

Impact of Heavy Vehicles on Urban Road Performance Using Indonesian Highway Capacity Guidelines 2023: A Case Study of an Urban Arterial Road in Kendari City Indonesia

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ABSTRACT: Big trucks totally mess up traffic in cities, specially when mixed in with cars n bikes. This study evaluates the impact of heavy vehicles on Z. A. Sugianto Road, Kendari City, using the updated Indonesian Highway Capacity Guidelines (PKJI 2023). We ran a three-day traffic survey during the busy morning, midday, and evening rushes. It captured things like traffic volumes, mix of vehicles, speeds, and those nagging side frictions. From there, we calculated roadway capacity, degree of saturation (DS), and Level of Service (LOS) under two setups: one with heavy vehicles and one without. The numbers tell a clear story—heavy vehicles make up just 4.2–5.3% of the traffic, but they bump DS up from 0.42 to 0.47 and drop LOS from B to C. Side frictions cut the effective capacity even more, from 6,800 down to 5,461 pcu/h. Overall, the new PKJI 2023 parameters do a better job spotting how heavy vehicles mess with urban mixed traffic. This work gives real-world tips for city traffic managers, like controlling heavy vehicles, tackling side frictions, and checking performance regularly to keep roads safe and running smoothly.

KEYWORDS: Heavy vehicles; urban road performance; urban traffic management; side frictions; PKJI 2023; level of service (LOS); degree of saturation.

1. Introduction

Urban roadway performance was strongly influenced by traffic volume, vehicle composition, and side frictions such as on-street parking and access-point activities [1–4]. Z. A. Sugianto Road in Kendari City frequently experienced recurrent congestion due to mixed-traffic conditions consisting of motorcycles, passenger cars, public transport vehicles, and heavy trucks [5]. Side frictions including vehicles stopping abruptly, pedestrian movements, and frequent turning maneuvers, further increased delays and reduced roadway efficiency [6, 7]. Similar conditions had been observed on other urban corridors in Indonesia, particularly those located near industrial or commercial areas, where heterogeneous traffic streams contributed to operational instability [8, 9].

A major concern was the increasing proportion of heavy vehicles. Due to their larger dimensions and higher passenger-car equivalency (PCE) values, heavy vehicles reduced effective roadway capacity and lowered operating speeds [10–12]. Although their proportion in the traffic stream was often relatively small, their presence significantly affected Level of Service (LOS), degree of saturation, and overall traffic safety [13–15]. This study introduced an updated analytical perspective by applying the 2023 Indonesian Highway Capacity Guidelines (PKJI 2023), which incorporated refined adjustment factors for lane width, side frictions, city size, and directional traffic distribution. The updated parameters provided a more accurate assessment of heavy-vehicle impacts compared with previous versions of the PKJI [16, 17].

Accordingly, this research aimed to (1) analyze the proportion of heavy vehicles and the intensity of side frictions, (2) calculate roadway capacity and degree of saturation, (3) evaluate changes in LOS under scenarios with and without heavy vehicles, and (4) propose policy recommendations to improve traffic performance on Z. A. Sugianto Road. Previous studies in Indonesia and other Southeast Asian cities had consistently reported that mixed traffic conditions, roadside activities, and heavy vehicles adversely affected roadway capacity and traffic flow. However, many of these studies relied on earlier capacity manuals or did not explicitly isolate the impact of heavy vehicles using updated analytical frameworks. To date, no study had specifically quantified the effect of heavy vehicles on urban road performance in Kendari City using PKJI 2023, which introduced updated correction factors for lane geometry, side frictions, urban scale, and traffic composition. This study addressed that gap by implementing PKJI 2023 on Z. A. Sugianto Road for the first time. It quantified how heavy vehicles influenced capacity, degree of saturation, and LOS, assessed the additional impact of side frictions, and developed practical traffic management recommendations. The main contribution of this research lay in demonstrating the improved sensitivity of PKJI 2023 in capturing heavy-vehicle effects under complex urban traffic conditions, with potential applicability to other Indonesian cities and comparable developing urban contexts.

2. Methodology

2.1. Study area and field conditions.

A quantitative method was applied in accordance with the PKJI 2023 guidelines, which incorporate the latest adjustments for evaluating urban road performance [18]. The study began with field observations to document the geometric characteristics of Z. A. Sugianto Road, including lane widths, shoulder conditions, roadside land use, access points, and traffic signal operations. These observations helped identify potential side-friction sources and determine appropriate survey locations, consistent with recent urban traffic research practices [19, 20].

2.2. Traffic survey and data collection.

Following the preliminary observations, classified traffic counts were conducted over three consecutive days during the morning, midday, and evening peak periods. Traffic volumes were recorded manually using tally sheets and subsequently converted into passenger car units per hour (pcu/h) based on standard Indonesian urban conversion factors. The survey covered motorcycles, passenger cars, medium vehicles, buses, and heavy trucks in order to accurately

represent the composition of mixed traffic flows, as commonly reported in Southeast Asian urban studies [21]. To enhance data reliability, traffic counts were independently recorded by two observers during each survey period. Any discrepancies between observers were reviewed and reconciled immediately after each observation session [22, 23].

2.3. Geometric and side-friction assessment.

Geometric measurements were carried out on-site using measuring tapes and digital measuring devices to obtain lane widths, shoulder dimensions, and the number of lanes. These variables are essential for capacity estimation under PKJI procedures [24]. Side-friction elements were quantified by observing the frequency of pedestrian crossings, on-street parking activities, vehicles entering and exiting access points, and slow-moving vehicles. These observations were evaluated using the weighted scoring system provided in PKJI 2023. Such components are widely recognized in the literature as significant contributors to reductions in roadway capacity and speed performance [25, 26].

2.4 Capacity and Saturation Calculation

The capacity of the roadway segment was calculated using PKJI adjustment factors for lane width, directional distribution, side friction, and city size. This approach reflected methodological principles similar to those employed in Highway Capacity Manual (HCM)-based evaluations [27]. The degree of saturation (DS) was determined by dividing the peak-hour traffic volume by the adjusted capacity, serving as a primary indicator of roadway performance. All passenger car equivalency (PCE) values and adjustment factors were derived strictly from PKJI 2023 to ensure methodological consistency and replicability.

2.5 Scenario Comparison and Sensitivity Consideration

The analysis compared two scenarios: traffic conditions including heavy vehicles and traffic conditions excluding heavy vehicles. This comparison was intended to quantify the specific contribution of heavy trucks to congestion levels, following approaches commonly used in heavy-vehicle impact studies [28, 29]. In addition, basic descriptive statistical methods were employed to describe variations in traffic volume, heavy-vehicle proportions, and side-friction frequency. All analytical procedures from data tabulation and conversion to pcu to the determination of Level of Service (LOS), were conducted in full accordance with PKJI 2023, ensuring alignment with current Indonesian traffic engineering practices [30, 31].

3. Results and Discussion

Descriptive statistics indicated that traffic volumes and side-friction frequencies did not vary significantly from day to day. Sunday recorded the highest average side-friction frequency and peak-hour traffic volume among the three observation days. The proportion of heavy vehicles ranged between 4.2% and 5.3%, showing only minor hourly fluctuations, which suggested relatively stable freight activity along the corridor.

3.1. Vehicle composition and heavy-vehicle proportion.

The three-day traffic survey on Z. A. Sugianto Road showed that the proportion of heavy vehicles varied slightly by day and time period. Tables 1–3 present the distribution of motorcycles, passenger cars, and heavy vehicles in passenger car units per hour (pcu/h) for Sunday, Monday, and Tuesday. This pattern was consistent with typical urban traffic conditions in mixed-use corridors, where heavy vehicles generally accounted for approximately 3% to 6% of peak-hour volumes, depending on surrounding land use and freight movement schedules. The continued presence of heavy vehicles during peak periods indicated that their operating patterns were closely associated with commercial and distribution activities in the study area.

Table 1. Heavy-vehicle proportion on Sunday.

Time	Motorcycles (SM)	Passenger Cars (MP)	Heavy Vehicles (HV)	Total Vehicles/h	SM (%)	MP (%)	HV (%)
07:00–08:00	1545	1003	130	2678	57.7	37.5	4.9
08:00–09:00	1384	973	124	2481	55.8	39.2	5
09:00–10:00	1547	1020	121	2688	57.6	37.9	4.5
13:00–14:00	1274	800	130	2204	57.8	36.3	5.9
14:00–15:00	1342	900	132	2374	56.5	37.9	5.6
15:00–16:00	1650	1115	140	2905	56.8	38.4	4.8
16:00–17:00	1768	1263	150	3181	55.6	39.7	4.7
Average (%)	–	–	–	2644	56.8	38.1	5

Table 2. Heavy-vehicle proportion on Monday.

Time	SM	MP	HV	Total Vehicles/h	SM (%)	MP (%)	HV (%)
07:00–08:00	1720	1543	158	3421	50.3	45.1	4.6
08:00–09:00	1766	1580	162	3508	50.3	45	4.6
09:00–10:00	1925	1790	167	3882	49.6	46.1	4.3
13:00–14:00	1423	1389	152	2964	48	46.9	5.1
14:00–15:00	1450	1400	149	2999	48.3	46.7	5
15:00–16:00	2145	1699	173	4017	53.4	42.3	4.3
16:00–17:00	2180	1774	185	4139	52.7	42.9	4.5
Average (%)	–	–	–	3561	50.4	45	4.6

Table 3. Heavy-vehicle proportion on Tuesday.

Time	SM	MP	HV	Total Vehicles/h	SM (%)	MP (%)	HV (%)
07:00–08:00	1700	1546	140	3386	50.2	45.7	4.1
08:00–09:00	1788	1560	138	3486	51.3	44.8	4
09:00–10:00	1823	1700	165	3688	49.4	46.1	4.5
13:00–14:00	1323	1285	126	2734	48.4	47	4.6
14:00–15:00	1350	1305	120	2775	48.6	47	4.3
15:00–16:00	1984	1766	143	3893	51	45.4	3.7
16:00–17:00	2030	1799	155	3984	51	45.2	3.9
Average (%)	–	–	–	3421	50	45.9	4.2

3.2. Traffic volume with and without heavy vehicles.

Figures 1A–1C present the total hourly traffic volumes (pcu/h), including heavy vehicles, over the three observation days. As shown in Figure 1A, the highest peak volume occurred on Sunday between 16:00 and 17:00, reaching 2,541 pcu/h. Figures 1B and 1C indicate slightly lower peak-hour volumes on Monday and Tuesday, although the general hourly pattern remained similar, with traffic increasing toward the late afternoon peak period. This trend

reflected typical urban activity patterns, where commercial and social activities intensified in the late afternoon. To evaluate the specific contribution of heavy vehicles to roadway performance, traffic volumes were recalculated by excluding heavy vehicles from the traffic stream. As illustrated in Figures 1D–!F, the overall hourly pattern remained consistent across all three days; however, the absolute traffic volumes were lower in each corresponding time period. The highest peak volume without heavy vehicles also occurred on Sunday between 16:00 and 17:00, as shown in Figure 1D, reaching 2,319 pcu/h. The difference of 222 pcu/h between the two scenarios during the peak hour demonstrated the significant influence of heavy vehicles on equivalent traffic demand. Although heavy vehicles constituted only a small proportion of the total traffic volume, their higher passenger-car equivalency (PCE) values substantially increased the calculated traffic load in pcu terms. Similar reductions were observed on Monday and Tuesday (Figures 1E and 1F), confirming that even modest heavy-vehicle proportions meaningfully affected total equivalent flow and, consequently, roadway performance indicators such as capacity utilization and degree of saturation.

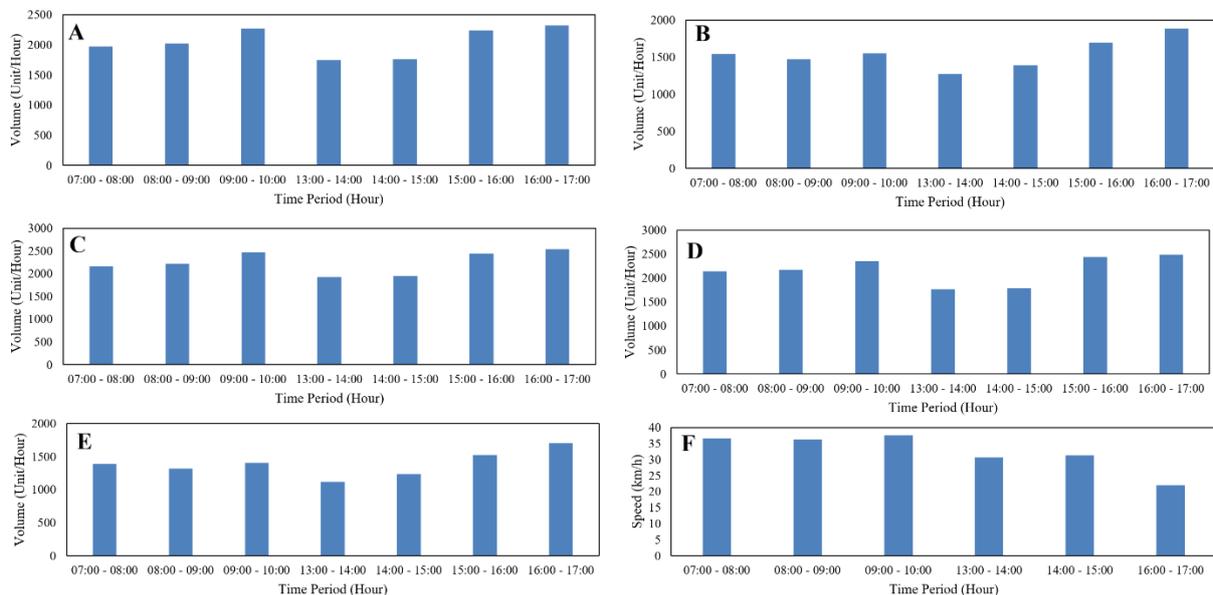


Figure 1. Hourly traffic volume with heavy vehicles on Sunday (A), Monday (B), Tuesday (C), and with heavy vehicles on Sunday (D), Monday (E), Tuesday (F),

3.3. Side-Friction characteristics.

Side frictions were recorded and quantified using the PKJI 2023 weighting factors for pedestrians (PED), parked vehicles (PSV), entering–exiting vehicles (EEV), and slow-moving vehicles (SMV). The weighted hourly totals for each observation day are presented in Tables 4–6. As shown in Table 4, Sunday exhibited the highest overall level of side friction, with an average of 83 weighted events per hour. The most critical period occurred between 09:00 and 10:00, reaching 96 events/h, followed by 08:00–09:00 (91 events/h) and 15:00–16:00 (90 events/h). Entering–exiting vehicles (EEV) consistently contributed the largest share, particularly during midday (65 events at 12:00–13:00), indicating intensive access activity along the corridor. Pedestrian movements and parked vehicles were also relatively high compared to the other days, which likely reflected increased weekend commercial and shopping activities.

Table 4 also indicates that Monday recorded a lower average side-friction level of 71 events per hour. The highest value was observed during 09:00–10:00 (88 events/h), mainly driven by high EEV (56) and PSV (44) frequencies. Although side frictions remained substantial during peak periods, pedestrian activity was noticeably lower than on Sunday, contributing to the overall reduction in weighted totals. As presented in Table 4, Tuesday showed the lowest average side-friction frequency at 67 events per hour. The highest hourly value was 76 events/h during 08:00–09:00. Compared to Sunday and Monday, pedestrian and parked-vehicle activities were generally lower, although entering–exiting vehicle movements remained a dominant component. Slow-moving vehicles (SMV) showed moderate variation across all days but did not constitute the primary contributor to total side friction. Overall, the results demonstrated that Sunday experienced the most intense roadside activity, followed by Monday and Tuesday. The consistently high contribution of entering–exiting vehicles across all days highlighted the significant influence of access density and roadside land use on traffic performance. These findings confirmed that side frictions substantially disrupted lane flow and reduced the effective roadway capacity, particularly during peak commercial activity periods.

Table 4. Side-frictions on Sunday, Monday, and Tuesday.

Day	Time	PED	PSV	EEV	SMV	Weighted Total (events/h)
Sunday	07:00–08:00	14	24	31	2	54
Sunday	08:00–09:00	17	47	48	5	91
Sunday	09:00–10:00	12	47	58	5	96
Sunday	12:00–13:00	7	36	65	8	88
Sunday	13:00–14:00	7	35	53	7	78
Sunday	15:00–16:00	11	41	57	9	90
Sunday	16:00–17:00	12	39	57	4	87
Sunday	Average	–	–	–	–	83
Monday	07:00–08:00	5	29	31	2	54
Monday	08:00–09:00	3	33	53	4	73
Monday	09:00–10:00	2	44	56	10	88
Monday	12:00–13:00	5	33	44	9	70
Monday	13:00–14:00	4	31	49	7	70
Monday	15:00–16:00	8	33	45	7	71
Monday	16:00–17:00	7	38	41	5	72
Monday	Average	–	–	–	–	71
Tuesday	07:00–08:00	3	25	25	9	48
Tuesday	08:00–09:00	4	42	41	7	76
Tuesday	09:00–10:00	2	38	45	7	73
Tuesday	12:00–13:00	3	38	29	10	64
Tuesday	13:00–14:00	3	40	32	6	66
Tuesday	15:00–16:00	6	34	46	6	72
Tuesday	16:00–17:00	8	37	42	4	72
Tuesday	Average	–	–	–	–	67

3.4. Vehicle speed characteristics.

Figures 2 illustrate the average travel speed profiles for motorcycles, passenger cars, medium vehicles, and heavy vehicles on Sunday, Monday, and Tuesday, respectively. As shown in Figure 2, Sunday recorded the highest speed levels during the morning period, ranging between approximately 36 and 40 km/h across vehicle types. However, speeds declined significantly in the afternoon and evening peak periods, dropping to around 20–22 km/h. This sharp reduction

corresponded with the increase in traffic volume and side-friction intensity observed during the same time intervals, particularly between 15:00 and 17:00. Figures 2 also indicate that average speeds on Monday and Tuesday were generally lower and more stable throughout the day compared to Sunday morning conditions. Speeds mostly ranged between 23 and 29 km/h, with the lowest recorded average speed of approximately 23.7 km/h occurring during the midday period. Unlike Sunday, where speeds started relatively high and then decreased sharply, weekday speeds remained consistently moderate to low, reflecting sustained traffic density and continuous roadside activities. Across all three figures, heavy vehicles consistently exhibited lower average speeds compared to motorcycles and passenger cars, while motorcycles tended to maintain slightly higher speeds due to their greater maneuverability in mixed traffic conditions. The overall speed patterns demonstrated a clear inverse relationship between traffic volume, side-friction intensity, and travel speed. Increased traffic demand and more frequent pedestrian crossings, parking maneuvers, and vehicle access movements during peak weekday periods contributed to reduced operating speeds and longer travel times. Collectively, Figures 7–9 confirm that both traffic density and side-friction activity significantly influenced speed performance, with weekday operational conditions showing more sustained speed reductions than the more fluctuating pattern observed on Sunday.

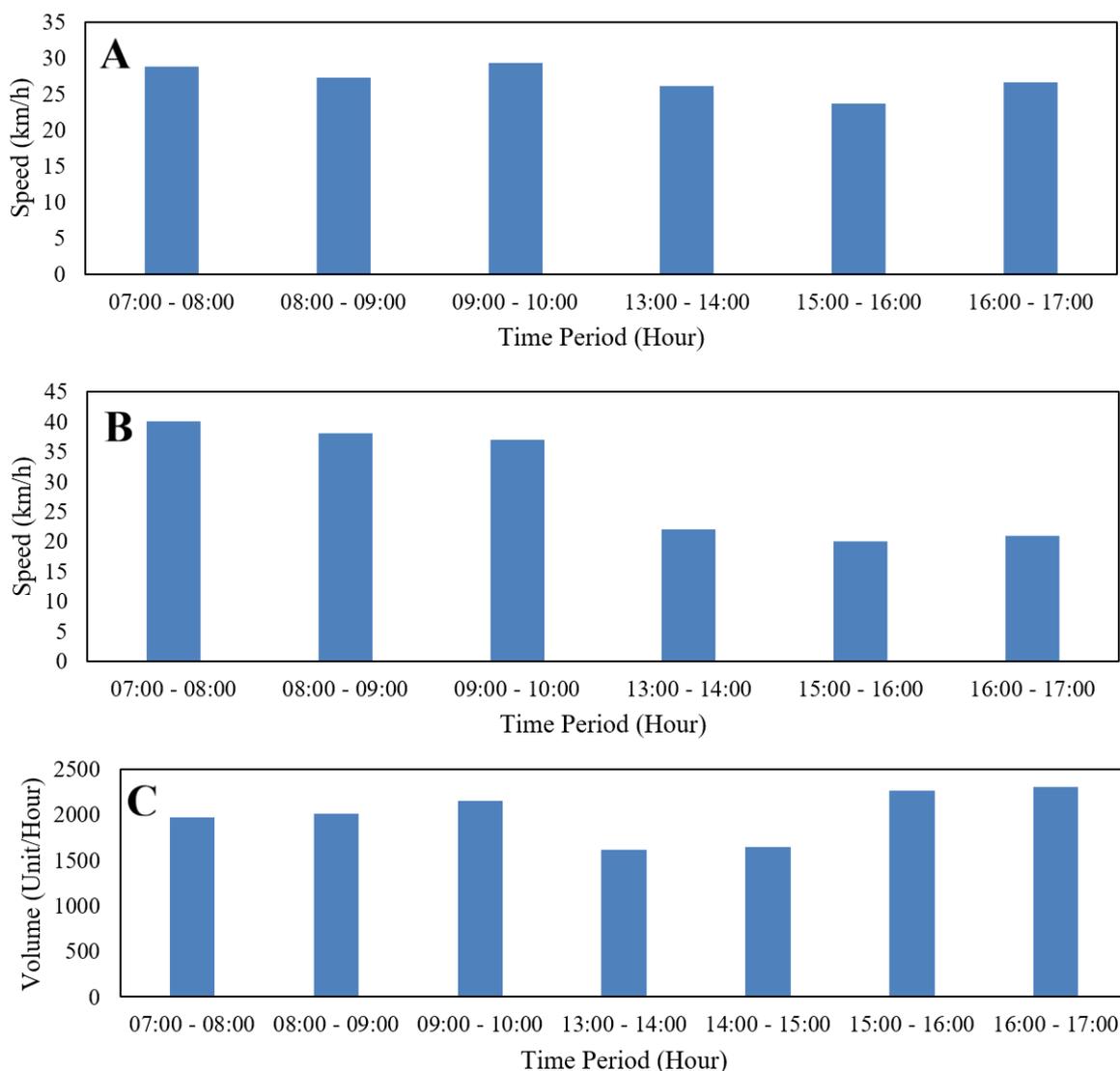


Figure 2. Average vehicle speed profile on Sunday (A), Monday (B), Tuesday (C).

3.5. Roadway capacity analysis.

Roadway capacity was estimated using the PKJI 2023 methodology by applying adjustment factors for lane width (FCLJ), directional traffic distribution (FCPA), side friction (FCHS), and city size (FCUK). The results are presented in Table 5. As shown in Table 5, the base capacity (C_0) for a 4/2 UD road type was 6,800 pcu/h. After applying the relevant adjustment factors, the effective capacity (C) was consistently calculated at 5,461 pcu/h for all observed time periods. The uniformity of the capacity value across time slots indicated that the geometric and environmental characteristics of the roadway segment remained constant throughout the day, and that capacity under PKJI 2023 depended primarily on these fixed factors rather than hourly traffic fluctuations. The reduction from the base capacity of 6,800 pcu/h to 5,461 pcu/h was mainly influenced by three adjustment components. First, the lane-width adjustment factor ($FCLJ = 0.92$) reflected narrower-than-ideal lane dimensions, which reduced vehicle maneuverability and constrained effective flow. Second, the side-friction adjustment factor ($FCHS = 0.97$) indicated a moderate level of roadside activity, including pedestrian movements, on-street parking, and access maneuvers, all of which slightly lowered operational capacity. Although the numerical reduction from side friction appeared modest, its cumulative effect remained significant in peak conditions. The most substantial reduction was associated with the city-size adjustment factor ($FCUK = 0.90$). This factor accounted for the characteristics of a smaller urban area, where roadway standards, network hierarchy, and available space are typically more limited than in major metropolitan cities. The FCUK value reduced the capacity by 10%, representing structural and contextual constraints inherent in medium- to small-sized urban environments. Overall, the application of PKJI 2023 demonstrated that geometric limitations and urban contextual factors collectively reduced the effective capacity of the roadway segment by approximately 20% from its theoretical base value. This adjusted capacity of 5,461 pcu/h formed the basis for subsequent degree-of-saturation and level-of-service evaluations.

Table 5. Roadway capacity calculation based on PKJI 2023.

Time	Road Type	C_0	FCLJ	FCPA	FCHS	FCUK	Capacity (C)
07:00–08:00	4/2 UD	6800	0.92	1	0.97	0.9	5461
08:00–09:00	4/2 UD	6800	0.92	1	0.97	0.9	5461
09:00–10:00	4/2 UD	6800	0.92	1	0.97	0.9	5461
12:00–13:00	4/2 UD	6800	0.92	1	0.97	0.9	5461
13:00–14:00	4/2 UD	6800	0.92	1	0.97	0.9	5461
15:00–16:00	4/2 UD	6800	0.92	1	0.97	0.9	5461
16:00–17:00	4/2 UD	6800	0.92	1	0.97	0.9	5461

3.6. Degree of saturation and level of service.

The degree of saturation (DS) was calculated for peak-hour conditions to evaluate the operational performance of the roadway segment under two scenarios: with heavy vehicles included and with heavy vehicles excluded. The comparison is illustrated in Figure 3. When heavy vehicles were included in the traffic stream, the DS reached 0.47. Based on PKJI 2023 criteria, this value corresponded to Level of Service (LOS) C, indicating stable flow conditions but with noticeable restrictions on maneuverability and speed. Under LOS C, drivers typically experienced limited opportunities to adjust speed freely, and interactions among vehicles

became more frequent, particularly during peak periods. When heavy vehicles were excluded from the calculation, the DS decreased to 0.42. According to PKJI classifications, this value fell within LOS B, which represented stable flow with relatively minor restrictions and greater operating comfort. At LOS B, drivers generally retained better flexibility in speed selection and lane-changing behavior. The difference of 0.05 in DS between the two scenarios demonstrated the measurable impact of heavy vehicles on roadway performance. Although heavy vehicles accounted for only a small proportion of total traffic volume, their higher passenger car equivalency (PCE) values increased the effective traffic demand in pcu/h, thereby pushing the roadway closer to its operational threshold. In mixed-traffic environments, a DS approaching 0.50 is often regarded as a transitional zone, where traffic conditions shift from stable operation toward increasing sensitivity to disturbances. The results indicated that the presence of heavy vehicles played a decisive role in moving the performance level from LOS B to LOS C.

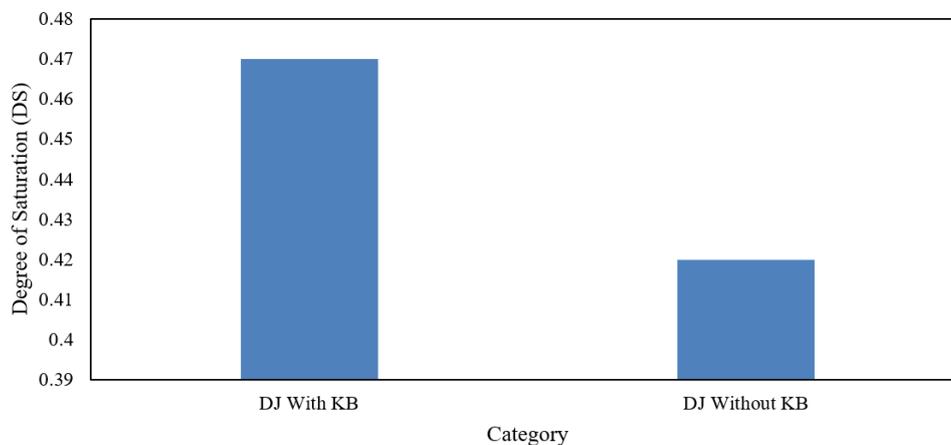


Figure 3. Comparison of degree of saturation with and without heavy vehicles.

3.7. Discussion.

The findings confirmed that heavy vehicles exerted a disproportionately large influence on urban traffic performance relative to their numerical share. Their larger physical dimensions, slower acceleration characteristics, and higher PCE factors reduced discharge rates and increased speed variability within mixed traffic streams. In theoretical terms, heavy vehicles introduced flow disturbances that amplified interactions among vehicles, especially under conditions of moderate to high side friction [22–25]. The impact was further intensified by the presence of roadside activities, such as frequent access movements and parking maneuvers, which already constrained effective capacity. Under such conditions, heavy vehicles not only reduced average speeds but also increased the likelihood of localized bottlenecks. The application of PKJI 2023 provided a more context-sensitive assessment compared to older capacity evaluation approaches, particularly in accounting for local roadside complexity and urban characteristics [28–31]. The observed reduction in effective capacity and the shift in LOS from B to C highlighted the vulnerability of the roadway segment to future freight growth. Even a moderate increase in heavy-vehicle volume could raise the DS beyond 0.50, potentially leading to unstable flow conditions. These results have important implications for traffic modeling, infrastructure planning, and policy development in rapidly growing urban areas such as Kendari. Strategic management of freight movements, access control, and side-friction

mitigation may be necessary to maintain acceptable levels of service as traffic demand continues to increase [20, 26, 30].

4. Conclusions

This study demonstrated that the application of PKJI 2023 provided a more precise assessment of heavy-vehicle impacts under complex urban traffic conditions. By incorporating updated adjustment factors for lane width, side friction, traffic distribution, and city size, the method was able to capture the operational sensitivity of a mixed-traffic corridor characterized by significant roadside activity. Although heavy vehicles represented only 4–5% of total traffic volume, their higher passenger car equivalency values increased peak-hour demand, raised the degree of saturation from 0.42 to 0.47, and shifted the level of service from LOS B to LOS C. These findings confirmed that even a modest proportion of heavy vehicles could meaningfully influence roadway performance in friction-intensive environments. From a practical perspective, the results support targeted traffic management strategies, such as time-of-day restrictions for heavy vehicles, designated freight lanes where feasible, and stricter control of roadside activities to reduce side friction. However, this study had several limitations. The analysis was based on a three-day survey, which may not fully reflect seasonal variations or long-term traffic trends. In addition, the use of standardized passenger car equivalency and side-friction weighting factors may introduce uncertainty in capacity estimation. Future research should extend observation periods, conduct comparative analyses across different cities, and employ simulation or dynamic traffic models to better evaluate temporal variability and policy interventions.

Author Contributions

All authors contributed to this study. Ridwan Syah Nuhun led the conceptualization and fieldwork supervision. La Welendo developed and validated the methodology using PKJI 2023. Indra Siolimbona conducted the data analysis and prepared the figures, tables, and correspondence. Endang Pratiwi Rausy supported the literature review and results writing. Muhamad Anwar performed statistical verification and technical review. All authors approved the final manuscript.

Ethics and Data Availability

This study used observational traffic data collected in public road spaces without involving any personal or sensitive information. All data were recorded anonymously and analyzed in aggregate form. The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Competing Interest

The authors declare that there are no competing interests or conflicts of interest regarding the publication of this research.

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