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TRAFFIC MANAGEMENT EFFECTIVITY OF BULAK KAPAL UNDERPASS DEVELOPMENT, BEKASI INDONESIA

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ABSTRACT

Crossroads are one of the places that become a source of congestion. One of the intersections that are a source of congestion in Bekasi is the Bulak Kapal Intersection. This study aims to analyze the effectiveness of traffic management in the Bulak Kapal Underpass. The data collection method was carried out by distributing questionnaires offline and online. Data processing from respondents' questionnaire answers is presented using a spider chart with Microsoft Excel tools. The results showed that eleven parameter assessments before the Underpass was built and after the Underpass was built experienced an increase. The three parameters with the highest gap values or parameters that share a significant increase are traffic density, vehicle speed, and comfort. Meanwhile, the three parameters with the lowest gap values are road condition parameters, road completeness, and environmental friendliness.

INTRODUCTION

Roads are transportation infrastructure that has a significant role in supporting the economic and social activities of the community. Roads are expected to streamline time and facilitate people's mobility, ensure the safety and comfort of their users, and be economical in their construction and maintenance. However, in reality, many of the roads that exist today need to meet the traffic demands of today's modern society. One of the things that have not met these demands is that there are still traffic jams that hinder mobility activities (Sun, Bocchini, & Davison, 2020); (Raji, Zava, Jirgba, & Osunkunle, 2017); (Jiang, Ma, Broyd, Chen, & Luo, 2022).

The rapid development and increasing use of cars have caused traffic congestion in major cities in Indonesia. Bekasi City, as the gateway and buffer for the capital city of Jakarta, has high mobility because of the density of the city of Jakarta. According to Johan Budi Gunawan, Head of the Traffic Division of the Bekasi City Transportation Agency, the number of vehicles in Bekasi City reached 1.5 million units, consisting of 300 thousand four-wheeled vehicles and 1.2 million two-wheeled vehicles. Meanwhile, according to data from the One-Stop Manunggal Administration Unit (Samsat) of Bekasi City, the number of vehicles reached 1,613,317 units consisting of 25% of four-wheeled vehicles and 75% of two-wheeled vehicles. (Saleh, Sugiarto, Hilal, & Ariansyah, 2017); (Dermawan, W. B., Imamsyah, A., 2020); (Dishub Kota Bekasi, 2019).

The high capacity of vehicles will trigger congestion and unstable traffic flow. A crossroads or a meeting place for the flow of traffic from several lanes is a place that is usually a source of congestion. With the congestion problem, the government is looking for a solution to deal with it. One of the options that the government is doing to deal with congestion and traffic congestion is to use lanes that are not in the same plot, be it (Jiang, et al., 2018); (Koźlak & Wach, 2018) *flyovers* or *Underpasss* (Yasin, et al., 2017).

Simpang Bulak Kapal is one of the road sections with high traffic flow and is a node of traffic density in the East Bekasi area. This intersection is the meeting point of vehicles that cross Jalan Ir. Juanda (connecting Bekasi City-Regency), Jalan Joyo Martono (from the entrance direction of the East Bekasi Toll Road), Jalan Pahlawan (direction of Perumnas 3), and Jalan Diponegoro (direction of Tambun or Pantura Lane). The construction of this (Alfian & Pangsetu, 2021)*Underpass* has a 690-meter-long main Underpass consisting of two lanes with a width of 3.5 meters each. The construction of the Bulak Kapal Underpass was due to traffic conditions at the intersection of a plot of Bulak Kapal, which was very congested due to the confluence of traffic from four directions. In addition, at the intersection of the plot, there is a railway crossing which causes a reasonably long queue on the legs of the intersection. The construction of this *Underpass* supports the planned urban road network handling program and reduces congestion at the intersection of a plot between the national road and the provincial city.

The solution to the congestion problem is challenging due to the lack of public awareness of traffic orders—the construction of the (Novitasari, N., & Sudibyo, T., 2020). *Underpass* aims to overcome congestion and improve pedestrians' safety, especially those who want to cross (Wibawa, Redana, Suthanaya, & Wiryasa, 2020). This paper aims to analyze the effectiveness of traffic management in the Bulak Kapal Underpass on safety, comfort, and other parameters for the *Underpass* user. This paper is also expected to provide an overview of the academic field to review the effectiveness of Underpass construction elsewhere.

LITERATURE REVIEW

Traffic Performance

The traffic system is a very interactive social system since it consists of various individuals who use different forms of transport. Road and transport users will interact with each other for mobilization through the traffic environment. In addition, these individual road users are required to adapt to applicable traffic rules to avoid conflicts. The traffic characteristics of a road system occur due to the interaction between road users or motorists and their vehicles with the road itself (Madigan, et al., 2019); (Fuest, Sorokin, Bellem, & Bengler, 2017).

Regular evaluation of road traffic performance to ensure optimization of road performance is one of the efforts to overcome congestion problems. Traffic performance indicators include vehicle speed, travel time, delay, and degree of saturation. Traffic performance is good if the saturation degree value is low and the vehicle's travel speed is high. Several alternative road repairs and changes are needed to meet traffic performance, especially the geometric road (Susilo & Imanuel, 2018).

An increase in the number of vehicles that are not aligned with the construction of infrastructure in an area will impact conflicts on the road, especially at intersections. The conflict will affect its traffic performance. Measurement of traffic performance on the road is divided into measuring the performance of networks, road sections, and intersections. For example, at the Bulak Kapal intersection, the roads affected by traffic performance in the event of a conflict are Jalan Ir. Juanda, Jalan Joyo Martono, Jalan Pahlawan, and Jalan Diponegoro. One of the efforts to improve traffic performance in a road system is to carry out traffic management and engineering (Fauzan, Prasetyo, Setiawan, & Soeratmodjo, 2022); (Cahyo Budiyanto, I. M. A., & Eko Sudriyanto, 2021).

Traffic Management

Fast and efficient mobility has become a basic need of modern society. Therefore, people can now use various means of transportation for their mobility. Motorized vehicles are still a favorite choice among the existing means of transportation because of their convenience and practicality. Assuming continuous population growth, the number of motorized vehicles will increase, especially in big cities. The increase in motor vehicles is much faster than the construction of transportation infrastructure facilities. If this is not anticipated with good regulation and traffic management, it will result in congestion (De Souza, et al., 2017).

Internationally, congestion has become a common but severe problem, so many ways have been found to overcome it. Some solutions to overcome congestion include road widening, adding traffic lanes, engineering one-way traffic flow circulation, limiting the use of road medians, construction of non-plot lanes such as *Underpasses* and *flyovers*, development of traffic management through an intelligent transportation system, and other systems. In big cities in Indonesia, several solutions have been implemented to overcome congestion related to traffic management, for example, the implementation of the 3in1 and odd-even systems. The 3-in-1 system means at least three people in one car, which is expected to reduce the number of cars passing in busy lanes. At the same time, the odd-even system is a traffic arrangement based on the date and license plate of the car. On even dates, cars can only cross specific roads, even license plates. Conversely, cars can cross certain streets on odd dates with only odd number plates (Rifai, Surgiarti, Isradi, & Mufhidin, 2021).

Bekasi City, a growing metropolitan city, faces several challenges in improving traffic management. These challenges include analysis and real-time traffic *collection, traffic density, and travel time predictions on routes* (Chavhan, S., & Venkataram, P., 2018). These challenges will impact the daily activities of society and the economy of commuters and public transport drivers. To overcome these challenges, commuters and public transport drivers must plan additional travel times to avoid arriving late. In addition, commuters and drivers of public transport should be aware of traffic density patterns and travel time patterns on specific routes or areas (Chavhan, S., & Venkataram, P., 2020).

Underpass Development and Effectivity

The development of society is currently getting faster, resulting in the government having to adjust these developments, one of which is the construction of road infrastructure. Road infrastructure construction in an area is directly proportional to population growth and technological progress. In addition, the structure of road infrastructure has led to an increase in traffic facilities and infrastructure to meet the community's needs, especially in overcoming congestion. One of the road infrastructures aimed at overcoming congestion is the Underpass (Purwanggono & Margarette, 2017).

An Underpass is a crossing, not a plot or transverse road, that is, one segment below another road by making Underpass below the ground level. Usually, (Tian, et al., 2020) Underpasses are built near railroad crossings to unravel the traffic density as the fire passes through. In addition, one of the purposes of building an Underpass is to improve connectivity and facilitate traffic. Therefore, the construction of Underpasses is expected to solve congestion and traffic management problems, especially in major cities (Luqman, Tabassum, & Khan, 2019).

Road infrastructure construction is practical if it is under its wishes and objectives (Masello, Castignani, Sheehan, Murphy, & McDonnell, 2022). The Bulak Kapal Underpass was built to unravel the congestion at Simpang Bulak Kapal. Simpang Bulak Kapal road system before the Underpass was an interchange that was the meeting place for four directions of traffic from Bekasi City and Bekasi Regency. Before the construction of the Bulak Kapal Underpass, at the intersection of the plot, there were often traffic jams, especially during rush hour. It is due to the crossing of a railway plot around the intersection and the density of settlements and industries in the East Bekasi area. After the construction of the Underpass, the capacity of the existing road at the Bulak Kapal interchange was increased from the original four lanes to six lanes. With the construction of the Underpass and the addition of the line, it is hoped that it can unravel congestion in Bekasi City and Regency.

METHOD

This study was located in the *Bulak Kapal Underpass*, East Bekasi, as shown in Figure 1. Construction of the Bulak Kapal *Underpass* began in 2020 and was completed in early 2022. *The* Bulak Kapal Underpass has two lanes with a total width of 7 meters or 3.5 meters for each lane, which connects Jalan Diponegoro (Tambun direction, Bekasi Regency) to Jalan Ir Juanda (Bekasi City direction) and vice versa.

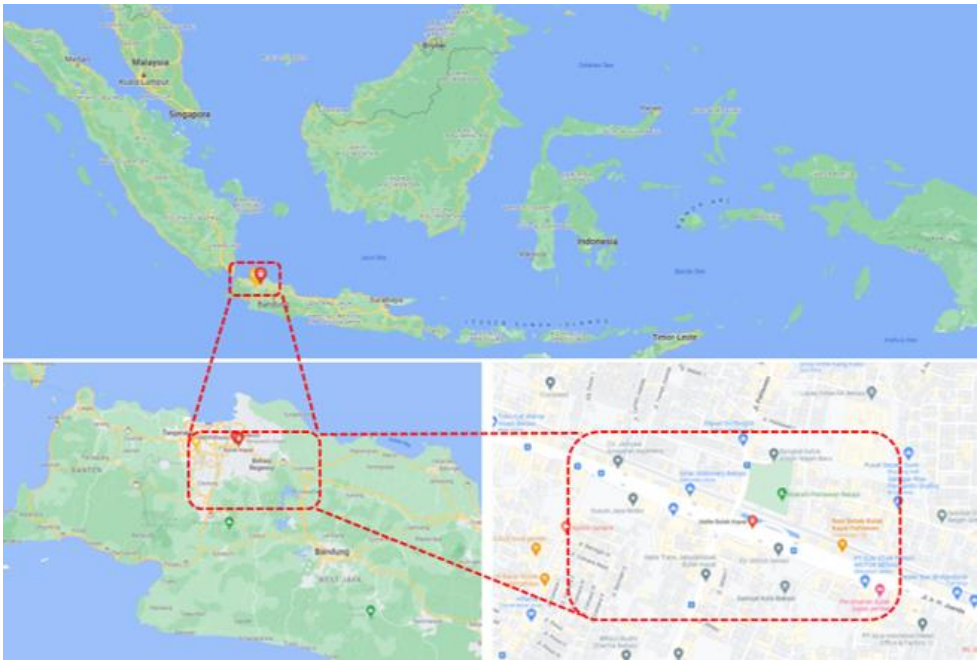

Figure 1. Research Location

The condition of the Bulak Kapal Underpass from the direction of STA 0 + 000 at 22 WIB and the condition of the Bulak Kapal Interchange after the construction of the Bulak Kapal *Underpass* at 10 WIB are shown in Figure 2.

Figure 2. Underpass Condition and Simpang Bulak Kapal

Research Parameters

Research is considered an application of problem-solving using the scientific method. The systematic scientific research process must begin with identifying appropriate problems. Therefore, it is necessary to make in-depth observations of this research (Pandey & Pandey, 2021); (Rifai, A. I., Hadiwardoyo, S. P., Correia, A. G., Pereira, P., 2016); (Dermawan, Rifai, Ramadhan, & Isradi). To determine the effectiveness of traffic management in the Underpass, several parameters are needed that will be compared based on the assessment of the respondents. The demographic characteristics of the respondents and the characteristics of the Underpass Road system influenced the respondent's assessment. The demographic characteristics of the

respondents consist of gender, age, occupation, and others. Knowing the features of the respondents will provide a reasonably clear picture of the relationship between the respondent's condition and the problem and the purpose of the study as for the assessment parameters to be compared (Agyapong & Ojo, 2018). The characteristics of the Underpass Road system can be seen in Table 1 below.

Table 1. Respondent assessment parameters

No.	Parameters	Source				
		(Malin, Norros, & Innamaa, 2019)	(Guo, Chen, Stuart, Li, & Zhang, 2020)	(Guanetti, Kim, & Borrelli, 2018)	(Glavić, Milenković, Trpković, Vidas, & Mladenović, 2017)	(Arifullin, 2017)
1.	Road Condition	✓	-	-	-	-
2.	Safety	✓	✓	✓	✓	✓
3.	Convenience	-	-	✓	-	-
4.	Road Equipment	-	-	-	-	✓
5.	Environmental Compatibility	-	-	✓	✓	✓
6.	Speed	✓	-	✓	✓	-
7.	Traffic Density	-	✓	-	✓	-
8.	Accessibility	-	✓	-	-	-
9.	Mobility	-	✓	-	-	-
10.	Traffic Flow Stability	-	-	-	✓	-
11.	Aesthetic	-	-	-	✓	-

Data Processing

Data is one of the main strengths in compiling scientific research and modeling. In this study, data collection was carried out using questionnaires (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, The data mining applied for the prediction of highway roughness due to overloaded trucks, 2015) *online* and *offline*. A questionnaire is several questions or written statements about factual data or opinions relating to the respondent, which are known facts or truths and need to be answered by the respondent. The respondents of this study devoted Bulak Kapal (Mariadi, Handayani, & Sepyanda, 2019) *to Underpass* users before and after construction. The questionnaire is distributed directly to respondents (*offline)* and indirectly through Google Forms (*online*). The distribution of offline questionnaires to members of the Bekasi City Transportation Agency, public transportation drivers, and online motorcycle taxis can be seen in Figure 3.

Figure 3. Offline Distribution of Questionnaires

Deep give answer Respondents Given scale valuation one until with 10. Value one shows that parameters that exist are Rated "not good", and value 10 shows that parameters that exist are "very good."

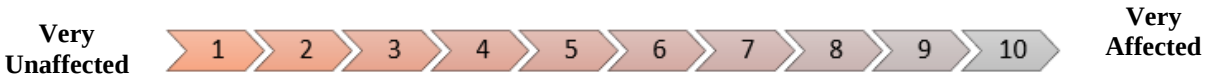

Figure 4. Scoring Range

The answers obtained from the questionnaire will be processed and analyzed. Data processing from the responses to the questionnaire will be presented in the form of *a spider chart*. Through the *spider chart*, it can be known and identified how the opinion from the point of view of road users on parameters related to the effectiveness of traffic management in the Bulak Kapal *Underpass.*

RESULT AND DISCUSSION

Characteristics of Respondents

From the questionnaire answers distributed to respondents, 118 respondents met the criteria, but only 100 respondents' answers were analyzed. The characteristics of the 100 respondents, if grouped by their genders, comprised 43% women and 57% men. When grouped by age, most respondents are in the age range of 21 – 30 years, with a percentage of 51% of all respondents. The domicile of Bulak Kapal Underpass users is 88% in Bekasi, with the primary goal of 55% to work. As for the work, most respondents are Private Employees, with a percentage of 27% and most vehicles used to cross the Bulak Kapal Underpass are private motors, with 55% of all respondents. The detailed characteristics of the respondents it is presented in Table 2 below.

Table 2. Respondent Characteristics

No.	Parameters	Category	Frequency	Value (%)
1.	Gender	Man	57	57
		Woman	43	43
2.	Age	< 20 years old	7	7

No.	Parameters	Category	Frequency	Value (%)
		21 - 30 years old	51	51
		31 - 40 years old	25	25
		41 - 50 years old	13	13
		51 - 60 years old	3	3
		>60 years old	1	1
3.	Occupation	Government Employees	11	11
		TNI/POLRI	1	1
		Private Employee	27	27
		SOE Employee	5	5
		Entrepreneur	18	18
		Student	9	9
		Public Transportation/Online Drivers	20	20
		Housewife	5	5
		Others	4	4
4.	Domicile	Jakarta	5	5
		Bogor	2	2
		Bekasi	88	88
		Depok	4	4
		Tangerang	1	1
		Others	-	-
5.	Purpose	Shopping	13	13
		Go to school	7	7
		Recreation	12	12
		Working	55	55
		Others	13	13
6.	Vehicles	Motorcycle	55	55
		Car	19	19
		Public Transportation	21	21
		Others	5	5

Traffic Management Effectiveness

In determining the effectiveness of traffic management at the Bulak Kapal *Underpass*, respondents' assessment was also influenced by other factors derived from the characteristics of the Underpass Road system. These characteristics comprise 11 parameters: road conditions, safety, comfort, completeness of roads, and environmentally friendly—speed, density, accessibility, mobility, traffic flow stability, and aesthetics. The results of respondents' assessment of these parameters will be compared based on the conditions before and after the construction of the Bulak

Kapal *Underpass*. The average assessment and the difference in assessment before and after the construction of the Bulak Kapal *Underpass* it is presented in Table 3.

Table 3. Respondent Assessment

No.	Parameters	Before	After	Gap
1.	Road Condition	5.48	8.13	2.66
2.	Safety	4.79	8.13	3.34
3.	Convenience	4.61	8.19	3.58
4.	Road Equipment	4.98	8.10	3.12
5.	Environmentally friendly	4.48	7.61	3.13
6.	Speed	4.53	8.22	3.69
7.	Traffic Density	3.87	8.11	4.24
8.	Accessibility	4.80	8.35	3.55
9.	Mobility	4.76	8.28	3.52
10.	Traffic Flow Stability	4.82	8.10	3.28
11.	Aesthetic	4.68	8.22	3.54

Furthermore, to find out which parameters have the highest and lowest scoring gaps, the data from Table 3 is presented in the form of *a spider chart* shown in Figure 5 below.

Figure 5. Spider analysis chart

The analysis of the average assessment of respondents addressed by Table 3 and the spider chart above shows the highest gap by traffic density with a value of 4.24. On the other hand, the traffic density assessment before the Underpass construction was 3.87 and experienced a significant increase to 8.11. According to several respondents, the traffic density at Simpang Bulak Kapal before the Underpass was considered poor because there were often long traffic jams due to high traffic density. The factors causing the congestion are railway crossings and side obstacles

due to public transportation stopping on the shoulder of the road. Congestion at railway crossings usually occurs during peak hours, on weekdays around 6.00 WIB – 8.00 WIB and at night at 20.00 WIB – 22.00 WIB, and on weekends at 8.00 WIB – 10.00 WIB and 18.00 WIB – 20.00 WIB.

The second parameter with the highest value *gap* is the vehicle speed, which is 3.69. The vehicle speed assessment before the Underpass was built was 4.53 and increased to 8.22. It indicates a relationship between velocity and density. If the traffic density is high, the vehicle speed is low, and vice versa. The respondents' vehicle speed assessment for the built Underpass (Azlan & Rohani, 2018) was down due to high traffic density. Meanwhile, the vehicle speeds increased after the Underpass construction because the traffic density was low.

Traffic jams often make road users feel stressed and uncomfortable. The comfort parameter was third, with the highest *value gap* according to respondents, which was 3.58. Where before the Underpass was built, the comfort value was 4.61 and increased after the *Underpass* was built to 8.19. It shows that the condition of the Bulak Kapal interchange after the Underpass is built creates comfort for its users due to reduced congestion.

Accessibility is a parameter that states the ease with which motorists can reach the center of activity. Simpang Bulak Kapal is one of the connecting accesses for Bekasi City and Regency. The accessibility parameter assessment increased by 3.55, according to respondents. Before construction, the Underpass averaged a respondent rating of 4.80, and it grew to after the Underpass was built 8.35. It shows that the structure of the Bulak Kapal *Underpass* makes it easier to access the City to Bekasi Regency and vice versa.

Furthermore, the parameter with the fifth highest *gap* value is aesthetic. The average aesthetic assessment of Simpang Bulak Kapal before the Underpass was 4.68. After the Underpass was built, the aesthetic value increased by 3.54 to 8.22. Therefore, the Bulak Kapal Underpass is considered to add to the aesthetics of the intersection. With the *Underpass* system, the road becomes more organized. In addition, the edge of the *upper Underpass* is decorated by greenery that adds aesthetic value.

Mobility is a parameter that indicates the quality of road service based on the ease of each driver after traveling through a route to reach his destination. As a link between Bekasi City and Regency, the Bulak Kapal interchange is known for its high community mobility. The mobility assessment, according to respondents, increased by 3.52. Before the *construction* of the Underpass, the average mobility value was 4.76 and increased after the *Underpass* to 8.28. This value shows that with the Bulak Kapal *Underpass*, people's mobility activities become smoother and more accessible.

The parameter with the seventh highest gap value is safety or security. Road safety is preventing road users from the risk of accidents during traffic. The cause of traffic accidents comes from humans or road users, the vehicles used, the roads traveled, and the surrounding environment. The results of the respondent's answer analysis obtained the average value of road safety before the Underpass of 4.79. The value increased after the Underpass was built by 3.34, to 8.13. These results show that the Bulak Kapal Underpass construction makes road users feel safer than before the *Underpass*.

One of the causes of congestion is the unstable flow of traffic. This parameter can also be seen from the vehicle's speed and traffic density. The lower the vehicle speed and the higher the traffic flow density, the more unstable the traffic flow will be. According to the respondents' assessment, the stability of traffic flow after the construction of the Bulak Kapal Underpass increased by 3.28, where the value before the Underpass was built was 4.82 to 8.10 after the *Underpass* was built. From these results, it shows that with the construction of the Bulak Kapal *Underpass*, the traffic flow on this section of the road has become more stable.

Environmentally friendly parameters are assessed from noise and air pollution derived from the dust and smoke of motor vehicles passing through Simpang Bulak Kapal. The *gap* value of the noise parameter is 3.02, while the air pollution parameter has a gap value of 3.24; if averaged, the *gap* value to 3.13. Therefore, the value indicates an increase in environmentally friendly parameters of 3.13. Before the Bulak Kapal Underpass construction, the value was 4.48 to 7.61 after the Underpass was built.

Road completeness parameters are judged by the condition of traffic signs, road markings, lighting lights, sidewalks, as well as waterways or drains. From the five indicators, an average (Lulie & Setiawan, 2022) *gap* value of 3.12 was obtained. The average rating before the construction of the *Underpass* was 4.98, where the completeness of the road was judged to be sufficient. Meanwhile, the average value after the construction of the *Underpass* rose to 8.10. The construction of the Bulak Kapal *Underpass* not only adds to its existing lanes but also improves the complementary indicators of its roads.

The last parameter, as well as the parameter that has the lowest *gap* value, is the road condition. The absence of cracks, no potholes, no amblas and the width of the road judges the parameters of the state of this road. Before the Bulak Kapal Underpass construction, the road condition value was quite good, which was 5.48. It is the highest before the *Underpass* is built compared to other parameters. After the Underpass was built, the assessment increased by 2.66 to 8.13. With the Bulak Kapal *Underpass*, the existing lane, which was initially only four lanes, was widened by adding two lanes to unravel congestion.

CONCLUSION

From the results of this research, it can be concluded that each parameter, according to the respondents, has increased after the construction of the Bulak Kapal *Underpass*. The three main parameters with the highest gap values or parameters that have experienced a significant increase are traffic density, vehicle speed, and comfort. For example, where the gap value for the traffic density parameter is 4.24, the gap value for the vehicle speed parameter is 3.69, and the gap value for *the* comfort parameter is 3.58. The three parameters with the lowest *gap* values are road conditions, road completeness, and environmental friendliness. The gap value for the road condition parameter is 2.66, the gap value for the parameter is 3.12, and the *gap* value for the eco-friendly parameter is 3.13.

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