based on field capacity analysis because analytical method is unsuitable for this analysis. The analytical method assumed fixed critical gap for specific vehicle, whereas varying u-turn geometry can alter this gap making the field based approach more appropiate.

Figure 8 shows the results on varying geometry in both Juanda and Cikapayang. The results show that modifying U-turn design significantly impacts U-turn capacity. In general, all designs gives a better capacity except on indirect right side U-turn indicating an inffective design for current situation.

A significant increase in U-turn capacity is observed with the channelization design, with increases of 34% and 104% for the Juanda and Cikapayang locations, respectively. This increase occurs because channelization allow U-turn vehicles to perform U-turn movement without significantly reducing their speed. This results in shorter service time and follow up time compared to existing conditions. Cikapayang experiences higher capacity increase with channelization because this design can effectively decrease service time for U-turn movement largerly consist of MC with smaller gap time. Next, we compare the results for the round about U-turn design. Interestingly, the two locations yield contradicting outcomes. At cikapayang, U-turn capacity increases by 31% while at Juanda capacity decreases by 8%. Further analysis on the service time and follow up time for this two scenarios reveals that that traffic with a large proportion of MC benefits from the roundabout design. Motorcycles can effectively navigate weaving section at roundabout reducing service time. However this is not the case for traffic domninted by LV. For such traffic weaving section cause LV to slow down significantly and thus reducing service time and subsequently U-turn capacity.

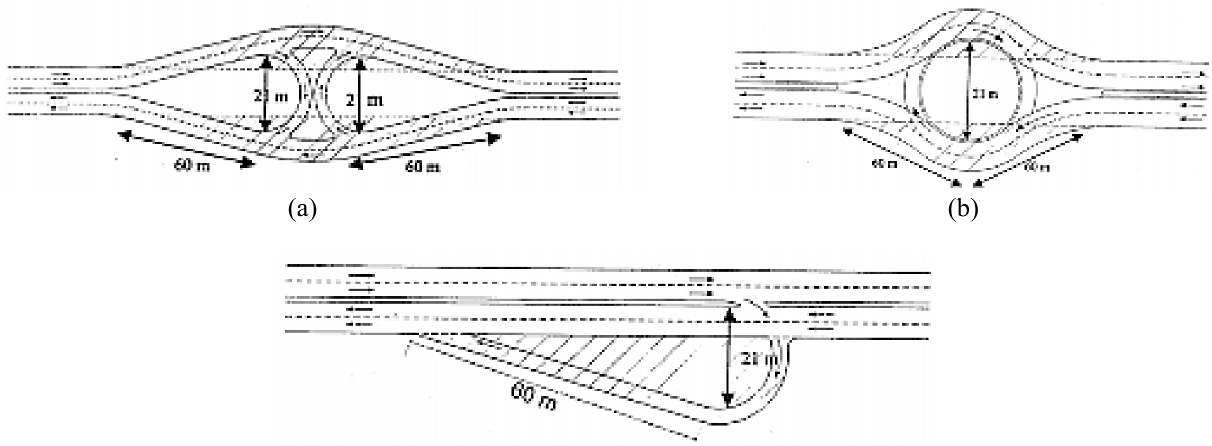


Figure 7. Modified U-turn Geometry (a) Channelization, (b) Round About, (c) Indirect Right-side U-Turns [14]

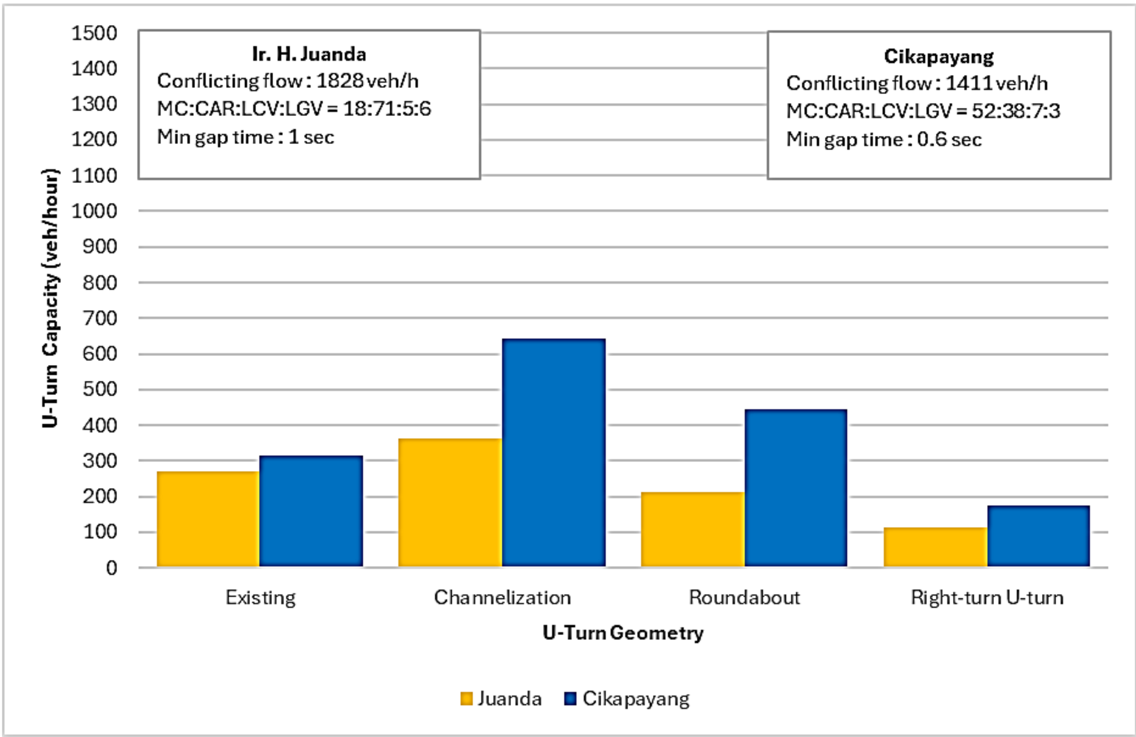
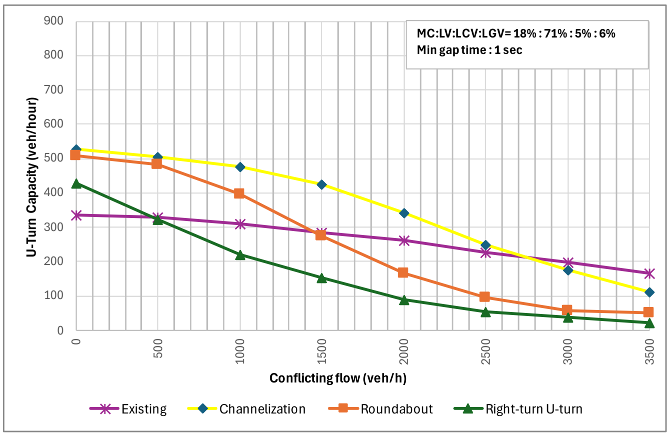


Figure 8. The Relationship between Various U-Turn Geometric vs. U-Turn Capacity

Lastly, we conduct analysis by combining various u-turn design with varying level of conflicting flow. The aim of this analysis is to find the optimal U-turn design for different conflicting flow conditions at both Juanda and Cikapayang. Consistent with previous findings, the results show that increasing conflict flow corresponds to a decrease in U-turn capacity. In general, the channelization design gives superior performance across a wide range of conflicting flow rates. Only when the conflicting flow is larger than 2500 vehicles per hour, a regular U-turn gives better capacity than channelization. Additionally, the sensitivity analysis reveals that indirect right side U-turn can gives a better performance than regular U-turn only when the conflicting flow is below 500 vehicles per hour. This implies that higher speed associated with the indirect right side U-turn are advantegous under relatively low conflicting flow condition. The relationship between U-Turn capacity, U-turn design and confliction flow is illustrated in the following Figure 9.



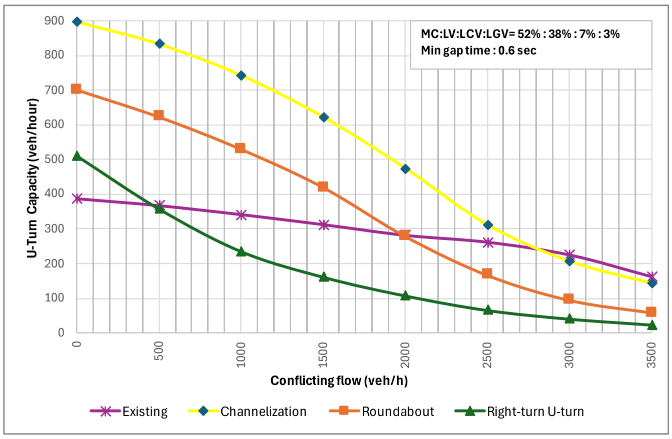


Figure 9. The Relationship between Various U-Turn Geometric and Conflicting Flow vs. U-Turn Capacity in Juanda (Left), and Cikapayang (Right)

CONCLUSIONS

This paper aims to analyse various U-turn design on U-turn capacity performance using micro simulation. Additionally, the impact of varying the conflicted flow levels on U-turn capacity is investigated. The analysis primarily employs Kyte's Field capacity method, with two case study – Juanda and Cikapayang – examined due to their distinct traffic characteristics.

The calculated capacities based on survey field data were 269 vehicles per hour for Juanda and 315 vehicles per hour for Cikapayang using the field based approach. This number is closer to the actual U-turn vehicles number obtained from survey indicating field based approach better represents real world data than analytical methods. Sensitivity analysis of U-turn capacity to conflicting traffic flow shows that conflicting traffic flow significantly affect U-turn capacity. U-turn capacity decrease as conflicting flow increases. This occurs because higher conflict flow increases the follow up time as each vehicles must wait for a sufficient gap to perform the U-turn maneuver resulting in fewer U-turn movements.

Modifications to U-turn designs significantly affect U-turn capacity. The channelization design demonstrate the most improvement, increasing capacity by 34% and 104% at Juanda and Cikapayang respectively. This is expected since channelization allow vehicles to maintain higher during U-turn movement. In contrast the roundabout design gives mixed results. U-turn capacity decreases by 22% at Juanda but increases by 41% at Cikapayang. This occurs because the differences in traffic composition: Juanda U-turn movement is predominant LV which experience significant delays in roundabout weaving section. In contrast, Cikapayang U-turn movement is predominantly motorcycle which can navigate weaving section effectively and thus minimizing delay at roundabout. The indirect right-side design performs poorly at both locations, with capacity decreases of 58% at Juanda and 45% at Cikapayang. This decline occurs because vehicles must perform two maneuvers in the indirect right-side design (i.e, crossing and merging) requiring more time and reducing the number of U-turns in high conflict flow conditions. Further analysi reveals that this design is effective only if the conflicting traffic flow very low.

Further research can develops U-turn model based on microsimulation that considers more advance traffic management in U-turn. Several idea that can be explored included, impact on signalized U-turns for U-turn, and integration to intellingent transportation system such as real time traffic monitoring, and connected vehicles. Another angle for future research regarding can include the influence of non motorized transport such as pedestrian and cyclist on U-turn capacity performance.

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