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Assessing the efficacy of contraflow strategies and ripple effects on peripheral road network performance: Insights from Brigjen Sudiarto Road, Semarang

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Abstract

Traffic congestion is a significant challenge in Semarang, Indonesia, a rapidly urbanizing metropolitan area. To address this issue, a contraflow strategy was implemented on Brigjen Sudiarto Road, aiming to alleviate congestion and enhance traffic efficiency. The assessment of the contraflow system's effectiveness utilized the Indonesian Highway Capacity Manual (PKJI). Data were obtained through direct observation and secondary sources, focusing on traffic volume, road capacity, and level of service (LOS) comparisons before and after implementation. Findings revealed a 75% reduction in westbound traffic saturation, attributed to adding one lane, while eastbound congestion increased slightly due to lane reduction. The analysis also highlighted the contraflow's impact on surrounding roads, such as Soekarno Hatta and Supriyadi Streets, which serve as alternative routes during peak hours. Simulations indicated that the contraflow system improves flow efficiency and travel time, especially during morning and evening rush hours. This evaluation underscores the potential of contraflow strategies as practical interventions for managing urban traffic, providing insights for cities facing similar challenges globally.

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Keywords

Contraflow strategies, Ripple effect, Peripheral road network performance

Introduction

Semarang City is one of the fifth largest metropolitan cities in Indonesia. Factor that influence urban form and how cities function is mobility [1]. With numerous access points to the city, whether by land, sea, or air, supported by the many tourist attractions and advanced education, Semarang has become a strategic city for tourists, students, and workers who migrate to the city. The increase in the urban population has led to a rise in motor vehicles, which is not matched by improvements in road infrastructure, causing traffic congestion [2]. When the access to key activities were obstructed, it could lead to insufficient participation in social and economic life [3]. The rise in population due to urbanization affects the increasing demand in various sectors, such as education, trade, transportation, and others. Population growth requires the traffic systems and infrastructure to keep pace with these developments [4]. Many people still prefer to use private vehicles for various purposes such as commuting to work, education, business, and social activities, this leads to crowded roads in Semarang, compounded by movement from surrounding areas [5]. With the high travel potential, there is concern that traffic congestion will arise due to the imbalance between transport demand and supply, eventually moving people and goods inefficient [6]. The research location is on Brigjen Sudiarto Street, which located in the city center, connecting the city center to the outskirts, especially East Semarang. This road function as a major access point to the city center and beyond, particularly to the Demak and Grobogan regions [7]. According to the concentric zone theory, which divides urban areas into five zones central business district, transition zone, worker residential area, better residence, and commuter zone Brigjen Sudiarto Street, with its characteristics, marks the boundary between Demak and Semarang, further establishing it as a commuter road. Changes in land use at the city border will influence the surrounding transportation development [8]. Brigjen Sudiarto Street also features many shops and community centers, such as markets. As residential development grows at the border between Semarang City and Demak Regency, it results in high traffic volumes on Brigjen Sudiarto Street, reducing road capacity [9]. Given the road's location, variety of activities, and its vital function, contraflow is implemented to improve traffic flow. After all of the challenges that the Semarang government needs to face the city required to provide various facilities, both infrastructure and amenities, to support all aspects of community activities [10], that's why the government uses the contraflow. There has been no evidence proving the effectiveness of contraflow in addressing potential congestion issues on Brigjen Sudiarto Street, which is the background for conducting this research using the Indonesian Highway Capacity Manual (PKJI). Some studies was evaluated contraflow lanes for hurricane evacuation and highlighted that their effectiveness depends on variables such as traffic volume, composition, road design, and the length of contraflow segments [11–13]. Similarly, Meng et al. analyzed speed distributions in freeway work zones and emphasized the role of these factors in determining traffic performance under varying conditions [14–16]. Various algorithms and simulation techniques have been employed to assess the outcomes of different contraflow configurations. Advanced software tools like DynusT [17], DYNASMART (Dynamic Network Assignment-Simulation Model for Advanced Roadway Telematics) [18], and CORSIM [19] have been designed to model and predict traffic volumes and travel times under different contraflow configurations. Optimization methods, including heuristic algorithms [20][21], genetic approaches [22], greedy techniques [23], and Tabu search [20][21][24], have been applied to determine the most effective contraflow strategies. These approaches, supported by modeling and simulation, have led to significant progress in utilizing contraflow for mass evacuation scenarios. However, these methodologies require substantial real-world data for parameter tuning and validation to ensure the accuracy and practicality of the proposed models.

Method

The research was conducted on the section of Brigjen Sudiarto Street, located in Semarang City. This road functions as a secondary collector road used to support community activities and serves as an entry route to Semarang City from outside the city. The road type is 4/2 T, consisting of 4 lanes and 2 directions with a divider. The road has a length of 7.6 km, and the entire Brigjen Sudiarto section is used for the contraflow implementations.

Road level of service analysis

After data collection, a capacity analysis was conducted to determine the capacity a road section can accommodate relative to the traffic volume passing through it. The following method used to calculate capacity of a road section.

$$C = Co \times FCLJ \times FCPA \times FCHS \times FCUK \quad (1)$$

Information:

C = Road Capacity (smp/hour)
Co = Road Base Capacity (smp/hour)
FCLJ = Road With Adjusment Factor
FCPA = Direction Separation Adjusment Factor
FCHS = Adjusment Factor for Side Obstacles and Roadside
FCUK = City Size Factor

Before determining the level of service (LOS) for a road section, it is necessary to calculate the traffic volume to identify the peak hour. Traffic volume is obtained by counting each vehicle passing through a road section, and then the result is converted into passenger car units (smp). Once the volume and capacity of a road section are determined, the level of service can be calculated to understand the characteristics of the road. The level of service can be found using the following formula,

$$V/C \text{ ratio} = V/C \quad (2)$$

Information :

V/C ratio = Road Level Of Service
V = Volume at Peak Hour
C = Capacity

After obtaining the level of service for the road section, a speed analysis is conducted using the percentile of 85%. The travel speed can be calculated using the following formula.

$$Vt = J/W \quad (3)$$

Information :

Vt = Travel Speed
J = Distance
W = Time

Then, an analysis of the travel time for passenger cars passing through the road section is conducted. The travel time for vehicles on a road section can be calculated using the following formula.

$$Wt = PJ/Vm \tag{4}$$

Information :

Wt = Travel Time
Pj = Road Length
Vm = Vehicle Speed

The analysis results will be used to determine the effect of contraflow on Brigjen Sudiarto Street in Semarang City and will serve as a traffic simulation before and after the implementation of contraflow on the road.

Results and Discussion

The results and discussion of this research aim to assess the traffic performance on Brigjen Sudiarto Street and surrounding roads affected by the contraflow. Traffic performance is analyzed to determine the level of service (LOS) for a road section, allowing the effects of contraflow implementation on the selected road section to be evaluated. Once the road section's performance is known. The following are the results and discussions from this research.

Brigjend Sudiarto level of service

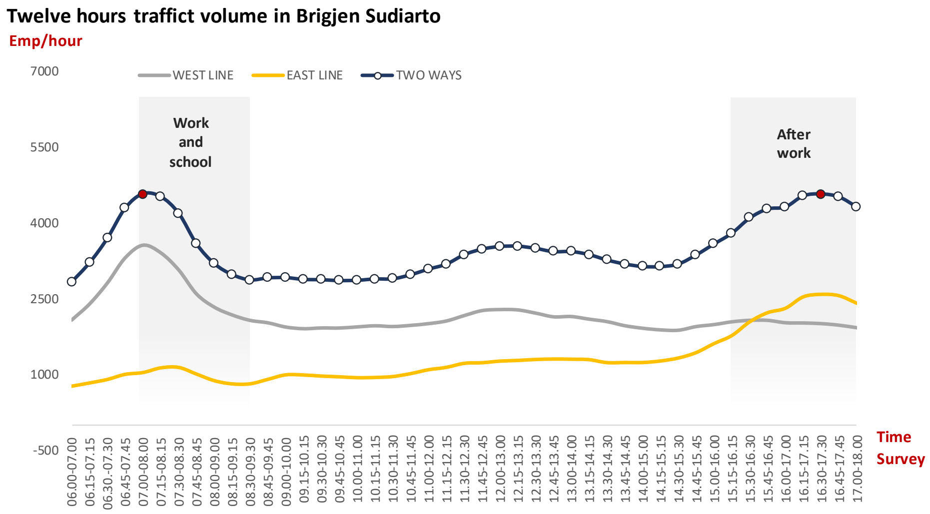

Figure 1. Vehicle Volume

To assess the traffic performance on Brigjen Sudiarto Street, traffic counts were conducted to obtain the highest volume during both the implementation and non-implementation of contraflow.

Based on Figure 1, the traffic volume in terms of smp/hour (passenger car unit per hour) was obtained. It was found that the peak traffic during the implementation of contraflow on Brigjend Sudiarto Road, westbound (towards the city center), occurred between 07:00-08:00 with a traffic volume of 3,550.1 smp/hour. When contraflow was not implemented, the peak occurred between 12:00-13:00 with a volume of 2,267 smp/hour. The eastbound peak traffic (out of the city) during the contraflow implementation occurred between 07:30-08:30 with a volume of 1.130 smp/hour. When contraflow was not in place, the peak traffic occurred between 16:30-17:30 with an eastbound traffic volume of 2,578.3 smp/hour. This indicates that Brigjend Sudiarto Road serves as a key route connecting the suburban or outlying areas of Semarang with the city center, and is primarily used by commuters. To determine the level of service on a road segment, it is necessary to calculate the capacity of the road. Table 1 below is the capacity of Brigjend Sudiarto Road using the 2023 PKJI formula.

Table 1. Brigjend Sudiarto Street Capacity

Capacity Factor					Capacity
Co	FClj	FCpa	FChs	FCuk	3480,6
3200	1,11	1,05	1	0,93	

Based on Table 1, the calculated road capacity for Brigjend Sudiarto is 3,480.6.

After obtaining the traffic volume and road capacity for Brigjend Sudiarto, the level of service is determined using the V/C ratio (volume to capacity ratio) and vehicle speed, measured using the 85th percentile speed. To understand the road characteristics, calculations for travel speed and travel time on the road segment were conducted.

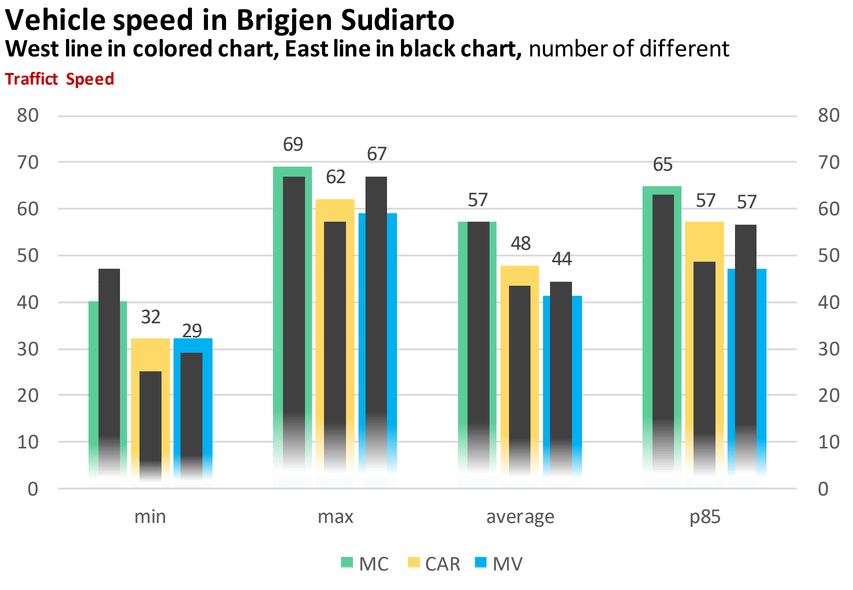

Figure 2. Vehicle Speed

Based on Figure 2, the speed results using the 85th percentile method for Brigjend Sudiarto Road were determined. The motorcycles speed was recorded at 65 km/h, passenger cars at 57 km/h, and medium vehicles at 57 km/h. Meanwhile, the travel time for vehicles passing through the road was 6.4 minutes.

Table 2. Brigjend Sudiarto Street Level Of Service

Condition	Capacity	Volume	LOS	Vehicle Speed			Time Travel
				SM	MP	KS	
Contraflow	7.270 smp/h	4579 smp/h	0,62	63 km/h	48 km/h	57 km/h	6,4 min
No Contraflow	7.270 smp/h	2578 smp/h	0,35				

The following is the analysis result of the traffic performance on Brigjend Sudiarto Road. According to Table 2, the road capacity was calculated to be 7,270.5 PCU/hour. The traffic volume during contraflow was 4,579 PCU/hour, while without contraflow, it was 2,578 PCU/hour. The level of service during contraflow was 0.62, and 0.35 when contraflow was not in effect. The travel speed for motorcycles was 63 km/h, passenger cars 48 km/h, and medium vehicles 57 km/h, with a travel time of 6.4 minutes. Then, it can be concluded that the level of service during contraflow does not significantly differ from when contraflow is not applied.

Level of service around Brigjend Sudiarto street

To assess the impact of the contraflow on the areas surrounding Brigjend Sudiarto Road, an analysis of traffic performance on several affected roads, such as Soekarno Hatta Road, Supriyadi Road, Gajah Raya Road, and Lamper Tengah Road, needs to be conducted. The performance analysis of these roads is based on calculating the capacity divided by the volume during peak hours on each road to determine the level of service. Additionally, vehicle speed and travel time are measured to identify the performance on each road segment. The following are the analysis results of the traffic performance on roads around Brigjend Sudiarto:

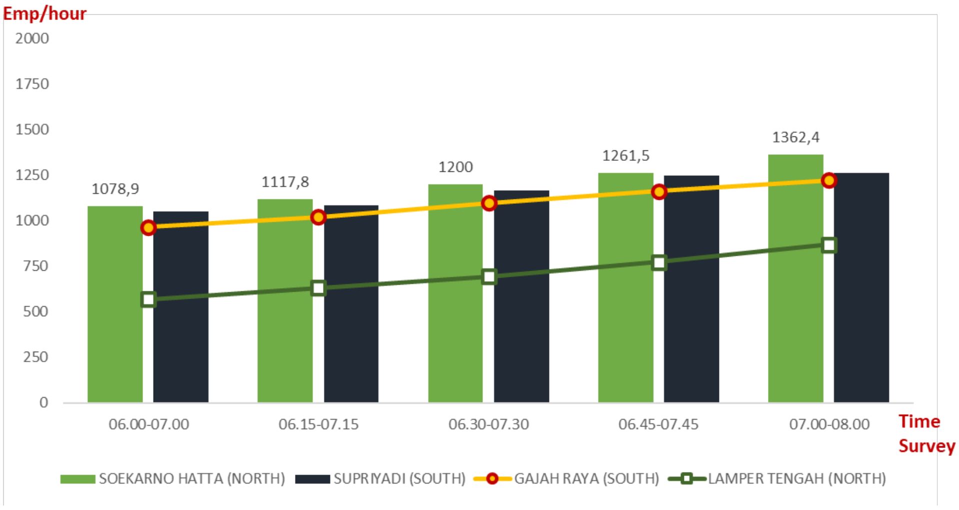

Figure 3. Traffic volume around Brigjend Sudiarto Street in the morning.

In the morning (Figure 3), the traffic volume around Brigjend Sudiarto Road is not very congested, as most drivers prefer to use Brigjend Sudiarto Road, where contraflow is applied during the morning rush hour. Roads such as Supriyadi, Gajah Raya, and Lamper Tengah serve as feeder routes for drivers from various areas to reach Brigjend Sudiarto Road and access the city center more quickly due to the contraflow.

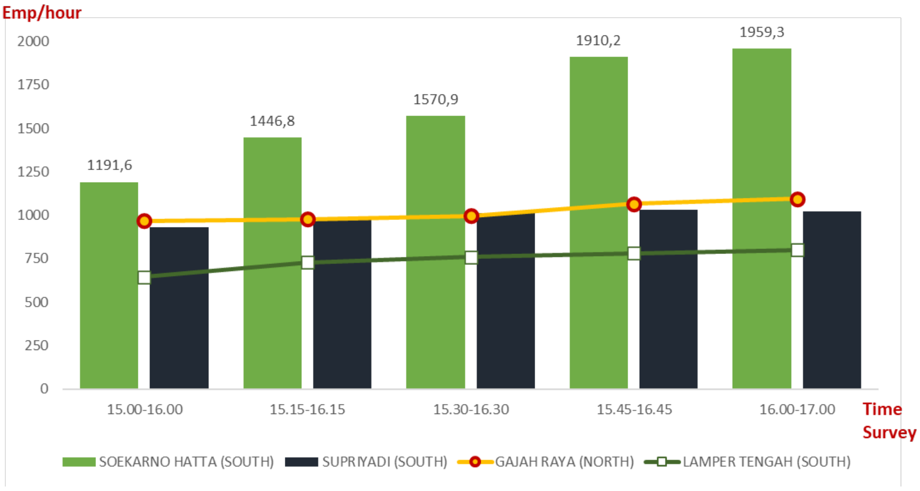

Figure 4. Traffic volume around Brigjend Sudiarto Street in the afternoon

In the afternoon (Figure 4), traffic congestion increases, largely driven by workers returning home, resulting in higher traffic volumes on roads around Brigjend Sudiarto road compare to the morning. On Soekarno Hatta Road, traffic increases as drivers try to avoid the congestion on Brigjend Sudiarto Road while heading toward the city outskirts or out of town, leading to higher traffic volumes than in the morning. Meanwhile, other roads (Supriyadi, Gajah Raya, and Lamper Tengah) continue to serve as connector routes for drivers returning to their homes, although they are less busy than in the morning.

Table 3. Level of service around Brigjend Sudiarto Street

Street Name	Capacity	Volume	LOS	Travel Speed			Time Travel
				SM	MP	KS	
Soekarno Hatta	6.081,9	3150 smp/h	0,59	55 km/h	36 km/h	32 km/h	9 min
Supriyadi	5.940,5	2.377,6 smp/h	0,39	47 km/h	37 km/h	34 km/h	3 min
Gajah Raya	2.840,8	2.272 smp/h	0,78	44 km/h	36 km/h	25 km/h	2,2 min
Lamper Tengah	2.632	1667 smp/h	0,63	33 km/h	36 km/h	24 km/h	2,4 min

Based on Table 3, the analysis results of traffic performance around Brigjend Sudiarto Road are as follows. On Soekarno Hatta Road, the level of service was 0.59, with motorcycle speeds at 55 km/h, passenger cars at 36 km/h, and medium vehicles at 32 km/h, with a travel time of 9 minutes. On Supriyadi Road, the level of service was 0.39, with motorcycle speeds at 47 km/h, passenger cars at 37 km/h, and medium vehicles at 34 km/h, with a travel time of 3 minutes. For Gajah Raya Road, the level of service was 0.78, with motorcycle speeds at 44 km/h, passenger cars at 36 km/h, and medium vehicles at 25 km/h, with a travel time of 2.2 minutes. On Lamper Tengah Road, the level of service was 0.63, with motorcycle speeds at 33 km/h, passenger cars at 36 km/h, and medium vehicles at 24 km/h, with a travel time of 2.4 minutes.

Conclusion

Based on the research conducted, the analysis of traffic performance on Brigjend Sudiarto Road during the implementation of contraflow concluded that the westbound peak occurred from 07:00 to 08:00 AM with a traffic volume of 3,550.1 PCU/hour, predominantly consisting of 49% of drivers coming from outside the city. The degree of saturation on Brigjend Sudiarto Road decreased by 75% westbound due to the addition lane to accommodate vehicles heading toward the city. In contrast, the eastbound direction experienced a 50% increase in saturation. The contraflow on Brigjend Sudiarto Road also impacted nearby roads, with certain routes becoming secondary choices for drivers, such as Soekarno Hatta Road both in the morning and afternoon. Additionally, other roads like Supriyadi, Gajah Raya, and Lamper Tengah served as connectors for drivers heading towards the contraflow in the morning; however, in the afternoon, the volume of traffic on these roads was not as high as in the morning.

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