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ANALYSIS OF THE EFFECT OF U-TURN ON TRAFFIC FLOW PERFORMANCE

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ABSTRACT
This paper aims to explore the impact of U-turn motions on traffic flow and service levels. The research employs the Guidebook (PKJI, 2023) to assess observations related to traffic volume, vehicle speed, and both disturbed and undisturbed flow, which are gathered during the field survey. The data used for analysis was obtained by collecting primary data and secondary data according to the needs of the research. In addition, the data was obtained from a number of reports and documents that had been prepared, as well as the results of other literature studies. The results show that the number of vehicles on a road section is significantly increased, resulting in a significant increase in traffic volume and a decrease in vehicle speed. Moreover, the frequency of the use of the maneuvers affects the level of congestion on the road section, highlighting the need for early and strategic planning in the development of transportation infrastructure, particularly land transportation, which is crucial for facilitating everyday mobility and economic activities. This paper also highlights the importance of incorporating advanced traffic modeling techniques and simulations to enhance prediction of traffic behavior under different scenarios, informing infrastructure improvements and traffic management strategies. Finally, comparing findings with similar studies in other regions could yield valuable benchmarks for assessing traffic efficiency and service quality.

INTRODUCTION

Transportation plays a vital role in human life, significantly impacting individuals, society, and the economic and socio-political development of a country (Alamgir et al., 2017; Hariram et al., 2023; Khreis et al., 2016; Lesutis, 2020; Porter, 2014). It serves as the backbone for connectivity, enabling the movement of people and goods essential for trade, communication, and social interaction. Without efficient transportation systems, achieving satisfactory development outcomes across various sectors becomes challenging (Lv & Shang, 2023; Nundy et al., 2021; Silva et al., 2018; Singh et al., 2022; Zhang et al., 2011). This underscores the necessity for early and strategic planning in the development of transportation infrastructure, particularly land transportation, which is crucial for facilitating everyday mobility and economic activities.

Land transportation encompasses the movement of people and goods using vehicles over land. According to Lubis (2010), this form of transportation is essential for ensuring accessibility and fostering regional development. However, several challenges hinder the efficiency of land transportation systems, one of the most notable being the issue of U-turn motions. U-turns can lead to significant delays and interruptions in traffic flow, as they often require vehicles to slow down or come to a complete stop (Datta et al., 2020; Hu et al., 2022; Jovanović et al., 2023; KRUKOWICZ et al., 2021; Shi et al., 2023). This disruption not only affects the vehicle making the U-turn but can also create a

ripple effect, impacting the movement of other vehicles in the same direction and potentially causing congestion.

Another critical concern associated with U-turn maneuvers is the turning radius required for vehicles to execute them safely and efficiently. Many vehicles may not possess the necessary turning radius to make U-turns directly, resulting in awkward positioning on the roadway and further exacerbating traffic disruptions. This inability to perform U-turns smoothly can lead to halted traffic, increased frustration among drivers, and a higher likelihood of accidents. Addressing this issue is essential for improving overall traffic flow and safety, highlighting the need for careful planning and design of roadways that accommodate U-turns while minimizing their impact on the surrounding traffic. Effective solutions could enhance the efficiency of land transportation, contributing to smoother traffic patterns and better outcomes for all road users.

Therefore, it is important to research the extent to which the frequency of U-turn use affects the level of congestion on a road section. This research is focused on the location of Jl. Raya Panembahan because the location often experiences congestion, and we want to find out what causes and factors contribute to congestion on the road. By understanding these causes and factors, it is hoped that effective solutions will be used to reduce congestion.

METHODS

The data used for analysis was obtained by collecting primary data and secondary data according to the needs of the research. The data collection method consists of, 1) Traffic Volume Data. 2) Side obstacle data. 3) U-turn Travel Time Data. To support the research, the data was obtained from a number of reports and documents that had been prepared, as well as the results of other literature studies. The data needed includes, 1) Population data, 2) PKJI, 2023. 3) Other Supporting Data.

The implementation of data and information collection is carried out by two data collection techniques, namely:

1) Field Survey:
   a. Placing survey officers at the survey location that has been determined, namely as many as 3 survey officers with their respective duties, namely volume recording officers totaled 2 officers, vehicle registrar who makes a u-turn, and the officer who recorded the long queue that will make a u-turn.
   b. Enumeration is done with counters cumulatively. The cumulative number of enumeration is written in the survey form at the end of each period. One period is done in 15 minutes.
   c. The division of vehicle types is adjusted to the needs of the survey. And in the survey it is divided into 3 types of vehicles, namely, light vehicles, heavy vehicles, and motorized vehicles.
2) Documentation: The documentation method is a data collection that produces important records related to the problem being researched.

The data collection survey is conducted in two stages: first, survey preparation, which involves a literature review, technical setup, and mobilization of personnel; and second, the implementation of the survey, executed after thorough planning. For data analysis, the research employs the Guidebook (PKJI, 2023) to assess observations related to traffic volume, vehicle speed, and both disturbed and undisturbed flow, which are gathered during the field survey.

RESULTS

Traffic Data

Traffic Volume

Traffic collection and volume were carried out in the observation time interval on Jl. Raya Panembahan, Cirebon Regency - Jakarta. The total observation time is 6 hours per day for six days. Pick-up time from 07.00-09.00 WIB, 12.00-14.00 WIB, and 16.00-18.00 WIB. The vehicle volume data is then converted from kend/hour to junior high school units/hour. And the multiplier factors for SM (0.5), MP (1.0) and TB (1.3) these numbers are taken based on the PKJI guidelines, 2023. The results of the calculation of the traffic volume of each location can be seen in Table 1.

Table 1. Traffic Volume Data.

Time	Intersection, Jl. Raya Panembahan, Kab. Cirebon - Jakarta			Total Vehicle/15 Minute	PHV	Intersection, Jl. Raya Panembahan, Kab. Cirebon - Semarang			Total Vehicle/15 Minute	PHV
	SM	*MP*	*TB*			*SM*	*MP*	*TB*		
Saturday, 27 April 2024										
07.00-07.15	385	321	72	778		319	422	89	830	
07.15-07.30	376	344	52	772		344	445	85	874	
07.30-07-45	399	321	27	747	3080	305	479	76	860	3492
07.45-08.00	389	364	30	783		370	460	98	928	
Total Vehicle/1 hour	1549	1350	181	3080		1338	1806	348	3492	
08.00-08.15	376	409	37	822		455	371	86	912	
08.15-08.30	401	419	30	850		444	363	84	891	
08.30-08-45	428	389	41	858	3385	418	304	86	808	3448
08.45-09.00	412	404	39	855		430	311	96	837	
Total Vehicle/1 hour	1617	1621	147	3385		1747	1349	352	3448	
12.00-12.15	327	310	76	713		345	324	99	768	
12.15-12.30	319	327	95	741		365	426	68	859	
12.30-12-45	342	362	79	783	2958	337	438	99	874	3292
12.45-13.00	316	308	97	721		373	334	84	791	
Total Vehicle/1 hour	1304	1307	347	2958		1420	1522	350	3292	
13.00-13.15	281	453	98	832		365	418	75	858	
13.15-13.30	256	470	87	813		379	434	87	900	
13.30-13-45	285	481	95	861	3270	382	497	89	968	3687
13.45-14.00	292	399	73	764		372	508	81	961	
Total Vehicle/1 hour	1114	1803	353	3270		1498	1857	332	3687	

16.00-16.15	357	425	86	868	3501	347	430	84	861	3268
16.15-16.30	334	436	88	858		330	427	86	843	
16.30-16-45	357	429	91	877		315	435	95	845	
16.45-17.00	376	441	81	898		331	319	69	719	
Total Vehicle/1 hour	1424	1731	346	3501		1323	1611	334	3268	
17.00-17.15	345	470	60	875	3659	293	488	96	877	3503
17.15-17.30	358	446	87	891		357	440	94	891	
17.30-17-45	389	457	89	935		307	479	83	869	
17.45-18.00	415	449	94	958		346	442	78	866	

To facilitate the calculation, only one sample of volume data was taken from each research location. From the calculations made, the largest volume is composed of the busiest 15 minutes for 1 hour.

1) Simpang, Jl. Raya Panembahan, Kab. Cirebon-Jakarta

$$PHF = \frac{PHV}{(4\ x\ Vmax)}$$

$$PHF = \frac{3643}{(4\ x\ 989)}$$

$$= 0{,}92$$

2) Simpang, Jl. Raya Panembahan, Kab. Cirebon - Semarang

$$PHF = \frac{PHV}{(4\ x\ Vmax)}$$

$$PHF = \frac{3500}{(4\ x\ 925)}$$

$$= 0{,}95$$

Cirebon Domography Data

Cirebon, located on the north coast of West Java, has a population of about 330,000 people with a density of more than 10,000 people per square kilometer. About 25% of the population are children (0-14 years old), 65% of productive age (15-64 years old), and 10% of the elderly (65+ years old). The gender ratio is almost balanced, with 51% male and 49% female. The majority of ethnicities are Sundanese, followed by Javanese and Chinese. About 95% of the population adheres to Islam, with Christian minorities (3%), Buddhists, and Hindus (1% each). The literacy level reaches more than 90%, with many educational institutions including Gunung Jati Independent University. Labor force participation is about 70%, with the main industries of trade, manufacturing, services, and agriculture. The average life expectancy is 72 years, and health facilities include several hospitals and clinics. Cirebon is very urban with most of the population living in urban areas.

Side Obstacle Data

Table 2. Side resistance data

Time	Jl. Panambahan, Kab. Cirebon - Semarang			
	Pedestrian (PED)	**Parking Vehicles (PSV)**	**Vehicle in/out (EEV)**	**Slow vehicles (SMV)**
Saturday, 27 April 2024				
07.00-08.00	36	10	10	10
08.00-09.00	38	18	21	15
12.00-13.00	28	17	14	11
13.00-14.00	26	16	21	14
16.00-17.00	23	17	26	18
17.00-18.00	28	21	20	18
Total	179	99	112	86
Total EMP Values	89,5	99	78,4	34,4
Category Code	301,3	M	Medium	
Sunday, 28 April 2024				
07.00-08.00	35	17	18	43
08.00-09.00	37	15	14	15
12.00-13.00	22	12	20	12
13.00-14.00	21	18	21	21
16.00-17.00	18	20	16	23
17.00-18.00	19	14	17	25
Total	152	96	106	139
Total EMP Values	76,00	96	74,2	55,6
Category Code	301,80	M	Medium	
Monday, 29 April 2024				
07.00-08.00	28	21	8	28
08.00-09.00	29	24	6	22
12.00-13.00	28	25	9	24
13.00-14.00	25	21	7	25
16.00-17.00	32	19	8	33
17.00-18.00	27	18	9	30
Total	169	128	47	162
Total EMP Values	84,5	128	32,9	64,8
Category Code	310,2	M	Medium	
Time	**Jl. Panambahan, Kab. Cirebon - Jakarta**			
	Pedestrian (PED)	**Parking Vehicles (PSV)**	**Vehicle in/out (EEV)**	**Slow vehicles (SMV)**
Sunday, 28 April 2024				
07.00-08.00	23	10	21	20
08.00-09.00	21	11	32	21
12.00-13.00	21	14	14	25

13.00-14.00	28	17	24	28
16.00-17.00	26	12	14	26
17.00-18.00	25	17	17	34
Total	144	81	122	154
Total EMP Values	72	81	85,4	61,6
Category Code		300 M	Medium	
		Monday, 29 April 2024		
07.00-08.00	23	18	14	21
08.00-09.00	32	13	14	24
12.00-13.00	24	14	13	25
13.00-14.00	21	15	13	23
16.00-17.00	25	16	11	26
17.00-18.00	24	13	14	27
Total	149	89	79	146
Total EMP Values	74,5	89	55,3	58,4
Category Code	277,2	M	Medium	

The calculation data is taken from the largest data:

1) Pedestrian (PED)
   PED = Total x emp = 139 x 0.5 = 69,5
2) Parking/stopping vehicles (PSV)
   PSV = Total x emp = 133 x 1.0 = 133
3) Vehicle in/out (EEV)
   EEV = Total x emp = 91 x 0.7 = 63,7
4) Slow vehicles (SMV)
   SMV = Total x emp SMV = 164 x 0.4 = 65,6
5) SCF = PED + PSV + EEV + SMV = 69,5 + 133 + 63,7 + 65,6 = 331,8 (Medium)

Road Capacity Data

The location of the research is on a road consisting of 4 lanes and 2 directions. The geometric data of the research location can be seen in Table 3.

Table 3. Geometric data of the research site.

Research location	Road Type	Road width (m)	Median width (m)	A-Turn Aperture Width (m)	Road Shoulder Width (m)
Jln. Besar Tanjung Morawa	4/2 D	11,8	1	14	1,5

Vehicle Flow Condition (V/C Ratio)

Capacity calculation uses the formula in the urban MKJI guidelines that have adjustment factors. It can be seen in Table 4.

Table 4. Calculation of road capacity

Research location	Adjustment Factors				
	Co (smp/hour)	FCw	FCsp	FCsf	FCcs
Simpang, Jl. Raya Panembahan, Kab. Cirebon	1650	1,08	1,00	0.96	1.04

The presentation of data from the table above shows the number of vehicles from each lane used with the observation distance limit that has been determined, converted to the adjustment factor

according to the type of vehicle whose unit is junior high school, the conversion made from the number of vehicles per lane, from the total number of vehicles added up to the unit changed to per hour of each lane, for the capacity of the traffic flow condition obtained from the multiplication of all adjustment factors according to PKJI, 2023 to obtain the V/C Ratio by dividing the traffic volume on each road section to the total capacity of each lane of the road section. Capacity calculation at the research site: Simpang, Jl. Raya Panembahan, Kab. Cirebon- Jakarta.

The 4/2 D road section obtained the capacity per lane C = Co x FCw x FCsp x FCsf x FCcs = 1650 x 1.08 x 1.00 x 0.96 x 1.04 = 1654.08 smp/h.

By having 4 lanes, the capacity is as follows: C = 4 x 1654.08 smp/h = 6616.32 smp/h.

Degree of Saturation

The degree of saturation is calculated using current and capacity expressed in smp/hour To facilitate the calculation, only one sample of volume data is taken from each research location, which is the largest volume data.

1) Simpang, Jl. Raya Panembahan, Kab. Cirebon - Jakarta

$$DJ = \frac{Q_{smp}}{C}$$
$$= \frac{2204,9}{6616,32}$$
$$= 0,32$$

2) Simpang, Jl. Raya Panembahan, Kab. Cirebon - Semarang

$$DJ = \frac{Q_{smp}}{C}$$
$$= \frac{2793}{6616,32}$$
$$= 0,42$$

Data on the number of vehicles making U-turns

The data on the number of U-Turn vehicles is differentiated according to 4 types of vehicles, namely motorcycles (SM), light vehicles (MP), and Heavy Vehicles (TB).

Table 5. Number of vehicles that curve U Turn (Saturday, 27 April 2024)

Time	Simpang, Jl. Raya Panembahan, Kab. Cirebon - Jakarta			Simpang, Jl. Raya Panembahan, Kab. Cirebon - Semarang		
	SM	***MP***	***TB***	***SM***	***MP***	***TB***
07.00-07.15	25	5	0	32	12	0
07.15-07.30	15	2	0	4	3	0
07.30-07-45	21	4	0	21	5	0
07.45-08.00	36	7	0	32	2	0
08.00-08.15	14	3	0	21	8	0
08.15-08.30	18	8	0	3	4	0
08.30-08-45	32	2	0	6	9	0
08.45-09.00	15	1	0	12	4	0
12.00-12.15	15	3	0	15	3	0

12.15-12.30	3	6	0	12	6	0
12.30-12-45	15	11	0	14	8	0
12.45-13.00	21	1	0	2	2	0
13.00-13.15	9	6	0	15	4	0
13.15-13.30	6	3	0	21	7	0
13.30-13-45	17	8	0	15	2	0
13.45-14.00	19	4	0	18	6	0
16.00-16.15	21	5	0	21	2	0
16.15-16.30	15	3	0	23	7	0
16.30-16-45	27	6	0	15	4	0
16.45-17.00	31	2	0	18	8	0
17.00-17.15	27	7	0	19	3	0
17.15-17.30	21	4	0	13	7	0
17.30-17-45	22	8	0	13	4	0
17.45-18.00	18	2	0	15	7	0

Calculating Vehicle Speed

To make the calculation easier, only one sample of the average travel time of the largest vehicle was taken.

1) Intersection, Jl. Raya Panembahan, Kab. Cirebon – Jakarta

Distance = 50 m = 0,05 km
Time = 6,43 sec = 0,0017 hour
Average travel speed $= \frac{Distance}{Average\ time}$
$= \frac{0,05}{0,0017}$
= 14 km/hour

2) Intersection, Jl. Raya Panembahan, Kab. Cirebon – Semarang

Distance = 50 m = 0,05 km
Time = 14,41 sec = 0,004 hour
Average travel speed $= \frac{Distance}{Average\ time}$
$= \frac{0,05}{0,004}$
= 12,5 km/hour

Road Service Level

To determine the level of road service, data on traffic volume and road capacity are needed. The following is a calculation using the V/C calculation ratio, which can be seen in Table 6.

Table 6. Distribution of V/C Values

Research location	Volume V (smp/h)	Capacity C (smp/h)	V/C	Service Level
Jl. Raya Panembahan, Kab. Cirebon	3643	6616,32	0,55	C

From the V/C value distribution data obtained from the analysis in the field, it can be seen that the service level of Jl. Raya Panembahan, Cirebon - Jakarta Regency has a service level of C. Where the service level in the flow zone is stable. Drivers are limited in choosing speed.

CONCLUSION

The study on Jalan Panembahan in Cirebon Regency reveals a traffic volume of 3,643 smp/h and a road capacity of 6,616.32 smp/h, resulting in a service level of C. The degree of saturation is determined using these flow and capacity metrics, with a single sample of the largest volume data taken from key locations, specifically 0.32 for Jl. Raya Panembahan, Cirebon Regency - Jakarta and 0.42 for Jl. Raya Panembahan, Cirebon Regency - Semarang. Side resistance, calculated from various factors, yielded a medium score of 331.8. Future research should expand on this by analyzing traffic patterns and service levels across multiple road sections, collecting longitudinal data to identify peak traffic periods, and examining the effects of side resistance on traffic flow. Incorporating advanced traffic modeling and comparing results with similar studies could further enhance understanding of traffic efficiency and management strategies.

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