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Article

Traffic Impact Analysis on the Road Network of Pantai Berkas Tourist Area, Bengkulu City, Due to Rising Traffic Volume

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Abstract. Ideally, the main access road to a tourist area should perform acceptably (degree of saturation, DS < 0.85) even during peak seasons. In reality, Pariwisata Road, the main access to Pantai Berkas, Bengkulu City, frequently becomes congested during Eid al-Fitr because of high volumes and side friction. Without management, traffic growth will worsen performance and threaten tourism access, making this analysis urgent. This study aims to evaluate road performance using PKJI 2023, simulate management solutions, and quantify network vulnerability. Survey data were processed with PKJI 2023 and PTV VISSIM microsimulation to evaluate two scenarios: one-way traffic to handle seasonal surges, and road widening for long-term needs under 15-year projections. Vulnerability was measured using the $INVE_F$ index. Validation yielded GEH < 5 and MAPE = 3.25%. Existing DS was 0.41 on Pariwisata Road and 0.30 on Ahmad Yani Road, but the 15-year projection raised Pariwisata DS to 0.82. The one-way scenario reduced DS to 0.29, while widening gave greater long-term benefit. Pariwisata Road remained vulnerable in both scenarios ($INVE_F$ = 0.44 and 0.09); Pari and Ahmad Yani Roads emained vulnerable under the widening scenario ($INVE_F$ = 0.01 and 0.07). One-way management suits short-term surges; widening suits long-term planning.

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1. Introduction

The rapid economic growth and urbanization in many parts of Indonesia, the demand for safe and reliable transportation has increased. Roads are essential for the movement of people, the transportation of goods, and for larger economic activities, as the number of vehicles increases every year [1-3]. Traffic congestion often occurs when traffic demand increases faster than road capacity, which affects the level of service of roads in many large and developing cities in Indonesia [4-5]

The performance of a road segment can be evaluated by several key indicators, such as road capacity, level of service (DS), free flow speed, and level of service [6-7]. DS is defined as the ratio of the traffic volume to the road capacity [8], therefore it is a key indicator for determining operational efficiency. A higher DS value indicates that the traffic flow is approaching the road capacity limit, and congestion is more likely to occur. Furthermore, the road capacity can be affected by additional obstructions, including on-street parking, pedestrian traffic, street vendors, and vehicles entering or exiting surrounding properties [9-10]

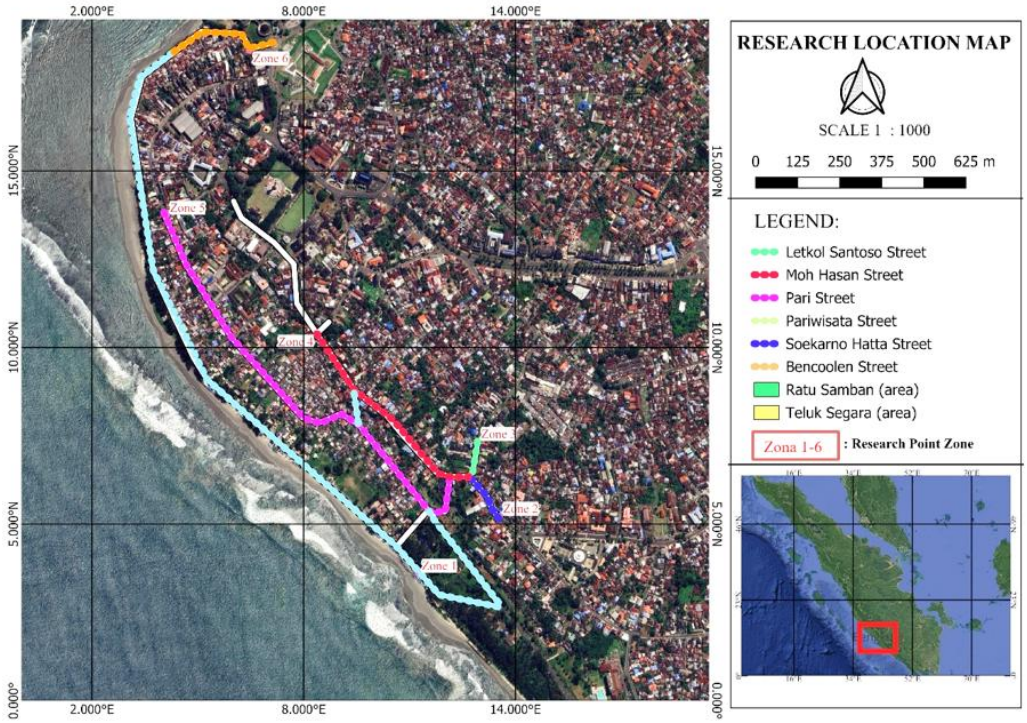


Figure 1. Research Location Map

As the capital of Bengkulu Province, the city of Bengkulu continues to develop, and according to DUKCAPIL data, it had a population of 407,843 in 2025, which is driving an increase in demand for private transportation. The coastal tourism route serves as a strategic corridor connecting the city's areas with major tourist destinations [11]. It faces side friction from sports activities, street vendors, and on-street parking, .Its volume surges toward the Pantai Berkas tourist area during Eid al-Fitr, a pattern of peak-period congestion also reported in other tourist cities [12]. The study location is shown in Figure 1.

Microsimulation has been widely used to test traffic management before implementation. In the Malioboro tourist area, a one-way system simulated in PTV VISSIM improved road performance, but the study used the outdated MKJI 1997 and examined a single scenario [13] .VISSIM has also been used to assess traffic impacts on a surrounding network [14-15], and its results are reliable only when calibrated and validated against field data [16-18]. Vulnerability analysis assesses the susceptibility of

a road network to variations in traffic volume and road capacity, which is quantified in this study using the Road Network Vulnerability Index (*INVEF).*Previous studies show that failure of a main road produces the largest network impact [19-21]. However, they generally focus on link failure rather than on traffic redistribution under tourism area management scenarios.

The shift from MKJI 1997 to PKJI 2023 is also technically significant. Although the passenger car equivalent (emp) values for two-lane undivided roads remain unchanged between the two guidelines [22], PKJI 2023 [8] revises the vehicle classification (MP, KS, SM) and updates the base capacity of urban roads, for example 2,800 PCU/h for two-lane two-way undivided roads versus 2,900 PCU/h in MKJI 1997. The novelty of this study is the combined use of PKJI 2023, PTV VISSIM scenario simulation, 15-year traffic growth projection, and the Road Network Vulnerability Index (*INVEF*) for a coastal tourist corridor. This study aims to: (1) evaluate existing and 15-year projected road performance using PKJI 2023; (2) simulate one-way and road-widening scenarios using PTV VISSIM; and (3) quantify network vulnerability using *INVEF*.

2. Method

2.1. Research Flowchart

The research was conducted in three stages Figure 2. The preparatory stage consisted of a literature review, problem identification, a preliminary site survey, and selection of the study segments.

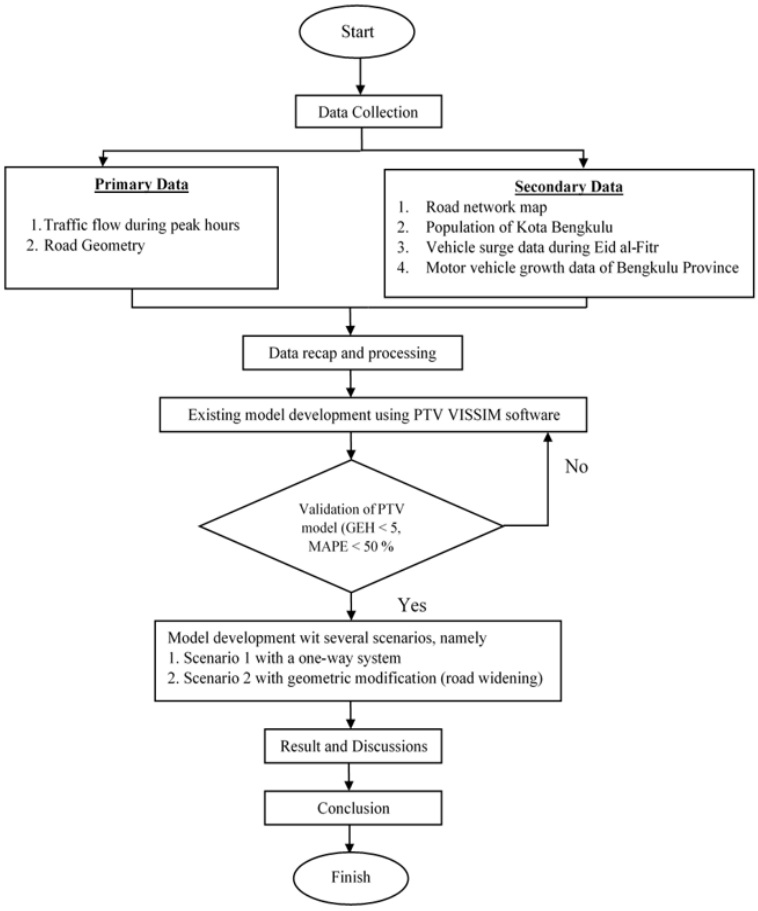


Figure 2. Research Flowchart

The implementation stage consisted of primary and secondary data collection, calculation of road performance based on PKJI 2023, traffic growth projection, development, calibration, and validation of the PTV VISSIM model, and simulation of the traffic management scenarios. The evaluation stage consisted of comparing DS values across scenarios, validating the model using GEH and MAPE, and calculating the road network vulnerability index (*INVEF*).

Primary data were collected by manual traffic counting using hand counters supported by video recording, classified into passenger cars (MP), medium vehicles (KS), and motorcycles (SM). Geometric data (lane width, shoulder, and median) were measured using a [measuring tape / roller meter], and side friction was recorded by direct observation. Secondary data consisted of road inventory [23] and status road classification [24] , population data, and vehicle growth data. Volumes were converted to PCU/hour using PKJI 2023 emp values, and road performance was interpreted using the DS thresholds in Section 2.3.3. Vulnerability was interpreted using the *INVEF* classification in Table 2.

2.2. Research Location

The study was conducted on Pariwisata Road in the Pantai Berkas area of Bengkulu City, covering Pasar Berkas and Teluk Segara. The area experiences high traffic volumes, and one-way traffic arrangements are periodically implemented by the Bengkulu City Police during Eid al-Fitr, New Year's Day, and the Tabot Festival to reduce congestion. The study location is presented in Figure 1. Field surveys were conducted over 12 days between March 5 and April 18, 2026, covering weekdays and weekends. Six road segments were analyzed, with their characteristics presented in Table 1 based on [23].

According to [24], Pariwisata Road and Ahmad Yani Road are classified as Collector 1 (JKP-1), Soekarno Hatta Road as Collector 3 (JKS), and Letkol Santoso, Moh. Hasan, and Pari Roads as Local Roads (JLP). Pariwisata Road and Ahmad Yani Road are classified as Collector Road Class 1 (JKP-1), Soekarno Hatta Road as Collector Road Class 3 (JKS), and Letkol Santoso, Moh. Hasan, and Pari Roads as Local Roads (JLP). Pariwisata Road, classified as JKP-1, functions as the main access road to Pantai Berkas and represents the primary focus of this research.

Table 1. Road Segment Characteristics

Section Number	Road Name	Road Type	Width (m)	Length (km)	Shoulder	Side Friction	Road Class	Function	Road Status
0054	Pariwisata	2/2 UD	7	8.715	Paved	High	Collector 1	JKP	City road
0526	Soekarno Hatta 1	2/2 UD	8	0.125	Curb	Low	Collector 3	JKS	City road
0014	Letkol Santoso	2/2 UD	4	0.725	Paved	Very low	Local 3	JLP	City road
0015	Moh.Hasan 3	2/2 UD	9	0.115	Curb	Low	Local 1	JLP	City road
0018	Pari	2/2 UD	4	0.450	Paved	Very low	Local 3	JLP	City road
0001	Ahmad Yani	2/2 UD	7	1000	Paved	High	Collector 1	JAS	City road

2.3 Analysis Data

The analysis in this study is based on [8], which covers traffic volume , road capacity, and the degree of saturation.

2.3.1 Road traffic Volume

Traffic Volume: This refers to the number of vehicles that pass through a given road segment over a defined time interval. It is calculated by converting the units from the field survey results (vehicles/hour) to (PCU/hour), using different conversion factors for each vehicle type, as shown in the following formula.

$$Q = [(emp_{MP} \times MP) + (emp_{KS} \times KB) + (emp_{SM} \times SM)] \quad (1)$$

Where:
Q = total traffic flow or vehicle volume (PCU/hour)
Emp = passenger car equivalents
MP = passenger cars
KB = medium sized vehicles
SM = motorcycles

2.3.2 Road Segment Capacity

Road Segment Capacity: refers to the maximum traffic volume that can be accommodated under specific roadway conditions and is determined using the following equation.

$$C = C_o \times FC_{IJ} \times FC_{PA} \times FC_{HS} \times FC_{UK} \quad (2)$$

Where:
C = road capacity (PCU/hour)
C_o = base capacity (PCU/hour)
FC_{IJ} = capacity adjustment factor related to lane width or traffic lanes
FC_{PA} = capacity adjustment factor related to directional separation
FC_{HS} = capacity adjustment factor related to lateral obstructions
FC_{UK} = capacity adjustment factor related to city size

2.3.3 Degree of Saturation

Degree of Saturation: The degree of saturation (DS) is the ratio of the traffic volume on a road segment to its available capacity. Based on the degree of saturation value, road service levels are classified into six levels, namely Levels A through F. Level A (DS ≤ 0.20) indicates normal traffic flow conditions with low volume and high speed. Level B (0.21 ≤ DS < 0.44) indicates that traffic flow is still normal, but speeds are beginning to be restricted. Level C (0.45 ≤ DS < 0.74) indicates that traffic flow is still stable, but vehicle speeds and movement are beginning to be restricted. Level D (0.75 ≤ DS < 0.84) indicates that traffic is approaching unstable conditions but remains manageable. Level E (0.85 ≤ DS < 1,00) indicates that traffic is approaching road capacity and has become unstable. Meanwhile, Level F (DS > 1.00) indicates congested traffic conditions with significant delays [25].

$$DS = \frac{Q}{C} \quad (3)$$

Where:
DS = degree of saturation
Q = total traffic flow (PCU/hour)
C = capacity (PCU/hour)

2.4 Microscopic Traffic Simulation Model

Figure 3 shows the PTV Vissim network, which comprises links, connectors, intersection priority rules, and six origin destination zones covering the study area. A Google Maps image was imported as the background reference for building the model. Input parameters, namely vehicle types, free-flow speed, origin destination routes, and traffic volume and composition, were taken from the survey [26]. Two simulation runs with different random seeds were averaged to obtain traffic volume and speed [27].

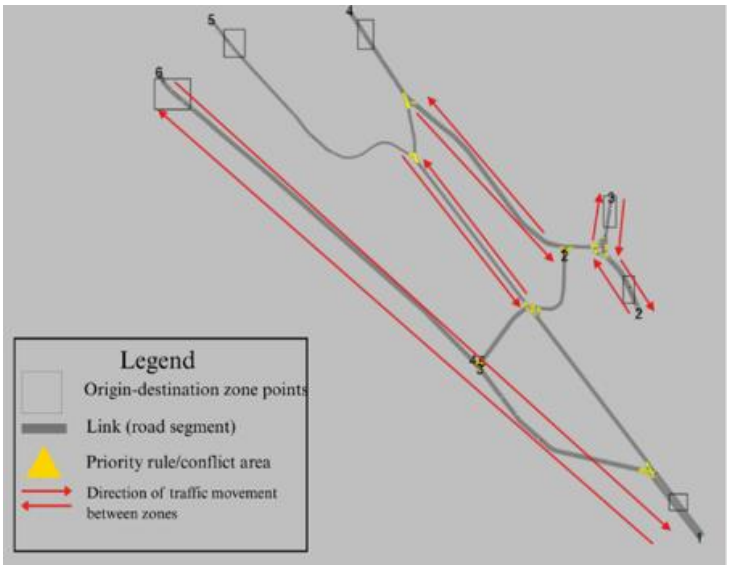


Figure 3. Model Road Network

The model was calibrated in two trials: the Vissim default parameters (Trial 1) and the parameter set adapted from an Indonesian urban road study [20] (Trial 2), as shown in Table 2. The desired speed was set to 40 km/h for passenger cars (MP), 45 km/h for medium vehicles (KS), and 50 km/h for motorcycles (SM). The calibrated model was then validated as described in Section 2.5 and used to evaluate the traffic management scenarios, including projected traffic growth [28], using travel time, delay, and queue length as performance indicators [29].

Table 2. Driving behavior parameters used in the PTV Vissim calibration [30]

No	Parameter	Trial 1 (default)	Trial (calibrated)
1	Look-ahead distance ([m])	0–250	0-200
2	Look-back distance ([m])	0–150	0-100
3	Additive part of safety distance	2	1.5
4	Multiplicative part of safety distance	3	2.5
5	Safety distance reduction factor	0.6	0.5
6	Overtake on same lane (left and right)	Off	On
7	Standing distance at 0 km/h (m)	0.2	0.1
8	Driving distance at 50 km/h (m)	1	0.5
9	Lane change rule	Slow lane rule	Free
10	Desired position at free flow	Middle of lane	Any

2.5 Model Validation

The VISSIM model validation was performed by comparing actual traffic data collected in the field with the results generated by the simulation [31-32]. The VISSIM model was validated using the Geoffrey E. Havers (GEH) test and Mean Absolute Percentage Error (MAPE) to assess differences between observed and simulated traffic volume and speed. The model was considered acceptable when the GEH value was less than 5. That formulated as follows.

$$GEH = \sqrt{\frac{(q_{simulated} - Q_{observed})^2}{0{,}5 \times (q_{simulated} + Q_{observed})}} \quad (4)$$

Where:

$q_{simulated}$ = simulated traffic volume data (vehicles/hour)
$Q_{Observed}$ = existing traffic volume data (vehicles/hour)

The model's accuracy was further assessed using MAPE to determine the average absolute percentage deviation between simulation results and field observations [33]. A smaller MAPE value indicates a greater capability of the model to replicate real world conditions, as this value indicates the magnitude of the deviation of the simulation results from the actual data, The threshold is a maximum MAPE of 50% [27]. It is calculated with the formula below.

$$MAPE = \frac{1}{n} \sum_{t=1}^{n} \left| \frac{A_t - F_t}{A_t} \right| \times 100\% \quad (5)$$

Where:

N = number of data points
A_t = field data
F_t = simulation model data

2.6 Road Vulnerability Index

Vulnerability describes how well a road network can withstand or adapt to disruptions in traffic condition [20]. A road network is considered vulnerable when changes in traffic volume or capacity cause a significant decline in the performance of its segments, such as higher saturation levels, longer delays, and lower levels of service. In this context, vulnerability analysis helps identify critical segments that require priority attention in traffic management planning [19].

A vulnerability analysis was conducted in the Pantai Berkas area by modeling the road network under existing conditions and a one-way system. The vulnerability assessment of the Pantai Berkas area involved simulating the road network under existing conditions and a one-way traffic scheme. A vulnerability index was calculated from variations in traffic volume across all road segments, which was then used to compare the road network's performance between the two conditions. A positive index value indicates that a segment is vulnerable because it is highly sensitive to changes in traffic conditions, while a negative value indicates the opposite [21]. Road segments are classified by vulnerability index value in Table 3, and the index is calculated with the following equation.

$$INVE_F = \frac{\left(\sum_{a=1}^{[A]} X_a^E\right) - \left(\sum_{a=1}^{[A]} X_a^D\right)}{\sum_{a=1}^{[A]} X_a^D} \quad (6)$$

Where:

$INVE_f$ = Index of road network vulnerability due to traffic flow
X_a^E = Traffic flow (PCU/hour) on link *a* on a normal day
X_a^D = Traffic flow (PCU/hour) on link *a* on the modeling day

Table 3. Classification of roads based on vulnerability [20]

VCR Value	Vulnerability Index	Color of Road Segment	Remark
0-0.85	Negative value	Green	Free flowing
0-0.85	Positive value	Yellow	Busy but flowing
> 0.85	Positive value	Red	Congested

3. Results and Discussion

3.1 Traffic flow survey results

The survey was conducted over 12 days (six weekdays and six weekends) from March 5 to April 18, 2026, in three two-hour time intervals per day: morning (06:30–08:30), noon (12:00–14:00) and afternoon (16:00–18:00 WIB). This division of days and hours follows a previous 2023 PKJI study, which showed that traffic performance varies by day and time [34-36]. Vehicles (SM, MP, KS) were manually counted using handheld counters at fixed points, supported by video recordings, at 15-minute intervals, and converted to SMP/hour using the 2023 PKJI conversion factors. The highest one-hour volume in each section was determined as its volume during the peak hour (Table 4), as in [35]. Table 4 forms the basis for calculating the existing DS (vehicles per hour).

Tables 5-6 and Figure 4 use the vehicles per hour unit in the VISSIM model, with existing volumes [volumes collected in the same peak hour / adjusted for the Eid al-Fitr factor] and projections based on a 4 percent annual increase (BPS, 2020–2024). Since the survey did not cover the Eid al-Fitr period, the traffic increase for this period is represented by an additional 16.90 %, based on data from the Transport Command Center for Eid al-Fitr 2026.

Table 4. Peak-Hour Traffic Volume Data

Road Name	Day Type	Time	Traffic Volume (PCU/hour)
Pariwisata	Weekend	Afternoon	934.3
Soekarno Hatta	Weekday	Morning	477.6
Letkol Santoso	Weekend	Midday	279.1
Moh.Hasan	Weekday	Morning	292.1
Pari	Weekday	Midday	266.7
Ahmad Yani	Weekend	Afternoon	633.5

3.2 Comparison of Observed and Simulated Traffic Volumes

In Figure 4, traffic volume increases from the current condition to the 15-year projection scenario as a result of the accumulation of annual traffic growth. In the road widening scenario, the width of the Tourism Road is increased from 7 m to 9 m, while the input volume remains the same as in the 15-year projection scenario. Therefore, the simulation results remain close to the projected volumes (for example, 2,819 versus 2,647 vehicles/hour on Pariwisata Road; 1,872 versus 1,795 vehicles/hour on Ahmad Yani Road), with the difference due to stochastic variation in the simulation (GEH < 5). Road Pariwisata and Road Ahmad Yani ecorded the highest traffic volumes as primary tourism access routes, while other roads showed more moderate increases due to their secondary access functions.

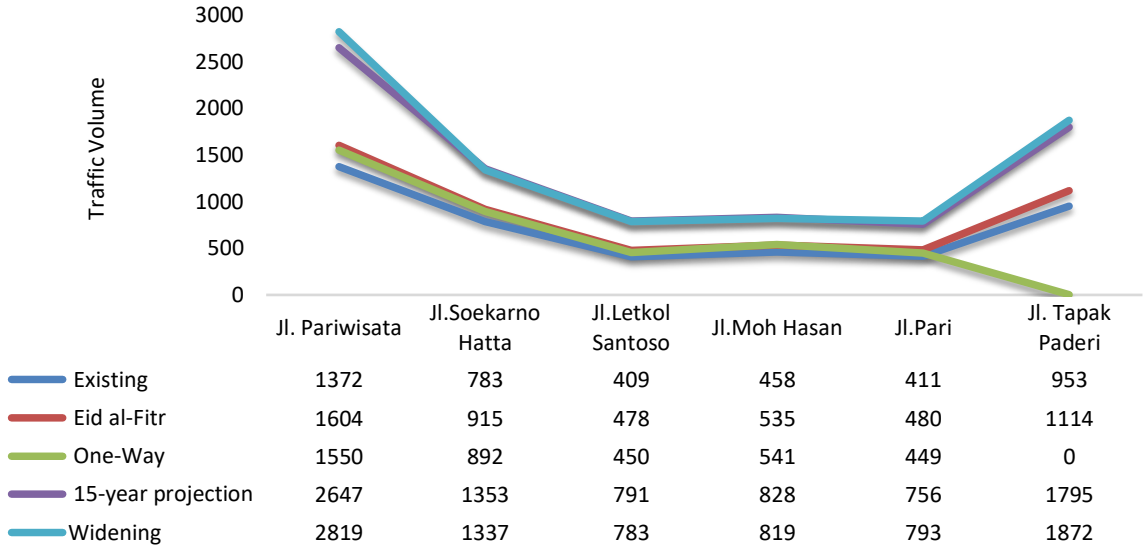


Figure 4. Graph Comparing Traffic Volume

Induced demand that is [37-38], the increase in trips resulting from expanded road capacity can stem from changes in land use [39] or an increase in the frequency of individual trips [40] and in heavily congested corridors, interventions at the lane level alone are insufficient to alter traffic conditions [41]. This increase in traffic was not modeled in this study and is discussed in the section on research limitations.

3.3 Traffic Volume Validation: Simulation vs. Survey Results

The GEH statistic was calculated using the formula in Section 2.5 and formulated 4, with a value below 5 considered acceptable [42]. Volumes were compared for the [peak hour, e.g., 07:00-08:00] period, using [15-minute] counts aggregated to hourly flow, as total volume in [veh/hr or PCU/hr]. Simulation values are the average of two simulation run [43].The results of the VISSIM model validation for the one-way system scenario in Table 5 show that all road segments have GEH values below < 5 [44], with the highest value on Jl. Pari (1.4) and the lowest on Jl. Moh. Hasan (0.25); thus, all segments are classified as "Acceptable" and the model is considered valid. Jl. Ahmad Yani was excluded from the GEH test because, under the one-way system, it forms a single corridor with Jl. Pariwisata, so no separate simulated volume exists for comparison.

Table 5. GEH Validation Results for Scenario 1

Road Name	Existing (Veh/hr)	Simulation 1 One-Way (Veh/hr)	GEH	Status
Pariwisata	1604	1550	1.35	Accepted
Soekarno Hatta 1	915	892	0.76	Accepted
Let Santoso	478	450	1.3	Accepted
Moh.Hasan 3	535	541	0.25	Accepted
Pari	480	449	1.4	Accepted
Ahmad Yani	1114	-	-	N/A

The VISSIM validation results for the road-widening scenario in Table 6 indicate that all GEH values are below 5. The highest value was found on Jl. Pariwisata (3.29), while the lowest was recorded on Jl. Letkol Santoso (0.28). These results confirm that the model is acceptable for simulating projected traffic volumes under the road-widening scenario.

Table 6. GEH Validation Results for Scenario 2

Road Name	Projection (Veh/hr)	Simulation 2 Widening (Veh/hr)	GEH	Status
Pariwisata	2647	2819	3.29	Accepted
Soekarno Hatta 1	1353	1337	0.43	Accepted
Let Santoso	791	783	0.28	Accepted
Moh.Hasan 3	828	819	0.31	Accepted
Pari	756	793	1.33	Accepted
Ahmad Yani	1795	1872	1.79	Accepted

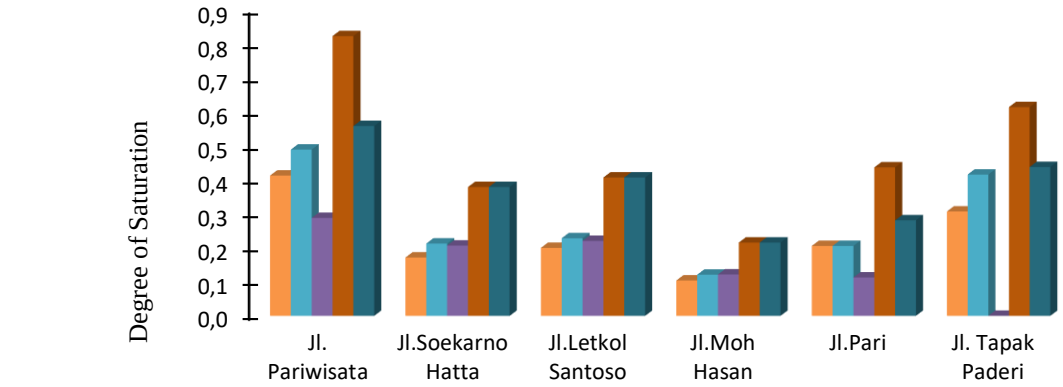
3.4 Road Network Performance Analysis Results

The evaluation of the pathways' performance is the degree of separation (DS) for each pathway, which is used to compare individual tasks. Good performance (DS < 0.85; A–D reference range) and poor performance (DS > 0.85; E–F reference range) using the indicators. This threshold is consistent with studies in other Indonesian regions that have applied the PKJI 2023, where a DS > 0.85 is considered the acceptable performance threshold [45-46]. Prior to the DS calculation, the current capacity of each road segment in one-way and expanded views was determined, as shown in Table 7.

Table 7. Comparison of Road Segment Capacities

Road Name	Capacity Existing (SMP/Hour)	Capacity Simulation 1 One-Way (SMP/Hour)	Capacity Simulation 2 Widening (SMP/Hour)
Pariwisata	2268	3029.4	3055.5
Soekarno Hatta 1	2786.6	2786.6	2786.6
Letkol Santoso	1397.1	1397.1	1397.1
Moh.Hasan 3	2811.1	2811.1	2881.1
Pari	1298.3	2646.3	2017
Ahmad Yani	2066.4	1713.6	2585.5

The capacity of the Pariwasta road increased from 2,268 vehicles per hour to 3,029.4 vehicles per hour (one way) and 3,055.5 vehicles per hour (with the expansion) was achieved, which aligns with previous studies based on VISSIM and PKJI, where geometric improvements increased capacity and reduced DS [47-48]. Road Sukarno–Hatta and Letkol Santoso routes remained unchanged because they were not included in any scenario, while Moh. The capacity of the Hasan route increased only slightly with expansion. These capacities serve as the basis for calculating the DS, and the DS comparison for all scenarios is shown in Figure 5.



	Jl. Pariwisata	Jl.Soekarno Hatta	Jl.Letkol Santoso	Jl.Moh Hasan	Jl.Pari	Jl. Tapak Paderi
DS Existing	0,41	0,17	0,20	0,10	0,21	0,31
DS Eid al-Fitr	0,49	0,21	0,23	0,12	0,21	0,41
DS One-Way	0,29	0,21	0,22	0,12	0,11	0,00
DS 15-year projection	0,82	0,38	0,41	0,22	0,44	0,61
DS Widening	0,56	0,38	0,41	0,22	0,28	0,44

Figure 5. Graph Comparing Saturation Degree Values

Today's traffic volumes, when examined with the 2023 PKJI, indicate that both road segments are still functioning well, with DS values of 0.41 (Pariwisata Road) and 0.30 (Ahmad Yani Road), which means the road's capacity is still sufficient. Similar low DS values under current conditions have been reported in other segments examined with the PKJI 2023, for example 0.38 on Bacharuddin Jusuf Habibie Road [46] and 0.29-0.35 on Maguwo Road [49]. However, since both road sections are tourist areas, they have the potential to experience an increase in traffic volume during peak tourist seasons, which leads to the two scenarios proposed below.

Scenario 1. Based on data from the Transportation Command Center for Eid al-Fitr 2026, traffic volume during the post-Eid peak (H+2) increased by 16.90%, which was applied as a factor for the volume increase for each road section. The PTV VISSIM one-way simulation, re-analyzed with PKJI 2023, reduces the DS to 0.29 (Figure 6), which is consistent with the Gilingan, Surakarta study [50] .However, a one-way conversion can shift traffic to parallel routes, as shown in Opatija [51] .The solution is therefore only effective in the short term [52], and long-term projections require an analysis of traffic growth and geometric changes.

Scenario 2: The number of motorcycles in Bengkulu was projected based on its annual growth of 4% over a 15-year period (BPS, 2020 –2024), as shown in Figure 7, and was also validated with the PKJI 2023. The same long-term projections were also used in other Indonesian studies [49],[53]. The road widening simulation was modeled in PTV VISSIM by modifying the road geometry and working with the calculated large volumes. The travel time experiments were validated with a MAPE of 3.25%, thus demonstrating the high accuracy of the model, in accordance with VISSIM's validation procedure [54-55]. These results align with the impact-handling recommendations in [45], particularly regarding capacity improvement through the validated widening scenario. Figure 5 shows DS rising on all segments through Year 15, sharpest on Pariwisata Road (0.41 to 0.82), approaching the 0.85 threshold, while the other segments remain good, led by Ahmad Yani Road (0.61) and Soekarno Hatta Road (0.38). A similar trend was reported on Tukad Pakerisan Road, Denpasar, where the five-year projection exceeded the PKJI 2023 limit [45] and at the Banyurejo toll exit, where DS rose from 0.49 to 0.71 by the 20th year [46].



Figure 6. Visualization of a one-way system simulation in PTV VISSIM

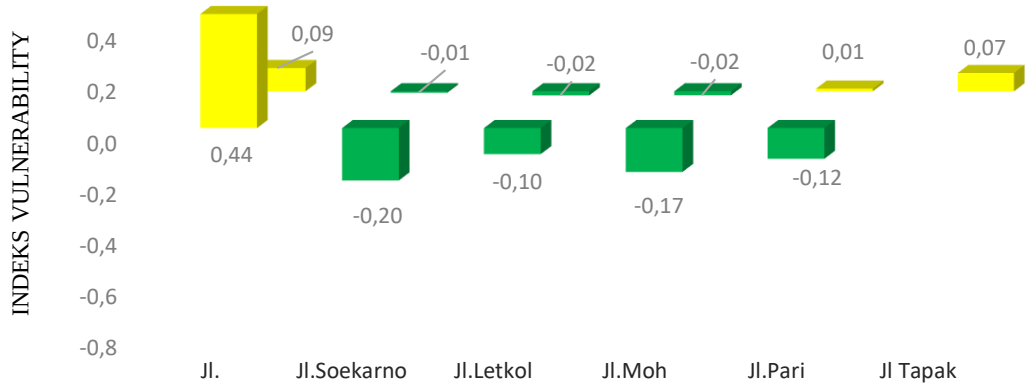
Although widening is proposed as a long-term solution, this study evaluates it only through DS. Its overall benefit must also be weighed against land acquisition costs, impacts on the tourism area, parking, pedestrian safety, and induced demand, and widening alone may be outperformed by measures such as grade separation in the long term [56]. Moreover, DS does not fully represent service quality: delay, queue length, and travel time were not analyzed as performance measures (travel time was used only for validation, MAPE = 3.25%), whereas other VISSIM-based studies include them [53]. These limitations should be addressed in a follow-up feasibility study.

Table 8. Traffic Condition Projections for Road Sections

Road Name	Existing		Projection					
	2026		5 Years		10 Years		15 Years	
	AADT	DS	AADT	DS	AADT	DS	AADT	DS
Pariwisata	1046	0.41	1268	0.56	1537	0.68	1863	0.82
Soekarno Hatta	592	0.17	717	0.26	869	0.31	1054	0.38
Letkol Santoso	318	0.20	386	0.28	468	0.34	567	0.41
Moh Hasan	339	0.10	339	0.12	499	0.18	605	0.22
Pari	317	0.21	385	0.30	466	0.36	565	0.44
Ahmad Yani	711	0.30	862	0.42	1045	0.51	1266	0.61

3.5 Vulnerability Index Results

Figure 7 presents the Road Network Vulnerability Index (*INVEF*) for each segment under both scenarios. *INVEF* and DS answer different questions. DS (VCR) is the ratio of volume to capacity and shows how close a segment is to saturation, whereas *INVEF* is calculated from the change in VCR between the normal day and the modeled scenario (Equation 6) and shows how sensitive a segment is to changes in traffic. A segment with low DS can still play a strategic role, and a segment with high DS does not necessarily have the highest *INVEF*.



	Jl. Pariwisata	Jl.Soekarno Hatta	Jl.Letkol Santoso	Jl.Moh Hasan	Jl.Pari	Jl Tapak Paderi
Scenario 1 One-Way	0,44	-0,20	-0,10	-0,17	-0,12	
Scenario 2 Widening	0,09	-0,01	-0,02	-0,02	0,01	0,07

Figure 7. Index Vulnerability Graph

In Scenario 1 (one-way), Pariwisata Road has a positive *INVEF*. of 0.44 even though its DS is only 0.29, because it becomes the sole access to Pantai Berkas and carries traffic previously spread over several segments. Based on Table 3, it is classified as yellow (busy but flowing) and vulnerable. Soekarno Hatta (−0.20), Letkol Santoso (−0.10), Moh. Hasan (−0.17), and Pari (−0.12) Roads have negative *INVEF* and are classified as green, because they act as detour routes with spare capacity. In Scenario 2 (widening), Pariwisata (0.09), Ahmad Yani (0.07), and Pari (0.01) Roads remain vulnerable, as added capacity attracts more traffic to these access routes, while Soekarno Hatta (−0.01), Letkol Santoso (−0.02), and Moh. Hasan (−0.02) Roads are not vulnerable.

Pariwisata Road runs along the Pantai Berkas coastline, so it is both the access route and the tourist corridor. A disruption, such as an accident, flooding, or closure during an event, would cut access to the beach area behind the blockage. Alternative routes can only redirect traffic toward other entry points. Based on existing volumes and capacities, Soekarno Hatta, Moh. Hasan, Letkol Santoso, and Pari Roads retain spare capacity of about 2,309, 2,519, 1,118, and 1,032 PCU/hour, so diverted traffic (934.3 PCU/hour) could be absorbed under normal conditions. During Eid al-Fitr, however, the volume rises to about 1,092 PCU/hour (+16.90%), exceeding the spare capacity of Letkol Santoso and Pari Roads, which are only 4 m wide and would saturate first. A disruption scenario was not simulated, so these consequences are inferred from capacity and volume. Signage, police-managed

diversion, and capacity improvement on these two routes should be prioritized.

Our results agree with link-failure studies [20], [56-57]. which find that failure of a main road has the largest network impact; here Pariwisata Road has the highest *INVEF*.in both scenarios. They differ in the source of vulnerability: link loss in those studies, traffic redistribution under management scenarios here [19],[21] applied *INVEF*. To evacuation conditions, whereas this study applies it to planned interventions, which may explain any discrepancy add the finding of on geometric changes. The one-way study in Malioboro [13] also reported improved performance, but *INVEF* shows that the improvement here comes with higher dependence on a single corridor. In the widening scenario, the remaining vulnerability is consistent with evidence that added road capacity attracts additional traffic [58].

The contribution of this study is combining PKJI 2023 (capacity and DS for Indonesian conditions), PTV Vissim (traffic redistribution under scenarios), and *INVEF*. (segment sensitivity). Together they show that DS alone would rate the one-way scenario as favorable, whereas *INVEF*. reveals its vulnerability. In the authors' view, one-way operation suits only temporary surges with prepared diversion routes, and the whole corridor should be planned together.

4. Conclusion

This study evaluated the Pantai Berkas road network using PKJI 2023, PTV Vissim, and the vulnerability index (*INVEF*). The model was valid (GEH < 5, MAPE = 3.25%). Currently, Pariwisata Road (DS = 0.41) and Ahmad Yani Road (DS = 0.30) perform well, but without intervention DS on Pariwisata Road reaches 0.82 by Year 15, close to the 0.85 threshold. The one-way scenario lowers DS to 0.29 during the Eid al-Fitr surge, yet raises vulnerability (*INVEF* = 0.44) because all access traffic is concentrated on one corridor, so it suits only short-term use.

Widening gives better long-term performance (DS = [DS with widening] in Year 15), but Pariwisata (*INVEF* = 0.09), Ahmad Yani (0.07), and Pari (0.01) Roads remain vulnerable. DS alone would rate the one-way scenario as favorable, whereas *INVEF* reveals its weakness. Hese findings guide the Bengkulu City Government in handling peak events and planning the Pantai Berkas corridor as a whole. Future studies should add delay and queue length indicators, explicit induced demand modeling, and economic and environmental impact analysis.

References

[1] Fisu, A. A., Syabri, I., & Andani, I. G. A. (2024). Urban dynamics and Gen-Z mobility: The influence of land use diversity and density on daily trip patterns in Indonesia. *Sustainable Futures*, *8*, 100388.

[2] Zulkarnain, Y. P., & Asmawi, B. (2022, November). Mikro Simulasi Kinerja Ruas Jalan (Studi Kasus Jalan RE. Martadinata Palembang). In *Forum Mekanika* (Vol. 11, No. 2, pp. 66-76)..

[3] Kristiadi, Y., & Herdiansyah, H. (2024). The impact of economic growth on urbanization, transmigration, employment opportunities, and urban population in the context of middle-income trap (a case study of Padang, West Sumatra). *Sustainable Urban Development and Environmental Impact Journal*, *1*(2), 53-70.

[4] Hussain, D., Jamal, A., Farooq, A., Almoshaogeh, M., Alharbi, F., & Farooq, D. (2026). Evaluation of traffic congestion mitigation techniques using an entropy-TOPSIS integrated method. *Scientific Reports*, *16*(1), 5036.

[5] Zalukhu, M. H., Giawa, J. F. K., & Halawa, I. H. (2026). The Effect Of Traffic Volume On Traffic Congestion Levels Along National Roads In Nias Regency, Indonesia. *Innovative Research in Civil and Environmental Engineering*, *3*(1), 46-55.

[6] Dangal, N. R., Wangmo, D., Meena, S., & Kumar, S. (2023). Study of traffic flow for estimation of level of service. *International Journal for Research Trends and Innovation*, 8(4), 1348

- 1353.
[7] Sembada, A., Candra, B. Y. Y., Ginting, R. R., Heryadiana, A. D., & Isradi, M. (2025). The Relationship Between Road Capacity and Road Level of Service: A Systematic Review of Recent Studies. *RIGGS: Journal of Artificial Intelligence and Digital Business*, *4*(2), 5193–5206.
[8] PKJI 2023, *Direktoral Jenderal Bina Marga*, no. 021. Jakarta: Direktorat Jenderal Bina Marga , Kementrian PUPR, 2023.
[9] Al-yasee, A. H. H., Leong, L. V., & Al-Jameel, H. A. (2025). Comprehensive assessment of side friction impacts on urban traffic flow: A case study of Hilla City, Iraq. *Open Engineering*, *15*(1), 20240093
[10] Othayoth, D., & Rao, K. K. (2020). Investigating the relation between level of service and volume-to-capacity ratio at signalized intersections under heterogeneous traffic condition. *Transportation Research Procedia*, *48*, 2929-2944.
[11] Naufal, J., & Santoso, R. P. (2023). Analisis pengembangan potensi sektor pariwisata Pantai Panjang di Kota Bengkulu. *Jurnal Kebijakan Ekonomi dan Keuangan*, 194-204.
[12] Cui, R., & Zhang, J. (2025). Exploring the Relationship Between the Built Environment and Spatiotemporal Heterogeneity of Urban Traffic Congestion During Tourism Peaks: A Case Study of Harbin, China. *ISPRS International Journal of Geo-Information*, *14*(12), 470.
[13] Kennyzyra, M., Fauziah, M., & Jannah, A. N. (2024). Kinerja Ruas Jalan Bhayangkara Setelah Penerapan Sistem Satu Arah di Kawasan Malioboro Kota Yogyakarta. *Jurnal Penelitian Rumpun Ilmu Teknik*, *3*(4), 49-58.
[14] Al Akib, Y., Zhafirah, A., & Lawalata, G. M. (2025). Evaluasi derajat kejenuhan jalan menggunakan PKJI dan VISSIM. *Jurnal Konstruksi*, *23*(2), 417-427.
[15] Saputri, F. A. A., Patriadi, A., & Tjendani, H. T. (2025). VISSIM Modeling and Simulation to Optimize the Performance of the Blimbing Ngoro Three-Way Intersection in Jombang Regency. *International Journal On Advanced Technology, Engineering, And Information SYSTEM*, *4*(2), 315–328.
[16] Hafram, S. M. (2023). Calibrating and validation microscopic traffic simulation models VISSIM for enhanced highway capacity planning. *International Journal of Engineering*, *36*(8), 1509-1519.
[17] Al Karimi, M. B. U., Haryadi, B., Setiadji, B. H., & Mahfuda, A. (2025). PTV Vissim Calibration and Validation of Median Opening U-Turn. *Rekayasa Sipil*, *19*(2), 257-265.
[18] Abdeen, M. A., Farrag, S., Benaida, M., Sheltami, T., & El-Hansali, Y. (2023). VISSIM calibration and validation of urban traffic: a case study Al-Madinah City. *Personal and Ubiquitous Computing*, *27*(5), 1747-1756.
[19] Muthohar, I., Balijepalli, C., & Priyanto, S. (2020). Analysing vulnerability of road network and guiding evacuees to sheltered areas: Case study of Mt Merapi, Central Java, Indonesia. *Case studies on transport policy*, *8*(4), 1329-1340.
[20] Mase, L. Z., Fauzi, Y., Edriani, A. F., Anugrah, D. S., & Shelina, A. (2023). Evaluation of The Road Vulnerability Network During the Evacuation Process (A Case Study in A Coastal Area of Bengkulu City, Indonesia). *Engineering Journal*, *27*(10), 81-91.
[21] Hardiansyah, H., & Hadiguna, R. A. (2023). Analisis kerentanan jaringan jalan karena putusnya ruas Jalan Mayjen Sutoyo Tanah Patah Kota Bengkulu akibat dampak bencana likuifaksi. *Inersia: Jurnal Teknik Sipil*, *15*(1), 40-46.
[22] D. J. B. Direktorat Jenderal Bina Marga.(1997). Manual Kapasitas Jalan Indonesia (MKJI) 1997. *Direktorat Jenderal Bina Marga*
[23] Peraturan Walikota Bengkulu, *Peraturan Daerah Kota Bengkulu Nomor 4 Tahun 2021 tentang Rencana Tata Ruang Wilayah Kota Bengkulu Tahun 2021 - 2041*. Indonesia, 2021, pp. 1–199.
[24] Peraturan Walikota Bengkulu, *Peraturan Walikota Bengkulu Nomor 38 Tahun 2018 tentang Klasifikasi Jalan dan Garis Sempadan Pagar/Garis Sempadan Bangunan dan Klasifikasi Wilayah*

dalam Kota Bengkulu. Indonesia, 2018, pp. 1689–1699.
[25] Manual, H. C. (2000). Highway capacity manual. *Washington, Dc*, *2*(1), 1.
[26] Al-Msari, H., Koting, S., Ahmed, A. N., & El-Shafie, A. (2024). Review of driving-behaviour simulation: VISSIM and artificial intelligence approach. *Heliyon*, *10*(4).
[27] Jepriadi, K. (2022). Kalibrasi dan Validasi Model Vissim untuk Mikrosimulasi Lalu Lintas pada Ruas Jalan Tol dengan Lajur Khusus Angkutan Umum (LKAU). *Jurnal Keselamatan Transportasi Jalan (Indonesian Journal of Road Safety)*, *9*(2), 110-118.
[28] Rivadeneira, A. M., Benavente, J., & Monzon, A. (2024). Efficient operation of metropolitan corridors: Pivotal role of lane management strategies. *Future Transportation*, *4*(3), 1100-1120.
[29] M. A. Arofah and E. Prahara, "Hubungan Parameter Permukaan Jalan terhadap Karakteristik Lalu Lintas Menggunakan Aplikasi Roadroid, Program PTV VISSIM, dan Pengamatan," Universitas Bina Nusantara, 2020.
[30] Arofah, M. A. (2024). *Simulasi permodelan lalu lintas mikro software PTV Vissim 25 demo version kasus = Evaluasi simpang 3 tanpa APILL*.
[31] Michael, M., Syaputra, F., Marina, B. C., & Khanza, A. K. (2025). Analysis of Road Network Performance in Universitas Islam Negeri Raden Intan Area using Microsimulation PTV VISSIM. *G-Tech: Jurnal Teknologi Terapan*, *9*(4), 2110-2119.
[32] Hu, J., Li, J., Yan, X., Lai, J., & An, L. (2025). A simulation platform calibration method for automated vehicle evaluation: accurate on both vehicle level and traffic flow level. *arXiv preprint arXiv:2512.16076*.
[33] Haryanto, B., Alkas, M. J., & Aditya, M. R. (2025). Analisis Kinerja Ruas Jalan Dengan Metode Moving Car Observer Dan Survey Lalu Lintas Reguler (Studi Kasus: Jalan Pm. Noor). *Teknologi Sipil: Jurnal Ilmu Pengetahuan dan Teknologi*, *9*(2), 124-138.
[34] Cut, M., Fitrika Mita, S., & Ruhdi, F. (2024). The analysis of service level on Diponegoro Road, Pasar Aceh: Comparing the existing condition and with on-street parking restriction. In *E3S Web of Conferences* (Vol. 476, p. 01053). EDP Sciences.
[35] Alfonso, C. G. J., Javier, C. C. N., & Faustino, M. G. (2023). Determination of the maximum hourly traffic volume of a traffic circle. *Journal of Language and Linguistic Studies*, *18*(3).
[36] Yansari, K., Sugiarto, S., & Saleh, S. M. (2025, June). Impact of campus activities on traffic performance in Lhokseumawe: A case study of Lhokseumawe State Polytechnic using PKJI 2023 approach. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1510, No. 1, p. 012075). IOP Publishing.
[37] Noland, R. B., & Lem, L. L. (2002). A review of the evidence for induced travel and changes in transportation and environmental policy in the US and the UK. *Transportation Research Part D: Transport and Environment*, *7*(1), 1-26.
[38] Duranton, G., & Turner, M. A. (2011). The fundamental law of road congestion: Evidence from US cities. *American Economic Review*, *101*(6), 2616-2652.
[39] Kalliga, V., Narayanan, S., & Antoniou, C. (2025). Who does new trips and why?: An analysis toward the modeling of induced demand. *Transportation Letters*, *17*(1), 135-143.
[40] Triadi, F., Jaya, A. K., Biabdillah, F., & Hanif, A. (2025). Hybrid Regression–Simulation Model for Evaluating Emission Policies in Oversaturated Urban Corridors: A Case Study of Jakarta. *Journal of Embedded Systems, Security and Intelligent Systems*, 654-666.
[41] Stigen, T. A., Nilsen, Ø. L., & Stevik, T. K. (2024). Impacts of highway induced land use changes on transport demand. *Transportation Research Procedia*, *78*, 578-585.
[42] Prapaporn, W., Chaipanha, W., & Kaewwichian, P. (2025). A multi-criteria decision-making approach of transport intersection toward sustainable urban transport index. *Ain Shams Engineering Journal*, *16*(8), 103453.
[43] Prakash, A., Ravinder, R., Vittalaiah, A., Krishna Munipally, S., & Al-Farouni, M. H. (2024,

May). VISSIM based traffic flow simulation analysis on road network. In *E3S Web of Conferences* (Vol. 529, p. 03009). EDP Sciences.

[44] Biszko, K., Oskarbski, J., & Żarski, K. (2024). Impact of Wiedemann 74 and Wiedemann 99 car-following models on estimating level of safety and emissions on signal-controlled intersections using microscopic simulations. *Archives of Transport*, *72*.

[45] Tapa, I. G. F. S., Yuliadewi, N. P. A., Candrawengi, N. L. P. I., Prakasa, I. M. P. T., Zainordin, N., & Sutapa, I. K. (2025). Performance Analysis and Traffic Flow Simulation of Tukad Pakerisan Road Segments Using VISSIM in South Denpasar. *TIERS Information Technology Journal*, *6*(1), 87-96.

[46] Hunta, N. F. J., Kadir, Y., & Desei, F. L. (2025). ANALISIS KINERJA LALU LINTAS PADA RUAS JALAN BACHARUDDIN JUSUF HABIBIE DENGAN MENGGUNAKAN PERANGKAT LUNAK VISSIM. *Composite Journal*, *5*(2), 75-84.

[47] Doansyah, F., Irawati, I., Pratiwi, Y., & Herdiarti, E. (2025). Analisis Kinerja Simpang APILL dengan Metode PKJI 2023 (Studi Kasus: Simpang Majapahit Kota Semarang). *Indonesian Journal of Civil Engineering Study*, *2*(2), 66-76.

[48] Stepanigari, E., Alkas, M. J., & Widiastuti, M. (2021). Analisis Redesain Pengendalian Simpang Dengan Menggunakan MKJI 1997 dan Program PTV Vissim. *Teknologi Sipil: Jurnal Ilmu Pengetahuan dan Teknologi*, *5*(2), 6-16.

[49] ST, A. P. A., Miftahul Fauziah ST, M. T., & Chasanah, F. (2026, February). Analisis dampak lalulintas akibat pembangunan kafe dan penginapan pada ruas Jalan Maguwo. In *CE ReForm* (Vol. 1, No. 1, pp. 449-456). Universitas Islam Indonesia.

[50] Hakim, L. M. (2025). Traffic Management and Engineering Based on Traffic Modeling in the Gilingan Area, Banjarsari, Surakarta City. *Eduvest-Journal of Universal Studies*, *5*(8), 9691-9701.

[51] Fatić, E., Deluka-Tibljaš, A., Ištoka Otković, I., Klobučar, M., & Šurdonja, S. (2024). Optimisation of traffic in the City of Opatija based on traffic microsimulation model. *Zbornik radova (Građevinski fakultet Sveučilišta u Rijeci)*, *17*(1), 91-107.

[52] Chiu, Y. C., Zhou, X., & Hernandez, J. (2007). Evaluating urban downtown one-way to two-way street conversion using multiple resolution simulation and assignment approach. *Journal of Urban Planning and Development*, *133*(4), 222-232.

[53] Al Akib, Y., Zhafirah, A., & Lawalata, G. M. (2025). Evaluasi derajat kejenuhan jalan menggunakan PKJI dan VISSIM. *Jurnal Konstruksi*, *23*(2), 417-427.

[54] Pratma, N., Aprianto, R., & Siswanto, J. (2025). Optimalisasi Kinerja Ruas Jalan Dengan Metode PKJI 2023 dan Aplikasi PTV Vissim. *Jurnal Teknik*, *23*(1), 42-58.

[55] Prahara, E., Pionar, R. G., & Suhendra, A. (2020, February). Traffic management for MRT construction phase II bundaran HI–kota. In *IOP Conference Series: Earth and Environmental Science* (Vol. 426, No. 1, p. 012036). IOP Publishing.

[56] Farghly, E., El-Sonbaty, A. A., Abbas, Y. A., & Owais, M. (2026). Mutual information–based line criticality analysis in public transport networks. *Innovative Infrastructure Solutions*, *11*(5), 258.

[57] Boeing, G., & Ha, J. (2024). Resilient by design: Simulating street network disruptions across every urban area in the world. *Transportation research part A: policy and practice*, *182*, 104016.

[58] Bucsky, P., & Juhász, M. (2022). Long-term evidence on induced traffic: A case study on the relationship between road traffic and capacity of Budapest bridges. *Transportation research part A: policy and practice*, *157*, 244-257.