Flood disaster mitigation on road sections: optimizing performance by implementing traffic engineering management

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Abstract. Flood disaster mitigation efforts are carried out through traffic engineering management to reduce the negative impacts of flooding on the community and infrastructure, where these efforts require a comprehensive disaster management plan and involve cooperation between the government, traffic authorities, emergency services and the surrounding community. This study aims to determine the traffic engineering scenario that can reduce congestion and improve traffic performance during floods. This study analyzes the road network in Gedebage District and Ujung Berung City which are affected by floods under normal conditions, flood conditions (do-nothing), and conditions when the traffic engineering scenario is applied (do-something) by developing an origin-destination matrix formed using the Furness method, traffic modelling using PTV Visum and traffic performance analyzed using the 2023 Indonesian Road Capacity Guidelines method. The results of the study indicate that there is an increase in traffic performance during floods with the implementation of do-something scenario 2. The study recommends that stakeholders implement flood disaster mitigation by providing information on mapping flood-prone areas, early warning systems, information on evacuation routes and emergency routes, and alternative routes.

1 Introduction

Flood disaster mitigation is a series of actions taken to reduce or eliminate the negative impacts caused by floods in order to protect human life, reduce property damage, and minimize disruption to communities and the environment that are carried out before, during, and after a flood, and involve planning, preparation, and implementation of strategic measures. Effective disaster management can reduce the damage caused by flooding to the natural and human environment by identifying actions to implement the stages of knowledge management including before, during and after the flood event [1]. Flood disasters pose a serious threat to human life and property, so it is necessary to reveal the spatial driving factors of flood disasters on a macroscopic scale in order to reduce their impact [2]. Indonesia is in a geographical area that is prone to disasters which requires serious preparedness in facing disasters [3]. Floods in Indonesia are often caused by heavy rain and land conversion, exacerbated by high rainfall intensity which results in frequent flooding [4].

The phenomenon of global climate change in various countries in the world has resulted in flooding that impedes road utility and this problem has increased drastically [5]. There is a need for flood resilience evaluation to ensure that various urban systems and segments can prevent, respond and recover efficiently to achieve sustainable development [6], need disaster identification scenarios and classification criteria for flood risk identification [7]. Therefore, powerful technology or tools are needed to support efficient flood disaster management for damage assessment, real-time monitoring, resource allocation, and faster response [8]. The analysis of congestion risk due to urban road networks facing flood risk in transportation systems based on static network characteristics, but fails to reveal the dynamic impact of developing flood events on network topology, so traffic engineering is needed to integrate dynamic flood models through network property measurements [9]. It is important to analyze comprehensive vulnerability to improve the management of road network vulnerability in complex urban environments due to disruptions to the road network that impact traffic flow through identification and mitigation of vulnerable components [10]. Flood inundation modelling method as a starting point reference for impact analysis and flood risk assessment on roads to provide insight into areas and regions at risk of flooding [11]. An important aspect in analyzing traffic flows in flood-prone areas is to note that traffic flows are dynamic and change over time, and it is important to identify who is in danger [12].

Bandung City is the capital of West Java Province as well as the center of Greater Bandung Metropolitan Area with a population growth rate of 0.35% per year. The population growth rate has caused an increase in land needs in Bandung City, which has an impact on the

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conversion of conservation land functions. In 2019, 57.23% of land in Bandung City was used for settlements and only 12.2% of land was used for green open space, far below the supposed figure of 30% of the city's area. Uncontrolled land conversion increases the risk of flooding in areas with lower elevations than the surrounding area, such as in the Gedebage Area.

The Gedebage area which is in the coverage of the Gedebage City Sub-Region and the Ujung Berung City Sub-Region is located at the lowest point of Bandung City with an altitude of 666 – 892 meters above sea level. This area functions as a City Service Center and a City Strategic Area for the East Bandung area so that the level of community mobility and the volume of vehicles that cross this area is relatively high and often causes severe congestion [13]. At the time of flooding in the Gedebage area, the flooded transportation infrastructure is practically unusable so that the transportation operation pattern is disrupted and eventually causes congestion.

Floods that occur in the Gedebage area are included in the category of moderate flood risk with a height between 0.3-0.5 meters. The following is the distribution of flood inundation points in the Gedebage Area with low to high inundation height category.

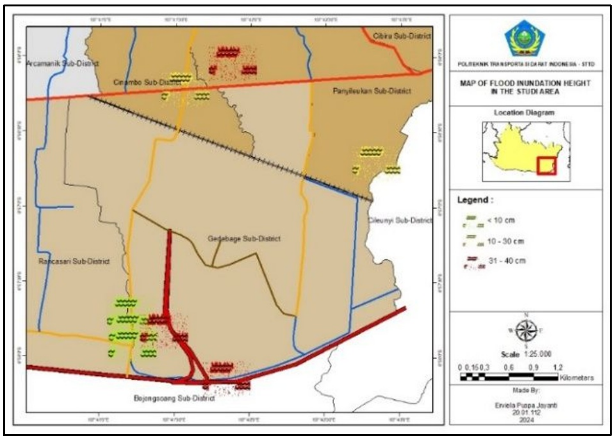

Fig. 1. Map of flood inundation height in the study area

Based on Fig. 1 above, there are two flood inundation points with a height of 10-40 cm located on the main road network, namely at the intersection of Soekarno-Hatta Street with Rumah Sakit Street (Gedebage Intersection) and on Sor GBLA Street. Flooding at Gedebage Intersection is one of the main problems that is the main priority for handling by the Bandung City Government. The flood at the intersection has an average height of ≥ 30 cm with a receding time of ≥ 60 minutes, which greatly hampers traffic movements in the Gedebage Area considering that the road network is a primary arterial road network as well as a national road that is the main access to movement in the Gedebage Area. Meanwhile, on Sor GBLA Street, the flood height ranges from 31-40 cm with a receding time of about 1-8 days. Thus, traffic on Sor GBLA Street was stopped during that time span.

Flood inundation will cause damage to highway infrastructure such as holes covered by flood puddles. This will result in the driver falling into the hole and the occurrence of motor vehicle tire leakage [14]. Therefore, traffic engineering management is needed as a solution to overcome congestion due to flooding while efforts to control water systems continue to be carried out. This is done in order to ensure that transportation operations continue to be carried out and to facilitate the evacuation of victims or distribution of logistics for flood victims [15]. This study aims to find out traffic engineering scenarios that are able to break down congestion and improve traffic performance during floods.

2 Theoretical studies

A disaster is a serious disruption to the functioning of a community or society that results in widespread humanitarian, material, economic, or environmental losses and impacts, exceeding the capacity of the affected community [16]. Disasters can be triggered by natural factors, non-natural factors, or human actions that cause significant losses [17]. Flooding is a type of disaster caused by various factors, such as due to high rainfall, obstruction of waterways due to siltation and accumulated garbage, and so on [18]. Flooding occurs due to water that is not contained in the sewer so that it overflows and floods the surrounding area [19].

Traffic engineering management is the process of regulating the supply and demand of highway systems to overcome short-term traffic challenges and handle traffic within a certain period of time [20]. Another opinion states that traffic engineering management is a technique for managing and controlling traffic flows by optimizing the use of existing infrastructure to facilitate traffic efficiently in the use of road sections and improve the smoothness of the movement system [21]. Some strategies in traffic engineering management are capacity management, priority management, and demand management [22].

Awakening refers to the number of trips that start from a zone or region in a period of time [23]. The trip generation model functions to estimate and predict the number of trips originating from a zone [24]. Trip distribution is the total trips that start from a zone/region spread to various destination zones [25]. The number of movement flows is expressed in the origin destination matrix (OD Matrix). One of the methods in forming OD Matrix is the easy-to-use Furness method [26]. The distribution of future movements is obtained by multiplying the distribution at the time of the nest by the growth rate of the origin zone or destination zone which is carried out alternately [27].

The mode selection stage serves to determine the burden of the trip or to know the number of people and goods who will use or choose various modes of transportation available to serve a certain point of origin of a certain destination [28]. The process of loading traffic requires data such as the matrix of origin of travel destinations, road capacity, and network characteristics [29]. The road network is a system consisting of sections that are interconnected and bind the centers of activity in it. There are three main parameters of the road network performance used, travel time (passenger car unit-hour) (pcu-h), distance travel pcu-km), and network speed (km/h) [30].

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The performance of a road segment refers to its ability to meet the needs of traffic flow according to its role, which can be measured and compared to road service standards [31]. The performance indicators of the road section used include the degree of saturation of the road section (D_J), traffic speed, and traffic density. There are several methods of assessing the level of road service levels, one of which is using highway capacity manual [32].

Intersection performance assessments are differentiated based on the type of control. The intersection performance component consists of the degree of saturation of the intersection (D_J), delay time, and the length of the intersection queue. The level of interchange service is determined based on the average delay time. Intersection performance assessment is an important process in traffic management and transportation planning. Good intersection performance not only improves traffic flow but also plays a role in road user safety, time efficiency, and comfort. In the implementation of traffic engineering in emergency conditions such as during natural disasters, temporary barriers are used that can be easily moved. In placing signs, it is necessary to consider things such as the operational speed of the vehicle, the geometric condition of the road, the roadside environment, and the efficiency of the number of signs.

3 Research methodology

The research was conducted in Gedebage and Ujung Berung City Sub-Region, which are one of the flood-prone areas in Bandung City. The flood inundation point that submerged the road infrastructure with a height of >30 cm and a receding time of >60 minutes is located at the intersection of Soekarno – Hatta Street and Rumah Sakit Street, Soekarno – Hatta Street (in front of the Gedebage Main Market), Rumah Sakit Street, and Sor GBLA Street. Data collection was carried out in November – December 2023 while data processing was carried out in January – June 2024.

The first stage in this research process is data collection to find out the existing conditions of the research location. There are 2 types of data needed, namely primary data and secondary data. Primary data includes information about the geometry of the road network, vehicle flow data on roads and intersections, and travel speed. Primary data was obtained through road and intersection inventory surveys, traffic counting (TC) surveys, classified turning movement counting (CTMC) surveys, and moving car observer (MCO) surveys. Secondary data includes administrative maps and road networks, data on affected road networks, flood characteristics in previous events, and existing traffic data.

Traffic zones are set on road sections that are used as access in and out of the study area [33]. Then a matrix of origin of travel destinations (OD Matrix) was formed using the Furness method. The Furness method is an easy-to-use, flexible, and non-accessible method so it was chosen as a method of forming OD Matrix. After that, OD Matrix is charged to the road network using assistance Software PTV Visum to get the traffic volume of the model, one of the tools in transportation planning used to analyze, model, and plan transportation systems at the macro level. PTV Visum has a use to manage GIS data, model transportation requests, and load the network with modelling principles four step modelling, and an essential tool in transportation planning and management due to its ability to analyze, model, and plan transportation systems at a macro level. It is used by urban planners, transportation engineers, and policy makers to understand and manage transportation dynamics at a large scale.

4 Results and discussion

In this study, there are 13 zones formed based on the entry and exit points of traffic flows in the study area show in Fig. 2. The following is a map of the distribution of traffic zones in the study area in this study.

The establishment of traffic zones based on the entry and exit points of traffic flow in a study area is an important approach in transportation planning and analysis. This division allows for a deeper understanding of the dynamics of traffic movement and more effective planning. Traffic zones allow for a more detailed analysis of travel patterns, including the origin and destination of trips, the number of trips made, and the choice of transportation mode. This helps in understanding the transportation needs of the community and the distribution of traffic load. By understanding the main entry and exit points in each zone, planners can manage traffic flow more effectively, reduce congestion, and optimize the use of road infrastructure.

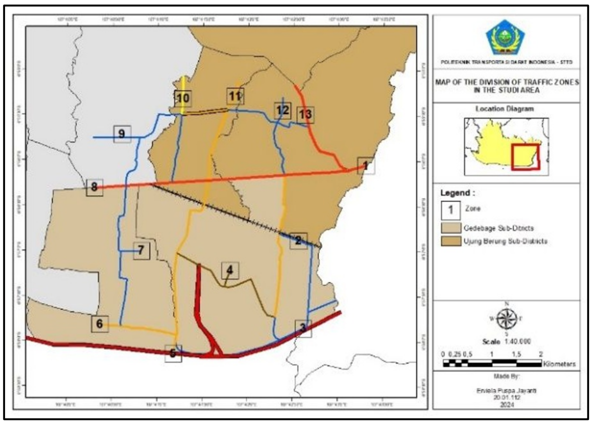


Fig. 2. Division of area zones

The zones that have been formed will then be calculated the number of traffic movements which will then be modelled into the number of rises and draws of trips in the zone. The number of traffic movements leading into the study area is determined as the number of trip awakenings, and the number of traffic movements leading out of the study area is determined as the number of trip pulls. The number of rides and rides are separated based on the classification of the vehicle to make it easier to analyze the traffic load. Then the number of rises and pulls of each type of vehicle is added up to get the total rise and pull of each zone.

The results of the traffic counting (TC) survey in the zones in the study area showed that there was still a difference between the number of awakenings and trips in all zones in the study area. Therefore, adjustments are made to the number of awakenings or travel pulls into the highest value so that it will produce the same amount. The adjustment is made for each type of vehicle. The following is the number of awakenings and travel attractions of each zone in the study area.

Table 1. Total awakening and attraction of travel

Zone	Information	Before Customization		After Customization	
		Awakening (Veh/Hour)	Attraction (Veh/Hour)	Awakening (Veh/Hour)	Attraction (Veh/Hour)
1	Cirebon - Bandung St.	2.335	3.362	2.441	3.381
2	Sor GBLA Segment 3 St.	615	520	644	522
3	Sor GBLA Segment 3 St.	554	379	579	383
4	Boulevar Utama St.	366	466	381	467
5	Raya Sapan St.	586	548	612	550
6	Raya Terusan Derwati St.	403	496	421	497
7	Terusan Saluyu St.	786	733	815	733
8	Soekarno- Hatta Segment 2 St.	3.739	3.330	3.900	3.351
9	Cingised St.	293	309	306	309
10	Golf Raya St.	267	145	279	145
11	Rumah Sakit Segment 2 St.	561	688	586	692
12	Sukamaju St.	192	125	200	125
13	AH Nasution Segment 2 St.	1.628	1.697	1.702	1.711
TOTAL		12.325	12.798	12.866	12.866

Based on Table 1 above, before the adjustment, the trip revival in the study area amounted to 12,325 vehicles/hour and the trip pull amounted to 12,798 vehicles/hour. Meanwhile, after adjustments, the number of awakenings and pulls in the study area already has the same value, which is 12,866 vehicles/hour.

Based on the results of adjusting the number of rises and travel attractions of each vehicle, an analysis of the distribution of trips was carried out to produce a matrix of origin of travel destinations between zones. In building the origin destination matrix using the Furness method, the initial OD Matrix is determined with a value of 1 and then multiplied by the origin zone growth factor which is the result of dividing the number of trips from the survey results with the number of trips in the analyzed matrix. The results of the first iteration of the OD Matrix were then multiplied by the growth factor of the destination zone. Next, the results of the second iteration of OD Matrix are multiplied again by the growth factor of the origin zone until the growth factor value is equal to 1 or O_i = oi. Here is the matrix of origin destination (OD Matrix) of the total trip using the Furness method.

Table 2. Total travel origin destination matrix in study area (vehicle/hour)

OD	1	2	3	4	5	6	7	8	9	10	11	12	13	O_i
1	0	119	84	97	119	105	158	1.085	65	31	151	26	406	2.445
2	181	0	17	19	24	21	32	215	13	6	30	5	80	644
3	159	21	0	17	21	19	28	194	12	6	27	5	72	579
4	103	12	9	0	14	13	22	128	8	4	17	3	47	381
5	170	22	16	18	0	20	29	208	12	6	28	5	78	612
6	115	15	10	14	16	0	23	141	9	4	19	4	52	421
7	224	26	20	30	31	29	0	281	19	8	37	7	102	816
8	1.533	191	143	174	207	184	283	0	113	52	259	45	706	3.890
9	83	11	8	10	11	10	16	101	0	3	14	3	37	306
10	75	10	7	9	10	9	14	91	6	0	13	2	34	279
11	162	21	15	18	22	19	29	204	12	6	0	5	74	586
12	54	7	5	6	7	7	11	65	4	2	9	0	24	200
13	522	69	49	54	68	60	88	637	37	18	88	15	0	1.704
D_j	3.381	522	383	467	550	497	733	3.351	309	145	692	125	1.711	12.866

Table 2 above shows the distribution of trips from the origin zone to the destination zone in the study area with a total movement of 12,866 vehicles/hour. In forming the OD Matrix, each type of vehicle is repeated (iteration) with different numbers until E = 1 or O_i = oi. The motorcycle and passenger car OD Matrix is completed in the 6th iteration, the medium vehicle OD Matrix is completed in the 12th iteration, the large bus OD Matrix is completed in the 7th iteration, and the large truck OD Matrix is completed in the 8th iteration.

The loading model on the PTV Visum will produce a vehicle volume (pcu/h) for each section which will then be tested using the GEH method to find out whether the model has represented the actual condition or not. Models with test scores below 5 can be declared valid and acceptable as models that represent the actual conditions. Meanwhile, models with test scores in the range of 5-10 are declared doubtful models with the possibility of corrupted or invalid data, and models with test scores above 10 are declared invalid/rejected because the data cannot reflect the actual conditions in the field. The following are the results of the traffic volume validity test on the model created against the volume of survey results.

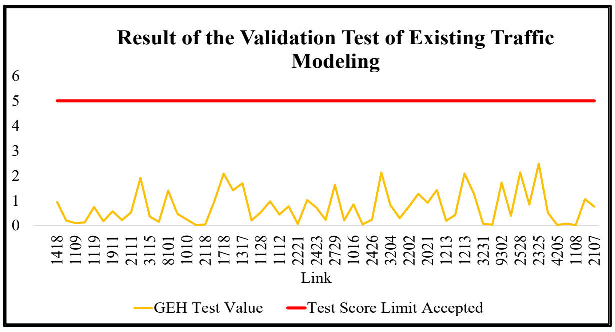
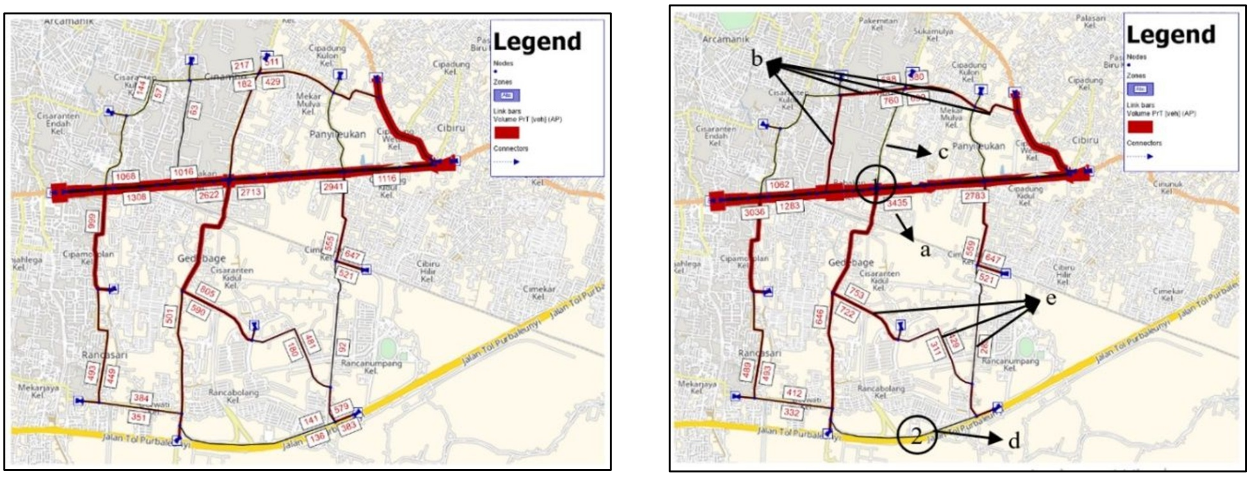


Fig. 3. Results of the existing model validation test

Based on Fig. 3, it can be seen that the entire traffic volume of the modelling results is below 5 so that the model can be declared valid and can represent the actual conditions in the field. After the existing model is declared valid, the model can be modified to form other conditions, namely flood conditions and conditions when traffic engineering is applied.

Floods cause a significant decrease in capacity on roads and intersections, which means that the number of vehicles that can be served by the road and intersection is drastically reduced. In some cases, the capacity can even be 0, meaning that the road or intersection cannot be passed at all by vehicles because it is inundated. The main cause of this decrease in capacity is waterlogging that makes the road or intersection impassable, due to the water depth being too high or due to infrastructure damage caused by the flood. PTV Visum is a software for traffic planning and simulation that is used to analyze and model changes in traffic flow. The analysis is carried out using the same OD matrix as the existing conditions, which means that data on travel patterns and driver destinations before the flood is reused to understand how the flood affects traffic flow. This analysis aims to see the changes in traffic volume that occur in the study area during flood conditions by taking into account the influence of impassable roads and intersections.

The results of this analysis can be used to design adjustments in traffic management such as route diversion or access restrictions to certain areas that are severely affected by flooding. This information is essential for emergency planning including evacuation and other critical flood response. By understanding the impact of flooding on road network capacity and using the data to model traffic changes, authorities can plan and implement more effective strategies to keep traffic flowing and road users safe. Figure 3 shows the change in traffic volume loading that occurs during normal conditions with flood conditions.



(a) (b)

Fig. 4. Comparison of traffic loading results in normal conditions (a) and flood conditions (do-nothing) (b)

Based on Fig. 4, it can be seen that there are several points of road sections and intersections that have undergone significant changes when flooding occurs in the study area. The intersection marked by circle 1 is Gedebage Intersection, while the road section marked by circle 2 is Sor GBLA Street Segment 1, both of which are the worst flood points in the study area. At the time of the flood, the Gedebage intersection experienced a build-up of traffic volume because the north arm (rumah sakit street) and part of the east arm exit were flooded and could not be crossed by vehicles (Fig. 4a). As a result of the accumulation of vehicles that occurred at Gedebage Intersection, there was also an increase in traffic volume on Cisaranten Wetan Street, Cinambo Street, Panghegar Street, and Pangaritan Street which were identified as alternative routes for vehicles when flooding occurred at Gedebage Intersection (Fig. 4b).

Proposal for do-something 1 in improving traffic performance and unraveling congestion in the event of flooding in the study area shown in Fig. 5. Implementing contraflow on Soekarno-Hatta 1 Street Fast Lane 2 to increase the exit width of the western approach of Gedebage Intersection as follows.

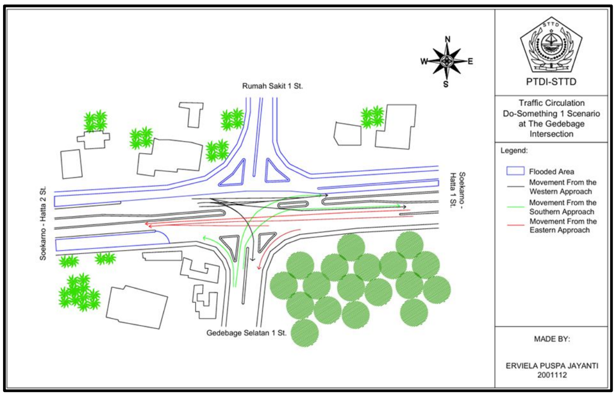


Fig. 5. Traffic circulation do-something scenario 1 at Gedebage intersection

To support the contraflow regulation on the road segment above, traffic flow regulation is also carried out on the median opening of the U-turn that has been free from flooding to direct vehicles on the contraflow lane to return to the original lane and divide the traffic volume from the east of Soekarno-Hatta 1 Street Fast Lane 1 so that it does not accumulate on the contraflow lane. Closing access to the intersection arm whose entire road body is flooded so that motorists do not cross. Adjust the type of approach of the SPBU – Rumah Sakit Intersection to be a protected type (P) during floods. Change the phase and optimize the cycle time of Gedebage Intersection and Intersection SPBU – Rumah Sakit as follows.

Proposal for do-something 2 in improving traffic performance and unravelling congestion during floods in the study area shown in Fig. 6. Changing the direction of traffic on Soekarno-Hatta 1 Street Fast Lane 2 which was originally an intersection approach (traffic direction to the intersection) into an intersection exit lane as follows.

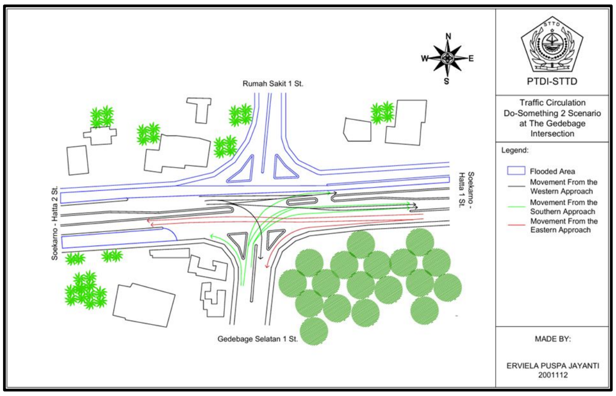


Fig. 6. Traffic circulation do-something 2 scenario at Gedebage intersection

To support circulation regulation on the road segment above, traffic flow is regulated at the median opening of the U-turn that has been free from flooding to direct vehicles on the new exit lane to return to the original lane. In addition, traffic flow diversion on the fast lane leading to the intersection to the slow lane at the median opening of the fast lane and the slow lane before the traffic flow return point is also carried out so that there is no conflict between the confluence of different flows. Closing access to the intersection arm whose entire road body is flooded so that motorists do not cross. Prohibiting motorcycles from passing on the fast lane on the north side of Soekarno – Hatta 1 Street. Prohibiting large vehicles from crossing alternative routes that are local roads. Adjust the type of approach of the SPBU – Rumah Sakit Intersection to be a protected type (P) during floods.

In each traffic engineering scenario, a reload analysis was carried out using PTV Visum with the same OD Matrix as the existing conditions to see the changes in traffic volume that occurred in the study area during the implementation of the do-something 1 scenario or the implementation of the do-something 2 scenarios. The following is a comparison of the results of traffic loading on flood conditions, do-something 1 conditions, and do-something 2 conditions.

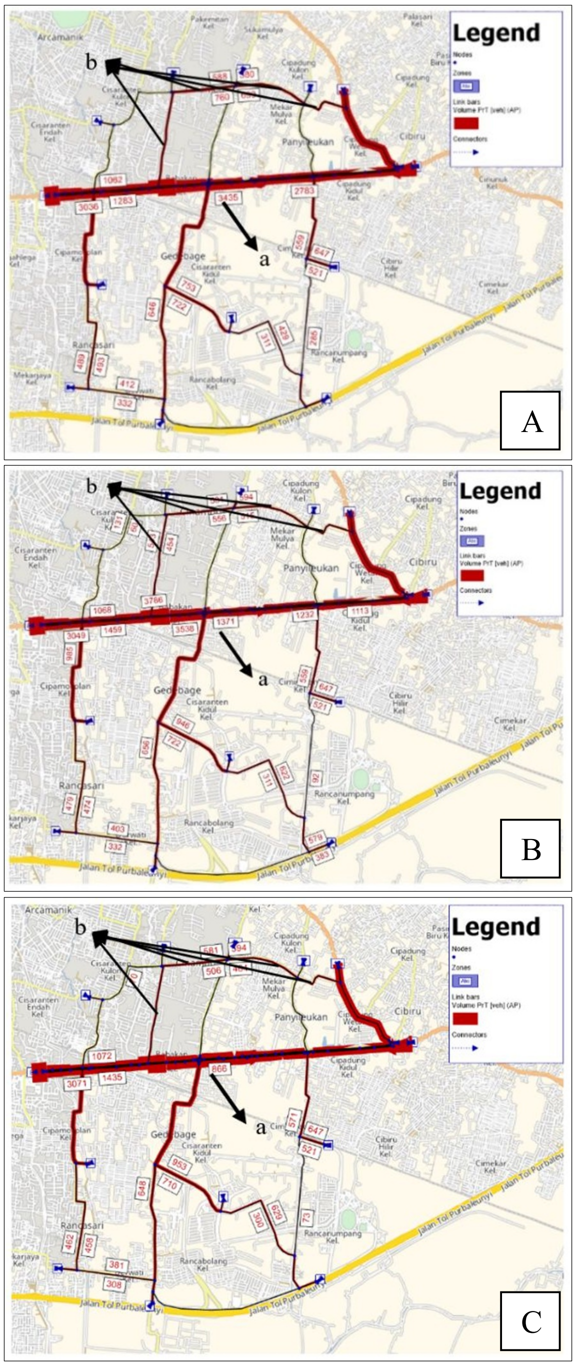


Fig. 7. Comparison of traffic loading in flood conditions (do-nothing) (A), do-something 1 (B) and do-something 2 (C)

Based on Fig. 7, there is a significant change in traffic volume on the Gedebage Intersection which is the main point of congestion (see letter a). In addition, there was also a decrease in traffic volume on Cisaranten Wetan Street, Cinambo Street, Panghegar Street, and Pangaritan Street (see letter b). The results of traffic loading showed a decrease in traffic performance when the do-something 1 scenario and do-something 2 scenarios were implemented. The following is a comparison of road network performance, section performance, and intersection performance between flood conditions, do-something 1 conditions, and do-something 2 conditions.

Gedebage intersection is considered a major congestion point, meaning that this area often experiences severe traffic congestion. There is a significant change in traffic volume at this intersection, indicating a diversion or redistribution of traffic flow as a result of the applied scenario. Traffic volume decreased, which could be caused by the redistribution of traffic flow to other routes or a reduction in vehicles on the road due to the applied scenario. The decrease in traffic volume on these roads can reduce congestion and improve driver comfort and travel efficiency. The results of the analysis show that despite the adjustment or diversion of traffic, overall traffic performance decreased during the implementation of the do-something 1 and do-something 2 scenarios.

Table 3. Comparison of road network performance in flood conditions (do-nothing), do-something 1 conditions, and do-something 2 conditions

No.	Network Performance Parameters	Performance		
		Do-Nothing Condition	Do-Something Condition 1	Do-Something Conditions 2
1	Average Speed (km/h)	31,55	32,02	32,36
2	Total Travel Distance (pcu-km)	82028,96	80991,63	83441,80
3	Total Travel Time (pcu-hours)	3352,47	3070,54	3107,52
4	Average Delay (seconds/pcu)	48,35	17,91	16,27

Table 4. Comparison of performance and service levels on several road sections in do-nothing condition, do-something 1 condition, and do-something 2 condition

Street Name	Do-Nothing Condition		Do-Something Condition 1		Do-Something 2 Conditions	
	Speed (km/h)	LoS	Speed (km/h)	LoS	Speed (km/h)	LoS
Soekarno - Hatta 1 Slow Lane 3 (N) St.	-	-	-	-	-	-
Soekarno - Hatta 1 Fast Lane 1 (N) St.	24,4	E	33,0	C	32,5	C
Soekarno - Hatta 1 Fast Lane 2 (N) St.	10,1	F	19,5	E	30,0	D
Soekarno - Hatta 1 Fast Lane 2 (S) St.	36,6	C	24,3	E	31,0	C
Soekarno - Hatta 2 Slow Lane 1 (N) St.	-	-	-	-	-	-
Soekarno - Hatta 2 Fast Lane (N) St.	27,5	D	26,4	D	25,9	D
Soekarno - Hatta 2 Fast Lane (S) St.	30,3	D	30,3	D	30,1	D
Soekarno - Hatta 2 Slow Lane 1 (S) St.	-	-	-	-	-	-
Cinambo St.	27,5	B	29,5	B	30,4	B
Gedebage Selatan 1 St.	23,7	B	22,9	C	22,7	C
Gedebage Selatan 2 St.	27,2	B	27,1	B	27,0	B
Rumah Sakit 1 St.	-	-	-	-	-	-
Rumah Sakit 2 St.	25,4	C	25,4	C	25,4	C
Raya Derwati 1 St.	22,2	C	26,7	B	26,7	B
Sor GBLA 1 (N) St.	-	-	-	-	-	-
Sor GBLA 1 (S) St.	-	-	-	-	-	-
Pangaritan St.	19,4	C	21,6	B	21,9	B
Panghegar St.	18,1	C	21,3	C	22,6	B

Table 3 shows a significant improvement in road network performance during the implementation of the do-something 1 scenario and do-something 2 scenarios during floods which are characterized by an increase in all road network performance parameter values. In do-something 1 conditions, the speed increases to 32.02 km/h. The total travel distance decreased by 1.2%, the total travel time decreased by 8.4%, and the average delay time decreased by 62%. Meanwhile, in the do-something 2 conditions, the improvement in the performance of the road network is slightly better than the do-something 1 condition even though there is an increase in travel distance compared to flood conditions (do-nothing). Travel speed increased to 32.36 km/h, total travel time decreased by 7.3%, and average delay time decreased by 66%.

The following are roads and intersections in the study area with poor performance values during floods (do-nothing) that have improved performance and service levels in do-something 1 and do-something 2 conditions. Although there was a slight increase in travel distance under the do-something 1 and do-something 2 scenarios, something 2, other improvements in terms of travel speed, total travel time, and average delay time indicate that this scenario is more effective in improving the performance of the road network. There are certain roads and intersections in the study area that perform very poorly during floods without intervention (do -nothing), but experienced significant performance and service level improvements with the implementation of do-something 1 and do-something 2 scenarios

Table 5. Comparison of performance and service levels at several intersections of do-nothing conditions, do-something 1 conditions, and do-something 2 conditions

Intersection Name	Types of Craving	Approach / Intertwining	Do-Nothing Condition		Do-Something Condition 1		Do-Something Condition 2	
			Delay (sec)	LoS	Delay (sec)	LoS	Delay (sec)	LoS
Gedebage	Signal Control	N	-	-	-	-	-	-
		E	58,09	E	30,88	D	27,67	D
		S	61,55	F	26,68	D	31,00	D
		W	430,90	F	57,13	E	19,32	C
Gas Station - Rumah Sakit	Signal Control	N	18,46	C	34,32	D	34,32	D
		E	20,13	C	34,20	D	34,24	D
		S	-	-	-	-	-	-
		W	328,99	F	32,83	D	32,41	D
Rancanumpang - Sor GBLA	No Signal Control	-	-	-	-	-	-	-
Derwati - Sor GBLA	No Signal Control	-	-	-	-	-	-	-

Based on Table 4, it can be seen that over all there is an improvement in the performance of the road sections in the study area at the time of flooding with the implementation of the do-something 1 scenario and the do-something 2 scenarios. The speed of travel on the above roads as a whole has increased, which then affects the level of road service, which also increases. However, based on Table 5 above, the do-something 2 scenario is more influential in increasing the speed and level of road service than the do-something 1 scenario.

These results indicate that two different scenarios called do-something 1 and do-something 2 scenarios have been implemented to address the impact of flooding on road performance in a study area. Both scenarios appear to be designed to improve vehicle travel speed and road service level during flooding. Overall, there was an improvement in road performance after the scenarios were implemented, meaning that road conditions during flooding, such as travel speed and traffic flow, improved. Vehicle travel speed on these roads increased, which in turn improved road service level. Road service level usually refers to the quality of traffic flow and driver comfort. The do-something 2 scenario was found to be more effective in improving road speed and service level compared to the do-something 1 scenario, meaning that the second scenario provided better results in terms of improving road conditions during flooding.

Based on Table 5, it can be seen that overalls there is an increase in the performance of the intersection in the study area at the time of flooding with the implementation of the do-something 1 scenario and the do-something 2 scenarios. The delay in approaching the signal control intersection has decreased significantly with the implementation of this handling scenario. However, based on the table above, the do-something 2 scenario is more influential in increasing the level of intersection services than the do-something 1 scenario. This can be seen from the delay time difference that occurs in the signal control intersection approach of the two scenarios. The delay time generated by the do-something 2 scenario is much shorter than the do-something 1 scenario.

5 Conclusion

Based on the results and discussion above, it can be concluded that at the time of flooding at Gedebage Intersection and Sor GBLA 1 Street, there was a significant decrease in traffic performance on the road network in the study area and there was a buildup of traffic volume on several road sections identified as alternative routes when flooding occurred in the study area. With the implementation of the do-something 2 scenarios in the event of a flood, the traffic performance in the study area has increased significantly and the congestion arising from floods can be minimized. This is marked by a decrease in total travel time and average intersection delays, as well as an increase in the average speed of travel in the study area. The results of the analysis explained that by adding an exit lane on the east arm of Gedebage intersection, optimizing the time of the second cycle of the signal control intersection, and limiting the movement of several types of vehicles when flooding occurs in the study area, it is able to improve the performance of the road network by 74.51% compared to flood conditions without the application of traffic engineering (do-nothing). Based on the findings of the study, it is recommended that researchers can further study the median opening of the U-turn as well as the median of the slow lane and fast lane on Soekarno-Hatta Street so that the influence can be known on the performance of the road section.

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