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Traffic Impact Analysis of an Underpass on the Performance of Nearby Signalized Intersections Using VISSIM

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Abstract

Medan City is one of the metropolitan cities with a high level of congestion and population density, resulting in traffic jams, delays, as well as air and noise pollution. This study aims to analyze the performance of intersections on S.M Raja – Halat road, Brigjend Katamso – Mesjid Raya road, and Brigjend Katamso - Pelangi road before and after the operation of the underpass at the Ir.H.Juanda – Brigjend Katamso road intersection using vissim software. Data were obtained from traffic surveys such as vehicle volume surveys, road geometry, traffic signal cycle times, and vehicle speeds. The data obtained from the vissim software simulation results include queue lengths, delays, and level of service at the intersection. For the simulation results at the Ir.H.Juanda – Brigjend Katamso road intersection before the operation of the underpass, the average queue length was 274.3 m and the average delay was 307.38 sec/vehicle, with an average level of service of F (very poor). After the operation of the underpass, the average queue length was 8.38 m and the average delay was 0.96 sec/vehicle, with an average level of service of A (excellent). With a 5-year scenario, the average queue length was 38.53 m and the average delay was 12.34 sec/vehicle, with an average level of service of B (good). Thus, a significant difference is clearly visible between before and after the operation of the underpass, such as the results of queue lengths, delays, and service levels, which have caused new conflicts at the intersections closest to the underpass.

Introduction

Medan City is one of the metropolitan cities with a high level of crowding and population density, and it has many problems, one of which is the still poor transportation system, resulting in traffic jams, delays, as well as air and noise pollution. The population of Medan city in 2024 reached 3.64 million units. This figure shows a significant increase compared to previous years (BPS Kota Medan, 2024).

This problem is caused by the imbalance between the number of vehicles and road capacity, the low level of human resources among road users, and the supporting transportation facilities (Nasution, 2017; Olugbade et al., 2022; Berhanu et al., 2023). This leads to high saturation flow and long queues at intersections, increasing delay and congestion on intersection approaches (Adisasmita & Adisasmita, 2011; Abdurakhmanov, 2022; Maddu et al., 2025).

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This research aims to analyze the intersection performance on S.M Raja – Halat road, Brigjend Katamso – Mesjid Raya road, and Brigjend Katamso - Pelangi road before and after the operation of the underpass at the Ir.H.Juanda – Brigjend Katamso road intersection using vissim software. The data were obtained from traffic surveys such as vehicle volume surveys, road geometry, traffic signal cycle times, and vehicle speed (Poliziani et al., 2022; Islam et al., 2024; Droj et al., 2022). Subsequently, the data obtained from the vissim software simulation results include queue lengths, delays, and level of service at the intersection (Maharani et al., 2019; Yulianto, 2018; Assolie et al., 2023).

The research location chosen for this study is at the intersection of Ir.H.Juanda - Brigjend Katamso road, S.M Raja – Halat road, Brigjend Katamso - Mesjid Raya road, and Brigjend Katamso - Pelangi road, Medan Maimun District, Medan City.

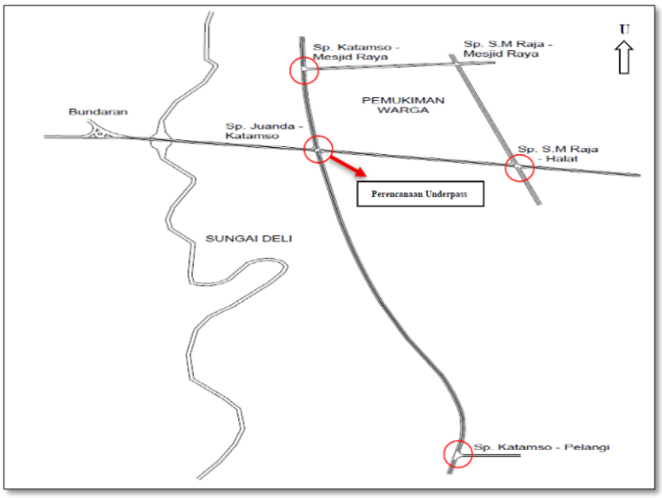

Figure 1. Study Location

From Figure 1, we can see that the underpass planning is located at the intersection of Ir.H.Juanda – Brigjend Katamso road, where the nearest intersections are to the north, namely the intersection of Brigjend Katamso – Mesjid Raya road with a distance of 332 meters, to the east, namely the intersection of S.M Raja – Halat road with a distance of 383 meters, and to the south, namely the intersection of Brigjend Katamso – Pelangi road with a distance of 1020 meters.

The Medan City Government plans to build a grade-separated intersection in the form of an underpass at the intersection of Ir.H.Juanda - Brigjend Katamso road (Aldi, 2023). So it is appropriate to analyze the traffic impact due to the construction of the underpass. The scope of this research does not consider the Juanda Monument roundabout located to the west of the Ir.H.Juanda – Brigjend Katamso road intersection. Vehicle growth is assumed to be 3% per year for a scenario of 5 years after the underpass becomes operational (Zubair et al., 2021; Vaccaro et al., 2024).

Methods

The data collection method used was a traffic survey conducted at the study intersection location, with reference to the survey (Hendrawan & Nurmeyliandari, 2017). According to the Federal Highway Administration in the Traffic Data Computation Method, travel can change over time due to the timing of the trip. The traffic survey in this study uses the development of 2 times factors as observation days, namely one weekday for the purpose of

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weekday travel represented by Monday, and one weekend day for the purpose of weekend travel represented by Saturday (U.S. Department of Transportation, 2008).

Data is obtained from traffic surveys such as vehicle volume surveys, road geometry, traffic signal cycle times, and vehicle speed. Next, the data obtained from the vissim software simulation results include queue length, delay, and intersection level of service (Park & Schneeberger, 2003).

This study use primary and secondary data. The primary data were from on-site traffic surveys, encompassing information such as road geometry, traffic volume, signal cycle time, types of vehicles, and vehicle speeds (Arliansyah & Bawono, 2018; Putra, 2020). The secondary data used in this study was underpass project planning data from the government office in Medan City.

This research was conducted through several stages of the process. The stages mentioned above can be seen in the flowchart below:

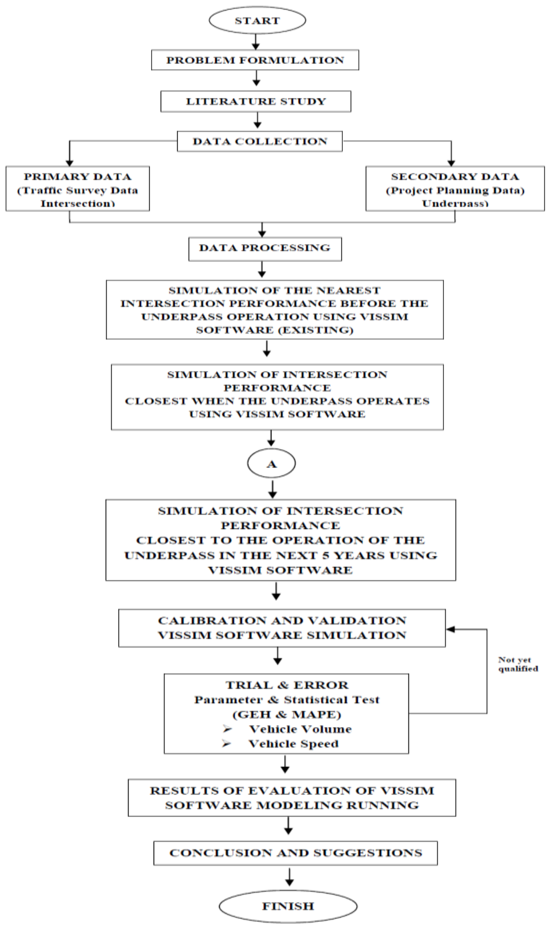

Figure 2. Research Flowchart

Figure 2 above explains the stages of the research process at the intersection of Ir.H.Juanda – Brigjend Katamso road.

Traffic data at the underpass intersection uses traffic survey data from the Brigjend Katamso - Ir. H. Juanda intersection during peak hours, with assumptions of movement changes due to the removal of right-turn access at the underpass. Some assumptions of intersection movement changes made include: (1) Right turns at the North approach intersection become straight

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movements because there is a U-Turn at the South approach intersection; (2) Right turns at the West approach intersection become left turns; (3) Right turns at the East approach intersection become left turns (Pemerintah Kota Medan, 2023).

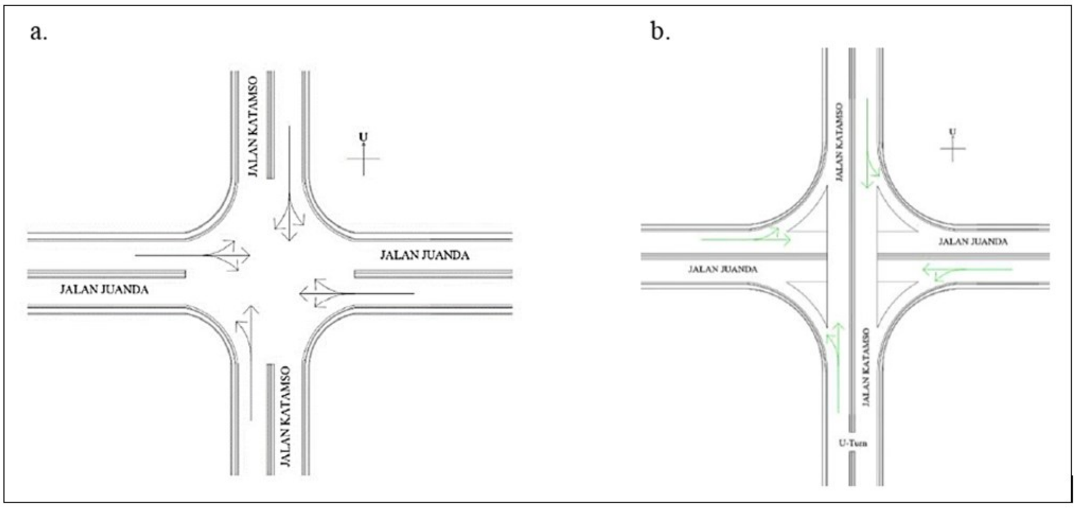

Figure 3.(a) Signalized Intersection (Do Nothing) ; (b) Underpass (Do Something)

Figure 3. above shows the assumed vehicle movements before and after the operation of the Ir.H.Juanda – Brigjend Katamso underpass.

Traffic simulation will be conducted using PTV vissim for three scenarios: (1) Do Nothing: Signalized Intersection (eksisting): in this scenario, PTV vissim will simulate traffic flow based on existing conditions, namely an intersection that use a signal-based traffic control system ; (2) Do Something: Non-intersecting intersection (underpass): in this scenario, PTV vissim will simulate conditions after the design change to a non-intersecting intersection and this model accounts for changes in vehicle speed, travel time, and traffic flow; (3) Do Something: Non-intersecting intersection scenario 5 years ahead (underpass): in this scenario PTV vissim will simulate the condition after the design change to a non-intersecting (underpass) and this model accounts for changes in vehicle speed, travel time, and traffic flow. Based on a projected vehicle growth rate of 3% per year (Rusmandani et al., 2019) the number of vehicles crossing this area is expected to increase significantly over the next 5 years.

After the traffic simulation is conducted, a traffic impact analysis will be performed for the Do Nothing and Do Something scenarios using the PTV vissim software. To analyze the impact of changing the Signalized intersection to a non-intersecting intersection on the nearest intersection, a comparison of simulation results using PTV vissim will be conducted for the three scenarios above (Umar et al., 2024).

Results and Discussion

After calibration and validation, it was concluded that the results of the vissim simulation modeling of existing conditions were acceptable. Next, traffic performance analysis was conducted using vissim software to obtain output data in the form of delay times, queue lengths, and service levels that describe the do nothing and do something conditions at an intersection from vissim data. The following is the existing condition output data from vissim as shown in Table 1.

Table 1 Traffic Distribution of Intersections (Do Nothing Scenario)

Intersection	**Do Nothing 2025**	**Do Something 2025**	**Do Something 2030**

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	Length of the queue (m)	Delay (sec/veh)	LOS	Length of the queue (m)	Delay (sec/veh)	LOS	Length of the queue (m)	Delay (sec/veh)	LOS
Juanda - Katamso	274.43	307.38	F	8.38	0.96	A	38.53	12.34	B
S.M Raja - Halat	148.45	178.24	F	214.76	244.68	F	312.44	342.27	F
Katamso - Mesjid Raya	132.19	159.09	F	175.81	200.86	F	237.81	262.91	F
Katamso - Pelangi	119.52	146.98	F	147.25	172.44	F	208.91	234.15	F

Based on the results of intersection performance calculations using vissim software and referring to Ministerial regulation 96 of 2015, it was found that before the underpass was operational, the intersection with an average level of service of F (very poor), and after the underpass was operational the intersection with an average level of service of A (excellent). This aligns with research[4] indicating that underpass shift conflict points to nearby intersections, namely the intersection of S. M Raja – Halat road, Brigjend Katamso – Mesjid Raya road, and Brigjend Katamso – Pelangi road.

Performance of Intersections under Existing Conditions

Traffic performance was assessed based on the current condition after calibration and validation of the VISSIM model based on the systematically observed field data. The approach to this step as a methodology provided the simulated traffic behaviour with the correct representation of the empirical conditions at the study site. Findings of Do-Nothing scenario in 2025 illustrate that traffic activities in the crossroad of Ir.H.Juanda and Brigjendkatamso are characterized with high traffic congestion. The average queuing length will be 274.43m and the average vehicle delay is 307.38s, the intersection will be at level of service F. According to such results, the demand of traffic is significantly higher than is possible, which leads to the appearance of queues and prolonged delays during rush hours.

The same features of performance are witnessed at the nearby signalized intersections of S.M Raja and Halat, Brigjend Katamso and Mesjid Raya, and Brigjend Katamso and Pelangi. Each of the three intersections has the level of service of F and a queue length of more than one hundred metres and a delay of more than one hundred seconds per vehicle. These observations imply that congestion is not an isolated problem of one intersection but is a systemwide problem of the local road network. The large traffic flows, coupled with the high occurrence of conflict points and signalised control are some of the factors that lead to inefficient traffic flow and poor intersection performance.

Impact of Underpass Operation on the Main Intersection

The underpass in the intersection of Ir. H. Juanda and Brigend Katamso provides a significant enhancement of the traffic performance on the Do-Something scenario of 2025. The results of simulation indicate that the mean queue length decreases to 8.38m and the average delay decreases to 0.96s/veh and the level of service would be upgraded to level of service A. This is an enhancement of the grade separation effectiveness in eliminating traffic conflicts and allowing vehicles to move continuously along the major traffic path. Removing the horizontal movement at the surface level, will decrease the reliance on signal control and will decrease the time of vehicle stopping. As a result, traffic movement is easier and more predictable especially to dominant movements. These findings indicate that the underpass is successful

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in managing the main congestion issue in the main intersection and greatly improves the efficiency of travels.

Performance of Adjacent Intersections after Underpass Operation

The situation at the intersection of the main intersection is made better by the underpass, but the performance of the adjacent intersections has an opposite pattern. After the operationalisation of the underpass, the intersection of S.M Raja and Halat has a mean length of queues of 214.76m and average delay of 244.68s per vehicle. The intersection is still on level of service F which means that there is still severe congestion. Similar growths in the length of queues and delay is also realized in intersections between Brigjend Katamso and Mesjid Raya, and Brigjend Katamso and Pelangi. The decline in performance at such places implies that traffic flows that were once constrained at the major intersection are reallocated to the neighboring intersections. The fact that these intersections were not modernized in either regards to geometry or signal timing leads to the increased congestion levels since the demand is compounded by more traffic. This result highlights the interdependence of intersections of an urban traffic network.

Long Term Traffic Performance under the Five Year Projection Scenario

The 2030 five-year projection scenario gives a clue on the sustainability of the underpass performance as the traffic demand goes up. When the growth rate of the vehicles in a year is assumed to be three percent, the cross-section of Ir. H. Juanda and Brigjend Katamso still does a satisfactorily good job. The average length of queues is 38.53 m and the average delay is 12.34 s/veh, which is at level of service B. These findings suggest that, despite the fact that traffic demand is increasing with time, the underpass has not failed to ensure that the operations of traffic are relatively stable at the main intersection. The adjacent crossings, though, are even worse in performance. The length of queues and delays become significantly large, and the level of service is F in all of the adjacent intersections. The tendency implies that the flow increases the existing capacity constraints at these sites. Without further traffic control precautions, congestion at these crossroads would tend to increase over time, and this may even influence the productivity of the entire road network.

The results of this research support the recent development of the literature on traffic-engineering that grade separation is among the most efficient interventions to alleviate extreme congestion at overloaded signalised crossroads. In the last five years, various studies utilizing the microsimulation methodology have demonstrated that underpasses can be significantly useful in enhancing the functioning of operation by removing at-grade conflict areas and minimizing the use of signal control. As described by Umar et al. (2024), the case of the Cibiru Roundabout is an example in which the installation of an underpass resulted in significant decreases in the delay and queue length of the prevalent traffic flows. Their article focuses on how continuous flow essentially changes the traffic conditions at the nodes of greatest concern, which is a trend that closely resembles the performance increment in the Ir. H. Juanda and Brigjend Katamso intersection of the current research.

In spite of these local advantages, the recent literature shows the growing significance of studying the network effects of grade-separated infrastructure in general. Studies by Maharani et al. (2019) and later by Rusmandani et al. (2019) prove that any improvements at one intersection will usually cause a redistribution of traffic to other nodes. These papers discuss that underpasses would be more inclined to accommodate greater amounts of traffic due to their provision of shorter travel periods, which may have the unfortunate effect of increasing congestion of adjacent intersections that have not received similar improvements. This point of view can be used in explaining why the intersections near the underpass in this research

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still remain at low service levels despite the fact that the central intersection in this research is enjoying a significant relief (Alam, 2025; Otto et al., 2023; Terron-Almenara et al., 2025).

The congestion transfer pattern has been widely discussed in the literature that dwells upon urban traffic networks but not on the intersections (Mohsen & Mohsen, 2025). As noted by Putra (2020), the development of underpasses often acts as a new source of discharge bottlenecks in the opposite direction where vehicles are discharged at an increased pace at the main node and more vehicles arrive at the signalised intersection. On the same note, Zubair et al. (2021) observed that underpass benefits are often spatially confined in the event that there is no coordination in the timing of EDs signals or geometrical enhancements. The findings are highly relatable to the current research, in which the shift in the demand of traffic has been seen to substantially increase the strain on adjacent intersections that were not initially intended to support any extra traffic (Samuel & Sharman, 2025; Adil, 2025).

The international research also contributes to the opinion that grade separation changes the traffic patterns in the complex and even unequal ways. Yulianto (2018) showed that route-choice behaviour can be altered by underpasses that prompt drivers to give preference to corridors that have fewer stops, which can redistribute congestion instead of eradicating it. This has been found to be similar in studies done in fast urbanising cities outside Indonesia, which observe that when underpass projects are undertaken, latent capacity constraints are usually found in other parts of the network. These insights can help to underline the importance of viewing underpass performance as a system of interdependence where any success or failure can produce a ripple effect somewhere else.

Another aspect that helps to address the benefits of a long-term view of underpass sustainability is the recent studies. As reported by Zubair et al. (2021), whereas grade-separated intersections were capable of sustaining acceptable performance within several years, the growing traffic slowly undermined these benefits until complementary actions became a part of them. This observation coincides with the medium-term forecast in the current paper, where the core intersection is still functioning well under higher demand, as compared to the intersecting ones which are becoming more and more unfavorable. These results imply that underpasses provide temporal strength at individual nodes, but not necessarily network-wide growth demands.

As a planning perspective, a number of writers posit that infrastructural solutions need to be incorporated in combined traffic-management systems (El-afifi & Sakr, 2023; Musa et al., 2023). According to Nasution (2017), it is important to note that the growth of physical capacity is not enough to address the problem of congestion in urban areas unless it is backed by operational measures, including signal coordination, access control, and demand control. A more recent study by Umar et al. (2024) is also concerned with the need to ensure that grade-separated efforts are aligned with a wider network-optimisation. In this respect, the conclusions of the current study may be understood as the indication of the fact that the underpass is a successful solution to a structural bottleneck, but it also indicates that the specific interventions should be provided at the crossroads nearby (Negi et al., 2024; Anwar et al., 2024; Medina et al., 2025).

The mode of study is also characteristic of the contemporary best practices in traffic-engineering studies (SAMAL et al., 2024; Hossain et al., 2024) The use of microsimulation models like VISSIM has been well known to capture the fine-grained interactions in the traffic where the models are calibrated and validated accordingly. Park and Schneeberger (2003) and then later works by Maharani et al. (2019) proved that microsimulation can give useful information on the effect of geometric and control modifications on traffic performance. The

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similarity in the results of the simulational experiment in this paper and trends described in the literature indicate the credibility of the modelling method and confirm its applicability to the assessment of the complex intersection interventions.

Instead of perceiving the occurrence of the secondary impacts as a weakness, recent scholarship proposes that the observed findings provide valuable insights that can be valuable in future planning. System-level performance Studies of the performance of systems argue that the need to identify new congestion points is an important step in the design of more balanced networks. The current research paper adds to this line of thought by showing how an underpass can significantly enhance the situation in one of the main intersections and at the same time create weaknesses in the neighboring nodes. This observation highlights the need to go beyond the single-solution approach and integrated approaches which target the network as a holistic entity.

Conclusion

It can be concluded that for the simulation data results at the intersection of Ir. H. Juanda – Brigjend Katamso road before the underpass was operational, the average queue length was 274.3 m and the average delay was 307.38 sec/veh, with an average intersection service level of F (very poor). The underpass reduced the average queue length to 8.38 m and the average delay was 0.96 sec/veh, with an average intersection service level of A (very good). The underpass significantly improved traffic flow, reducing average queue length to 38.53 m and delay to 12.34 seconds per vehicle, resulting in an average intersection service level of B (good) over a 5-year period, as evidenced by the queue length, delay, and service level, which have created new conflicts at the intersection nearest to the underpass.

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