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INVESTIGATION OF SERVICE T-JUNCTION DUE TO TRAFFIC FLOW CONFLICT: INTEGRATIVE APPROACH OF TRAFFIC CONFLICT TECHNIQUE AND REAL-TIME DATA

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Abstract

The Hombis Lepo-Lepo Kendari T-junction is an intersection with three arms that is not equipped with Traffic Signal Devices. The increasing interaction of motor vehicles at this intersection has led to traffic flow conflicts that negatively impact the performance of the junction. The analysis results indicate that the average degree of saturation is 0.80 with a delay time of 13.28 sec/veh. The level of service at the intersection is categorized at level 'B', where traffic operations remain smooth. Nevertheless, there are indications of an increased potential for conflicts, particularly during right turn and U-turn maneuvers. This research finds that the correction factors for the capacity of the intersection are significantly influenced by temporal variables and traffic maneuver characteristics. Therefore, the development of a differential approach based on days and types of maneuvers is necessary. The Hombis T-junction in Kendari can still be operated for several years to come.

Keywords: Intersection Performance, Conflicting Movements, Protected Conflicts

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INTRODUCTION

The increasing traffic on the roads has become a problem that can lead to congestion. Congestion typically occurs at intersection points due to conflicting traffic flows (Konge & Nikam, 2022). Besides congestion, it also creates noise. Traffic noise exposure is an aspect that needs to be considered in spatial planning and transportation system management (Lakawa *at al.*, 2025). Unsignalized three-way intersections are one type of intersection commonly found in urban areas. Although relatively simple compared to four-way intersections or other types, unsignalized three-way intersections also often become a source of traffic problems, especially in locations with high mobility levels. The absence of traffic signal devices at the intersection impacts the performance of that intersection. During peak hours, congestion frequently occurs, characterized by long queues and delays in traffic. Furthermore, if the traffic flow encounters conflicting movements and is obstructed, it may potentially lead to accidents.

Uncontrolled intersections are considered hazardous for drivers. The risk of accidents is higher in these locations, especially in countries with heterogeneous traffic. Such intersections require thorough investigation, considering traffic volume, geometry, and vehicle composition (Prasannakumar, 2018). This is supported by a report from the Ministry of Road Transport and Highways (2018), which states that unsignalized T-intersections significantly contribute to traffic accidents, particularly fatal ones. This is attributed to the lack of adequate traffic control, high vehicle volumes, and suboptimal intersection geometry. Unsignalized intersections are primary areas of traffic accidents and side impediments. Therefore, a microscopic analysis of each unsignalized intersection is required. This microscopic analysis includes traffic characteristics such as speed, volume, and capacity (Kumar *at al.*, 2022).

The Hombis Lepo-Lepo intersection in Kendari is a three-legged intersection that is not equipped with Traffic Signal Facilities. The increasing volume of traffic from both major and minor roads has led to conflicts in traffic flows. Traffic delay is an important measure in evaluating the efficiency of road and intersection operations. Therefore, delay analysis is essential for assessing the level of service and planning the signal phases at intersections (Ren & Geng, 2022). The lack of priority signage or road markings creates confusion for road users, increasing the risk of conflicts and accidents. Conflict between vehicle flows is higher at this intersection compared to others, particularly for vehicles wishing to turn right (right-turn conflicts) or cut across the road.

LITERATURE REVIEW

Traffic congestion is a term used to describe a situation where vehicles come to a complete stop for an extended period of time. The root causes of traffic congestion include the increasing number of vehicles on the road at high speeds

and poor traffic control at congestion points (Sampathkumar, 2018). Traffic congestion often affects road users. Traffic flow parameters indicate the total volume of vehicles over a specific period of time (Kashinath *et al.*, 2021).

Almost all cities in the world are experiencing a significant growth in the number of vehicles. This is one of the causes of traffic congestion on the roads. Traffic congestion will also lead to increased traffic noise, air pollution, fuel wastage, and a decrease in driving comfort (Guerrero-Ibanez *et al.*, 2018; Rifai, 2020; Mavrin *et al.*, 2020). An intersection is where two or more roads meet, which can be either at-grade or grade-separated. At-grade intersections are generally equipped with traffic lights to manage traffic (PKJI, 2023).

The capacity of an intersection refers to the maximum amount of traffic that can be accommodated by the intersection in one hour (Prasetyo, 2022). The capacity of an intersection is greatly influenced by the intensity of traffic flow, driver behavior, and the timing of entering the intersection (Pospelov, 2021). Evaluating the performance of intersections can enhance the efficiency of signal timing, lane configuration, and traffic flow patterns (Serok *et al.*, 2022).

The use of the Gaussian Algorithm at an intersection is capable of accurately classifying and counting vehicles compared to manual counting (Guilalas, 2022). Traffic control optimization using genetic algorithms is one method to reduce issues at intersections due to the high growth of motor vehicles (Sharma & Kumar, 2019). Isya (2023) conducted intersection modeling using the MKJI method and PTV VISSIM. Three modeling scenarios include one-way streets, the installation of traffic signal control devices, roundabout planning, and widening at each arm of the intersection. The modeling results indicate that widening at each arm of the intersection can achieve optimal service levels.

$$C = C_0 \times F_{LP} \times F_M \times F_{UK} \times F_{HS} \times F_{BK_i} \times F_{BK_a} \times F_{R_{mi}}$$

where;

C = junction capacity (PCU/h),

C_0 = basic capacity of intersection (PCU/h)

F_{LP} = the correction factor for average approach lane width

F_M = the correction factor for median type

F_{UK} = the correction factor for city size

F_{HS} = the correction factor for side obstacles

F_{BK_i} = the correction factor for left-turn traffic flow ratio

F_{BK_a} = the correction factor for right-turn traffic flow ratio

$F_{R_{mi}}$ = the correction factor for minor road traffic flow ratio

Table 1: Basic Capacity of T-intersections and 4-way intersections

Type of Intersection	C ₀ , PCU/h
322	2700
324	3200
344	3200
422	2900
424	3400

Source: Indonesian Road Capacity Guidelines (PKJI, 2023)

The saturation degree of an intersection is a measurement that indicates the level of utilization of the capacity of an intersection (both signalized and non-signalized) in serving traffic flow. This term is commonly used in traffic planning and evaluation to assess the performance of intersections.

$$D_J = q/C$$

Where;

D_J = degree of saturation

C = intersection capacity (PCU/h)

q = the flow of motor vehicle traffic in vehicles per hour

- $D_J < 0.75$: the intersection is functioning well (smooth conditions).
- $D_J = 0.75-0.85$: the intersection is becoming congested (requires evaluation for improvements in the future).
- $D_J = 0.85-1.00$: the intersection is approaching saturation (action is urgently needed to increase capacity).
- $D_J > 1.00$: the intersection is already saturated or congested (this condition indicates that the volume of traffic exceeds the capacity of the intersection).

According to Hariyanto (2022), delays include traffic delays and geometric delays. Delay is the extra time required to pass through an intersection. Delays and traffic queues are issues at intersections, particularly in large cities, thus negatively impacting the economy and social aspects of the community. To address this, one of the solutions is to widen the roads at intersections or to manage intersections properly (Çıldır, 2022). Due to land limitations in urban areas, increasing intersection capacity is not feasible. Therefore, solutions such as the provision of flyovers at intersections are necessary (Sanik *et al.*, 2023). According to Lakawa (2023), increased traffic volume on highways can trigger noise. Further research has shown that traffic factors significantly contribute to the increase in traffic noise by 31.3% (Lakawa, 2024).

Table 2: Level of Service at Intersections

Level of Service	Operation Characteristics
A	Delay condition < 5 sec/veh
B	Delay condition > 5 sec - 15 sec/veh
C	Delay condition > 15 sec - 25 sec/veh
D	Delay condition > 25 sec - 40 sec/veh
E	Delay condition > 40 sec - 60 sec/veh
F	Delay condition > 60 sec/veh

Source: Minister of Transportation of the Republic of Indonesia Number PM 96 of 2015

RESEARCH METHODOLOGY

The research locus is the Hombis intersection in Kendari City. This intersection is an unsignalized intersection in the shape of a ‘T’, connecting Christina Martha Tiahahu Street (a two-way secondary arterial road) with Ade Irma Nasution Street (a local collector road). The traffic flow from both the main road and minor road does not have primary priority in passing through the intersection.



Figure 1: Research Location (*Hombis T-Junction*)

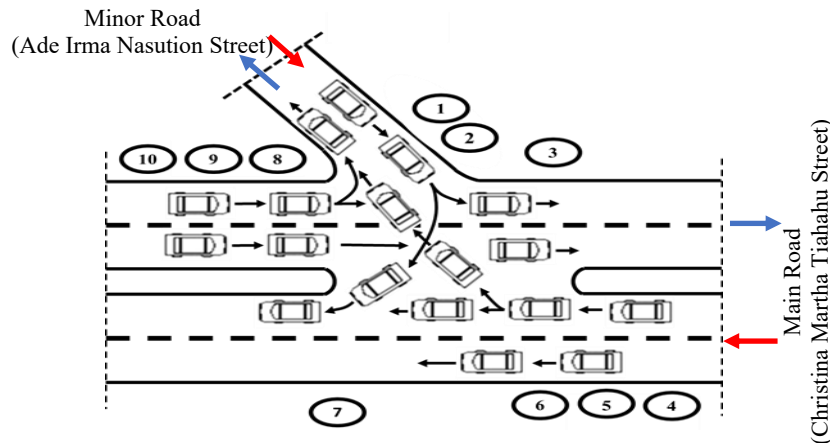


Figure 2: Traffic Flow Circulation at the Hombis Intersection (*Major and Minor Roads*)

This research uses a descriptive quantitative approach to analyze capacity correction factors based on traffic data. Field surveys were conducted over two days, namely Tuesday (working day) and Sunday (holiday), with observation periods being: from 07:00–09:00, 11:00–13:00, and 15:00–17:00. The data collected includes vehicle volume, queue length, delay time, vehicle speed, and geometric conditions of the intersection. Data analysis uses mathematically validated equations, both linear and polynomial. The calculation results are then visualized in the form of graphs to observe traffic characteristic patterns based on the day and type of maneuver.

The performance evaluation parameters for intersections refer to the Indonesian Road Capacity Guidelines 2023 and the Regulation of the Minister of Transportation of the Republic of Indonesia Number PM 96 of 2015, which includes calculations of intersection capacity considering correction factors such as approach width (F_{LP}), median type (F_M), city size (F_{UK}), side obstacle (F_{HS}), left turn flow ratio (F_{BK_i}), right turn flow ratio (F_{BK_a}), and flow ratio from minor roads ($F_{R_{mi}}$). The degree of saturation (D_j) is calculated by comparing the actual traffic flow (q) to the intersection capacity (C), while delay is calculated based on the average time it takes for vehicles to cross the intersection. Analysis is conducted to determine the differences in traffic characteristics between working days and holidays. Additionally, it aims to identify potential flow conflicts and the effectiveness of intersection services.

RESULTS AND DISCUSSION

Land use around the intersection includes schools, residential areas, and small-scale commerce (shops, stalls). Although pedestrian activities are not very high,

the activity of motor vehicles entering and exiting the intersection area is quite high, particularly involving students and residents crossing without a zebra cross. The risk of traffic accidents involving pedestrians is considerable due to the lack of safe crossing options.

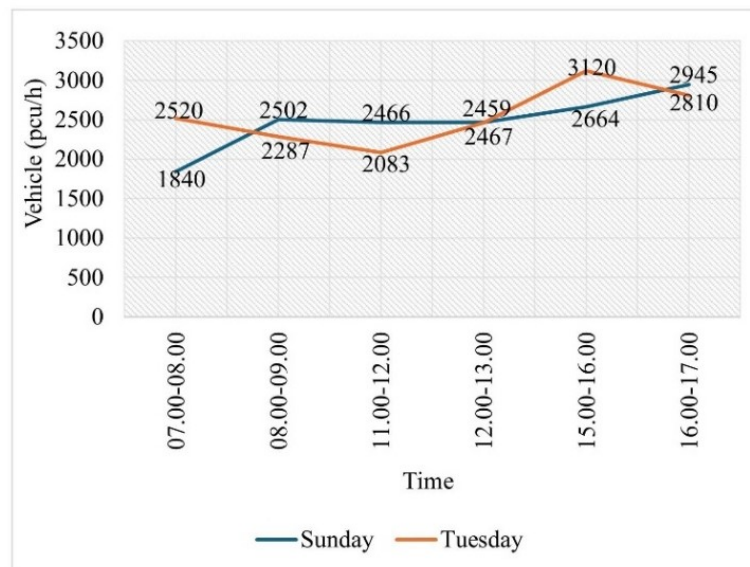


Figure 3: Traffic Volume at Hombis T-junction

The movement pattern of the main traffic tends to be constant on the major road (Christina Martha Tiahahu), while the traffic flow from Jalan Ade Irma Nasution is fluctuating. Conflicts often occur when vehicles exit from the minor road during high traffic volumes on the main road. Right turns and U-turns from the main road become additional sources of delays because there are no dedicated waiting lanes. Peak traffic volume on Sundays generally occurs in the afternoon with a total volume of 2945 PCU/h. Similarly, on Tuesdays, peak traffic volume also occurs in the afternoon with a total volume of 3120 PCU/h.

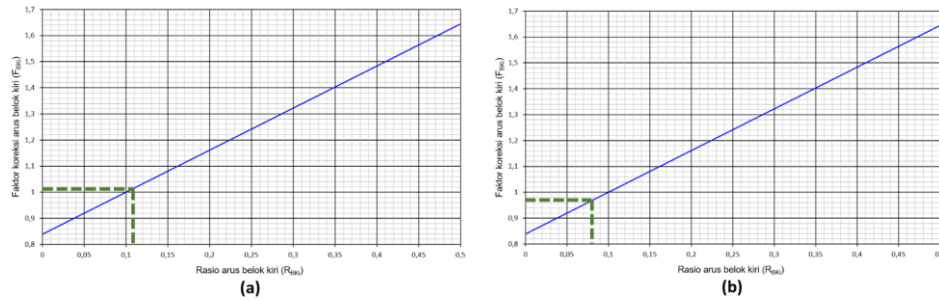


Figure 4: The Ratio of Left Turn Traffic Flow on Sunday (a) & Tuesday (b)

The left turn correction factor (F_{BKl}) for Sunday of 1.017 indicates that there is a 1.7% increase in intersection capacity requirements due to left turn maneuvers compared to the main flow without turns. The F_{BKl} value on Tuesday (office routine) is 0.969, indicating that intersection capacity requirements have decreased from baseline (0.84), which may indicate that left turn flows on weekdays have a lower corrective impact compared to Sunday. The graph shows a positive linear correlation between the left turn ratio and the correction factor, indicating that the higher the volume of left turns, the greater the capacity correction needed.

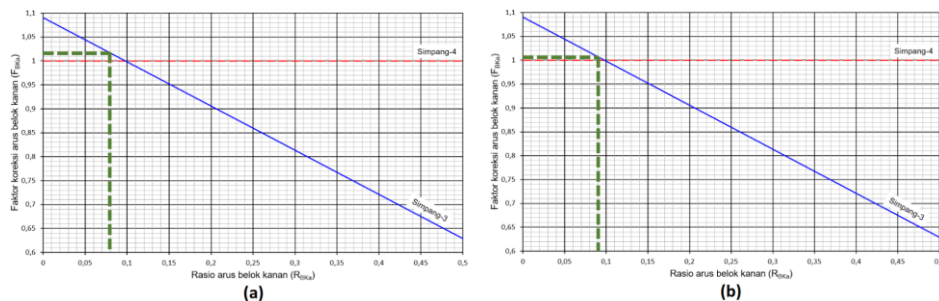


Figure 5: Ratio of the Right Turn Traffic Flow on Sunday (a) & Tuesday (b)

The right turn correction factor (F_{BKa}) on Sunday is 1.016, indicating a decrease in capacity due to right turn maneuvers. The graph shows a negative linear trend, meaning that the larger the right turn ratio, the lower the capacity correction value. On Tuesday, the F_{BKa} value is 1.007, indicating that on weekdays there are more right turn maneuvers compared to Sunday, but it still

results in a small capacity correction. Sundays tend to show a higher need for capacity correction for left turns, but lower for minor roads.

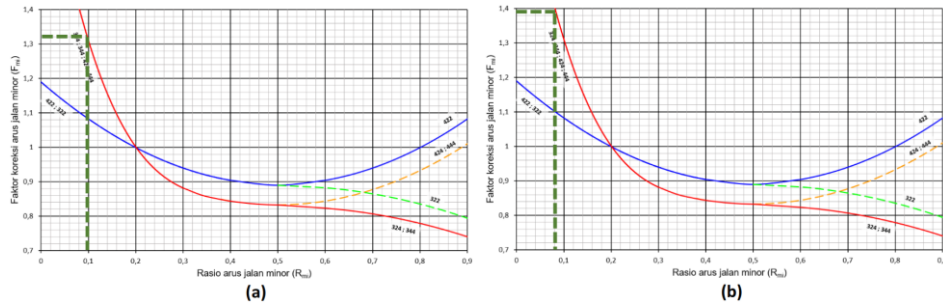


Figure 6: Correction Factor Graph of Minor Road Traffic Ratio on Sunday (a) & Tuesday (b)

Although the minor road flow ratio on Sunday is higher, the correction value of F_{Rmi} is actually higher on Tuesday (1.387 vs 1.320). This indicates a non-linear influence in the fourth-order polynomial model. The correction value does not always increase with the increase in the minor road flow ratio (F_{Rmi}). Mathematical Correlation: Linear models (F_{BK_i} and F_{BK_a}) represent a simple relationship, but the minor road correction requires a non-linear approach.

Table 3: Results of the Performance Analysis of Hombis T-Junction

Day	Traffic Flow (PCU/h)	Intersection Capacity (PCU/h)	Degree of Saturation (D_j)	Intersection Delay (sec/veh)	Level of Service (LoS)
Sunday	2945	3821	0,77	12,84	B
Tuesday	3120	3792	0,82	13,72	B

The performance assessment of operational traffic uses the D_j value. If the D_j value < 0.85 , the intersection is still considered feasible for operation for the coming years, but if the D_j value > 0.85 , changes are needed to improve intersection services. The traffic volume during peak hours reaches 2945 veh/h on holidays (Sunday) and 3120 veh/h on weekdays (Tuesday). Thus, the degree of saturation value obtained is 0.77 and 0.82 for Sunday and Tuesday, respectively. These values are still below the critical threshold of 0.85 according to PKJI 2023. Therefore, the intersection is still in an operational condition that can be tolerated and does not yet require structural intervention. However, the potential for congestion can occur daily if not controlled, especially during peak hours.

The average delay at this intersection is 13.72 sec/veh for Tuesday and 12.84 sec/veh for Sunday. Based on the classification of Minister of Transportation Regulation No. PM 96 of 2015, this delay categorizes the intersection at Level of Service (LoS) B, which indicates that vehicles experience light delays and traffic is still moving efficiently. This condition shows that even though it is not equipped with traffic light signals, the intersection is still able to manage traffic flow relatively efficiently. However, the dominance of vehicles from the main flow and conflicts from right turns or U-turns, especially during heavy traffic, becomes a crucial factor contributing to the occurrence of delays.

Factors Causing Flow Conflicts and Potential Risks

Geometric characteristics and intersection function show that the absence of traffic lights causes vehicles from the minor direction to have to utilize the natural space in the main flow. This often leads to high gap acceptance delays and significant potential conflicts, especially when vehicles are maneuvering to turn right and make U-turns. The lack of dedicated waiting lanes also exacerbates this situation, as vehicles stopping in the middle of the main road create additional conflict points and risk slowing down vehicles behind them. Spatially, the presence of schools, residential areas, and trade activities around intersections also affects traffic dynamics. Although pedestrian activity is relatively low, the lack of crossing facilities such as zebra crossings is an important factor that can trigger traffic accidents. In an Urban Spatial Plan, intersection conflicts can be addressed by integrating physical road planning and traffic flow control. In addition, traffic signal systems and improvements to intersection geometry are part of engineering strategies aimed at reducing queues and delays.

Implications for Urban Transportation Planning

The results of this research provide an overview that although the intersection is still functioning adequately, there is potential for performance decline due to vehicle growth and space limitations. Therefore, short-term recommendations that can be taken include installing clearer priority signs, adding road markings for traffic management, and educating drivers about the rules of unsignalized intersections.

Medium to long-term strategies may include redesigning intersections into mini roundabouts, widening lanes on minor approaches, or even conducting feasibility studies for the installation of automatic signaling systems if vehicle growth continues to rise. Such interventions are crucial to maintain traffic service quality and minimize conflicts that could potentially increase accident rates.

Opposing and protected conflicts are major phenomena that need to be considered in the evaluation of intersection performance. Therefore, the design of an intersection without traffic lights must pay attention to the distribution of

traffic volume and other factors to minimize conflicts and enhance vehicle flow efficiency. Additionally, widening the intersection arms is necessary to reduce queues and accelerate vehicle movement.

The integration of spatial planning and traffic engineering at intersections can be achieved through a holistic approach. In this context, spatial planning plays an important role in designing land-use patterns that support smoother traffic flow and reduce the potential for traffic conflicts. By combining the Traffic Conflict Technique (TCT) with real-time data, conflict analysis can be conducted more effectively. Furthermore, spatial and transportation planning needs to account for vehicle movement patterns, interactions among road users, and their broader impact on urban mobility.

CONCLUSION

The average saturation degree of the Simpang Tiga Hombis Lepo-Lepo Kendari intersection is 0.80 with a delay time of 13.28 seconds/vehicle. This indicates that the intersection has not yet reached a saturated condition but is approaching the critical threshold. The level of service at the intersection is categorized at level 'B', indicating that traffic operations are still smooth. However, there are indications of an increased potential for traffic conflicts, especially during right-turn maneuvers and U-turns. This is triggered by the absence of a dedicated waiting lane and suboptimal traffic flow management. The environmental conditions and land use around the intersection also contribute to the fluctuations and dynamics of traffic in the area. The lack of pedestrian crossings also negatively impacts pedestrian safety, especially during peak hours.

This research found that the correction factors for intersection capacity are greatly influenced by temporal variables and the characteristics of traffic maneuvers. Therefore, it is necessary to develop a differential approach based on the day and type of maneuver. Based on these findings, it is recommended to add road markings and priority signs to reduce ambiguity among drivers. If the trend of vehicle volume growth continues to increase, then the installation of traffic lights will be necessary.

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