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Method Development Determination of Bridge Damage Handling Priorities

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Abstract: Priority setting for bridge damage handling in Indonesia has been using the BMS'92 (Bridge Management System) method. The disadvantage of this method is that it does not pay attention to the function and value of the spatial where the bridge is located. The length of time it takes to decide whether or not to repair the bridge and the timeframe for handling the bridge damage will have an impact on the accessibility and socio-economic activities of the community in the area around the bridge. The results of the study on 3 bridges located on the national road section south of the province of West Java, Indonesia, namely the bridges (1) Pangandaran-Pananjung, (2) Babakan-Pangandaran, and (3) Ciandum-Cipatujah on primary and secondary data on bridge conditions, volume traffic, service center activities and regional activities using the gravity method, graphic method, accessibility measurement, LOS (level of services) and Benefit-Cost Analysis for economic analysis, showing different results between the results of the analysis using the BMS'92 method and new analysis method (BMS+) which incorporates function analysis and space value into the calculation model. This difference has a significant effect on the results of the assessment and priority decision making in determining the location for handling damage or replacing bridges

Key words: space function, space value, bridge handling, priority setting, BMS'92 method

1. Introduction

In-UU RI No. 38/2004 and Government Regulation of the Republic of Indonesia Number 34/2006 [1] concerning Roads, what is meant by "bridges" are roads located above water level and/or above ground level, and bridges are one of the strategic transportation infrastructures in Indonesia. a road network that serves to pass vehicular traffic so that the traffic is not interrupted. The development of road and bridge infrastructure aims to support the distribution of goods and human traffic and to form a regional spatial structure (Strategic Plan of the Ministry of Public Works 2010–2014). The construction and repair of bridge infrastructure are one of the government's priority programs to support the reliability of land transportation routes, connecting from one region to another to support and encourage regional progress and accelerate community economic growth. Based on the 2015-2019 RENSTRA Development of road and bridge infrastructure, not only new construction but also the handling and maintenance system.

In general, the condition of the bridge is planned to function properly during a certain service period under the design age, thus the condition of the bridge must always be in good condition and maintained. During its service life, the bridge requires maintenance, because with time the design age of the bridge will experience degradation, either due to the durability of the material, environmental conditions, or due to natural disasters that can reduce the serviceability of

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the bridge. Making decisions on maintenance, repair, and replacement of bridges requires a decision-making process in the form of choosing the bridge to be handled and the bridge maintenance action that must be taken [2]. As the volume and weight of the traffic load of vehicles passing through the bridge and the age of the bridge approach its design life, more and more elements of the bridge are damaged [3]. Therefore, the need for handling is very necessary and a priority in the bridge handling program.

If a bridge collapses, collapses/collapses will break the chain of transportation movement, whether it is caused by a natural disaster, building failure, or caused by other things, then the traffic movement will be disrupted and hamper all socio-economic activities of the community in the surrounding area, which in turn will have an impact. The area throughout the structure of space, and the activities of the area. As stated in UU RI No. 26/2007 [4] concerning spatial planning, article 1, paragraph 3, that spatial structure is the arrangement of settlement centers and a network system of infrastructure and facilities that function as a supporter of socio-economic activities of the community which hierarchically have functional relationships. Repair, maintenance, replacement of bridges, and even the construction of new bridges are aimed at maintaining the performance of the road network, all of these actions require costs and processing time which will become obstacles for road network users or disrupt the activities of the community around the bridge. The main consideration in proposing a bridge infrastructure handling program so far, whether it be maintenance, periodical, rehabilitation, or replacement programs is only based on the results of examining the physical condition of the bridge [5-8]. Likewise, studies of handling bridge maintenance so far have focused more on its physical condition [9].

In Indonesia, the process of examining bridge condition values has been using the BMS'92 (Bridge Management System) based method [10, 11], the assessment of bridge element damage using the BMS method itself is still focused on determining the general condition value of the bridge as an input for the maintenance program plan. Whereas as already mentioned that the non-functioning of the bridge due to the lengthy decision making on the repair or maintenance of the bridge and the length of time it takes to repair/maintain the bridge will greatly disrupt the activities of the surrounding community which has an impact on the economic and social losses of the local community and other people who use the bridge. Based on the problems mentioned above, a new method is needed to complement the BMS'92 method which has been used for making bridge repair/maintenance decisions. For this reason, it is necessary to conduct research and analysis of the function and value of the spatial [12] around the location of the repair handling area where the bridge is located, as a new entity to complete the BMS'92 method

2. Framework of Thought

The form of the process of the entire research that has been carried out as the basis for the analysis is contained in the following framework: (Fig. 1).

3. Overview of the Research Object

The research was conducted on 3 bridges that require corrective action located in three areas, namely, in the area, I Kalipucang sub-district and Region II Pangandaran sub-district, both of which are on the side of the Banjar-Pangandaran National road and are directed to be a development area (WP) with the main function as a tourism area on a national and international scale, as well as a national strategic area (KSN) and a provincial/district strategic area (KSP). While the third research location is in region III, the Cipatujah sub-district which is also on the Pameungpeuk-Cikangengan National-road section (Fig. 2).

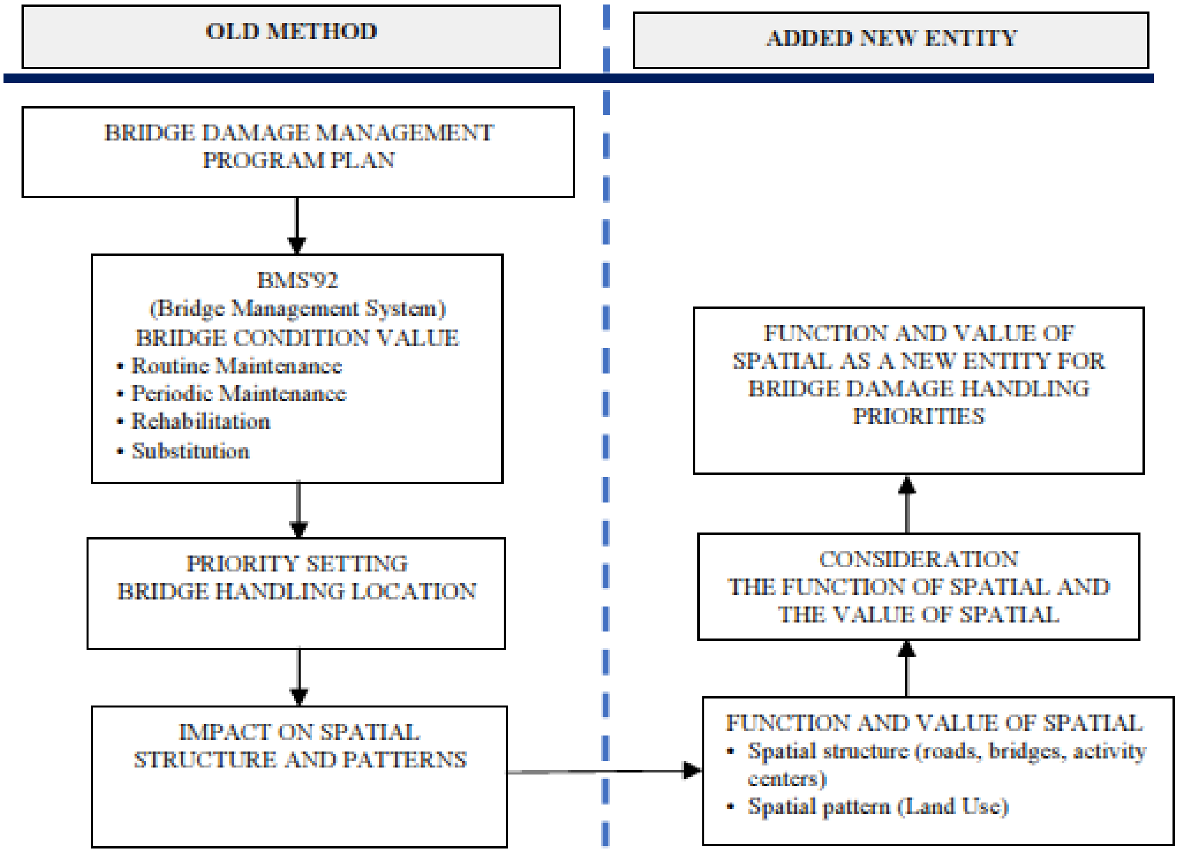

Fig. 1 Framework.

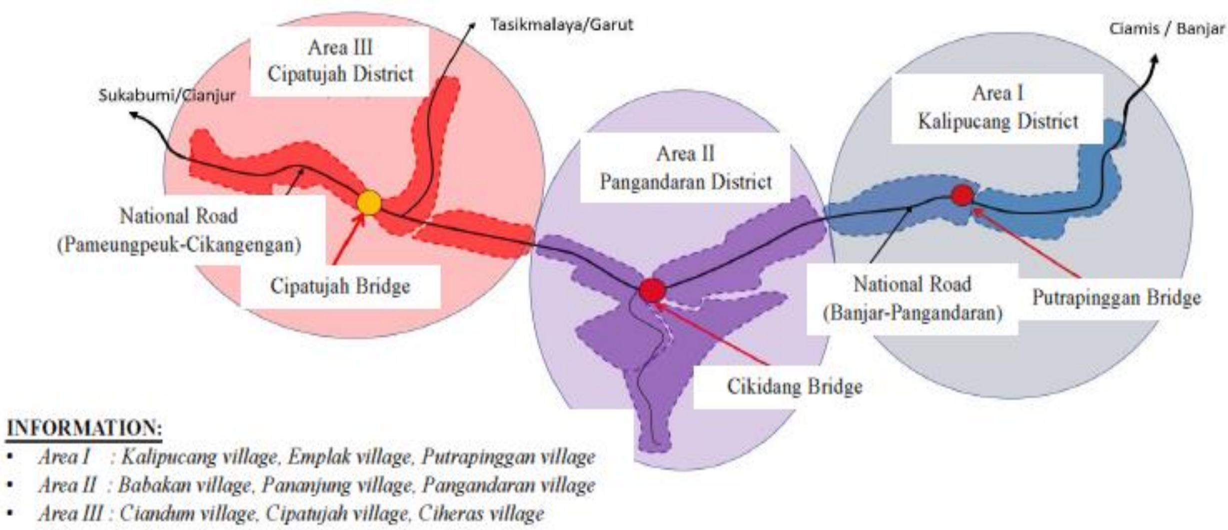

Fig. 2 Delineation of research locations.

4. Methodology and Data Analysis

4.1 Method of Inspection and Analysis of the Condition Value (NK) of the Bridge

The BMS'92 (Bridge Management System) method is one of the methods used in assessing the condition of the bridge through an INVI-J (Bridge Visual Inspection) [13, 14] application which has been developed since 1992. In this BMS'92, there are criteria for determining the level and level of bridge damage. The scoring system is between values 0 to 1, as well as the assessment of the condition value (NK) of the bridge following the criteria as shown in Table 1 and Table 2 below.

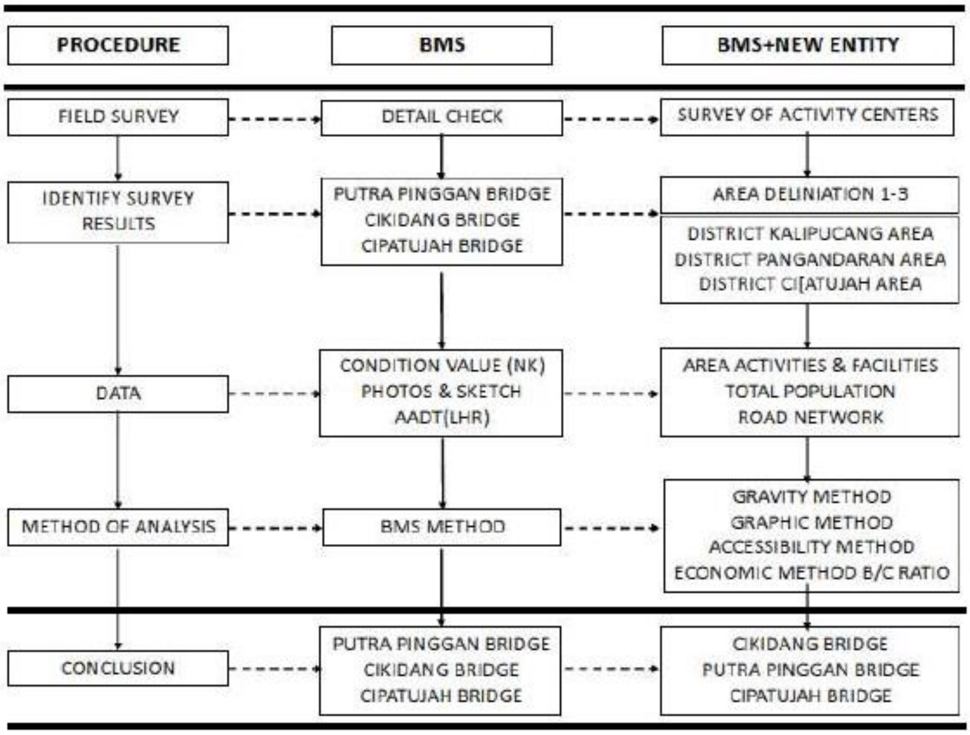

Fig. 3 Research method.

Table 1 Criteria for determining bridge condition values (BMS'92).

Scoring System	Criteria	Value
Structure (S)	Dangerous	1
	Not harmful	0
Damage (R)	Critical	1
	Not bad	0
Quantity (K)	More than 50%	1
	Less than 50%	0
Function (F)	Element works	1
	Element not working	0
Influence (P)	Influence other elements	1
	Does not affect other elements	0
Condition Value (NK)	NK = S+R+K+F+P	0-5

Table 2 Rating of bridge conditions (BMS'92).

Value	Bridge Condition	Handling Program
0	• The bridge is in new condition, with no obvious damage.	• Routine maintenance.
1	• Very little damage (damage can be repaired through routine maintenance, and has no impact on bridge safety or functionality.	• Routine maintenance.
2	• Damage that requires monitoring or maintenance in the future.	• Periodic maintenance
3	• Damage requiring attention (damage that may become serious within 12 months).	• Rehabilitation (repair and/or strengthening).
4	• Critical condition (serious damage requiring immediate attention).	• Rehabilitation (reinforcement and/or replacement).
5	• Bridges collapse or no longer function.	• Substitution

4.2 Bridge Location Analysis Method

In this study, location analysis uses the Gravity method and the Graph method. The gravity method is used to measure the strength of the spatial interaction between two or more regions. This method will be used to measure the level of interaction between the areas where the research is located:

$$I_{AB=k.\frac{P_A.P_B}{(d_{A.B})^2}}$$

Description:
I_{AB} = strength of interaction between regions A and B
k = number of empirical constants, the value is 1
P_A = population of area A
P_B = population of area B
$d_{A.B}$ = distance of region A and B

While graphical analysis is used to analyze the potential strength of interaction between regions in terms of the structure of the existing road network and connected via bridges which are being assessed as objects in this study. To calculate this connectivity index, the following formula is used.

$$\beta = \frac{e}{v}$$

Description:
β = connectivity index
e = number of road network
v = number of activity facilities

4.3 Accessibility Analysis Method

For the accessibility analysis, two types of analytical tools will be used, namely the accessibility index and the level of accessibility. As input data for the accessibility index analysis is the number of service facilities in each region. The accessibility analysis model used follows the model formulation below.

$$A_{ij} = E_j/d_{ij}a$$

Description:
E_j = number of facilities in the area
d_{ij} = physical distance from i to j
a = *exponential value*

To determine the level of accessibility of the research location with various existing facilities, the following accessibility analysis model is used.

$$A_i = KFT/d$$

Description:
K = transportation confitions (asphalt, pavement, soil)
F = transport function (arterial, collector, local)
T = functions and types of regional or local movements and routes
d = distance (i to j)

5. Research Results and Discussion

5.1 Condition Value (NK) of the Bridge

Based on the survey results, the three bridges assessed have a condition value (NK) = 3 and 2. The most severe damage occurred in the superstructure of the bridge where the concrete floor was weathered and the steel girders were corroded/rusted, while the asphalt surface was perforated and corrugated. , and specifically for the Putrapinggan bridge, when viewed from the road geometry, the location of the bridge is located at a corner with a narrow bridge width so accidents often occur. The data from the detailed inspection of the bridge is shown in Table 3 below.

To obtain the latest data on the condition value (NK) of the bridge, a detailed inspection survey and a bridge inventory survey were carried out repeatedly after the replacement. A detailed survey of the condition value and bridge inventory was carried out again to obtain the current condition value related to the two bridges, both the value of the condition of the superstructure, substructure, watershed, and other bridge complementary elements, and an inventory survey was carried out because from the results of the bridge replacement there were several bridge elements, type of bridge, type of foundation, pillars and others related to the changing bridge structure and year of construction. The results of the detailed survey of the condition values (NK) of the three bridges are shown in Table 4 below.

Table 3 Detailed inspection data of bridge condition value (NK).

NO	Description	Name of Bridge		
		Putrapingan	Cikidang	Cipatujah
1	Way link	Banjar-Pangandaran	Banjar-Pangandaran	Ciandum-Cipatujah
2	Year	1993	1971	1992
3	KM (Code of Location)	204 +600	210 + 900	201 +35
4	Length (m)	21,6	12,3	121,7
5	Wide (m)	6,00	6,00	6,00
6	Number of Spans	2	3	4
7	Type of Bridge	GBI	MBI	GPI
9	NK Upper Building	3	3	1
10	NK Floor	2	2	1
11	NK Lower Building	2	2	2
12	NK Watershed	1	2	2
13	Bridge Condition Value	3	3	2
14	Coordinate point	S : 7°40'22.10" E : 08°42'45.20"	S : 7°41'2.90" E : 108°39'18.10"	S : 7°44'45.43" E : 108° 0'38.53"

Source: survey BMS/INVI-J

Table 4 Update data for checking the condition value (NK) details of the bridge 2019.

NO	Description	Name of Bridge		
		Putrapinggan	Cikidang	Cipatujah
1	Way link	Banjar - Pangandaran	Banjar - Pangandaran	Ciandum-Cipatujah
2	Year	2019	2019	2019
3	KM (Code of Location)	204 +600	210 + 900	201 + 35
4	Length (m)	21,6	12,3	-
5	Wide (m)	6,00	6,00	-
6	Number of Spans	1	1	3
7	Type of Bridge	GPI	GPI	Bailey
9	NK Upper Building	1	1	5
10	NK Floor	1	0	5
11	NK Lower Building	0	0	5
12	NK Watershed	0	1	5
13	Bridge Condition Value	1	1	5
14	Coordinate point	S : 7°40'22.10" E : 108°42'45.20"	S : 7°41'2.90" E : 108°39'18.10"	S : 7°44'45.43" E : 108° 0'38.53"

5.2 Area Interaction Strength Analysis

To assess the strength of regional interaction, a comparison of the strength of the interaction between areas I, II, and III is carried out. For area-I, the strongest potential for population interaction is through Putrapinggan and Babakan villages, the strength of interaction = 6,331,095, because these two villages are seen at a closer distance than the other villages, then the number of residents is more and the facilities for activities are more and close so that the interaction between the two villages is stronger. For region II, the potential population to hold the strongest interaction is Pananjung village and Pangandaran village = 72,676,967, because as is known these two villages are located in the center of crowds and tourist attractions and seen from several sectors that are superior to other areas, plus the close distance and a large number of residents and all the facilities for the center of activity already exist in these two villages, so the interaction between the forces of the movement of people is very strong. The results of the analysis show that the strongest interaction strength in region III is Cipatujah village and Ciandum village = 2,525,420 because these two villages are connected by close distances and have a larger population and all facilities and facilities for socio-economic and educational activities are located in Cipatujah village. which also serves as the capital of the district. Schematically the interacting areas can be seen in Figures 4-6 below.

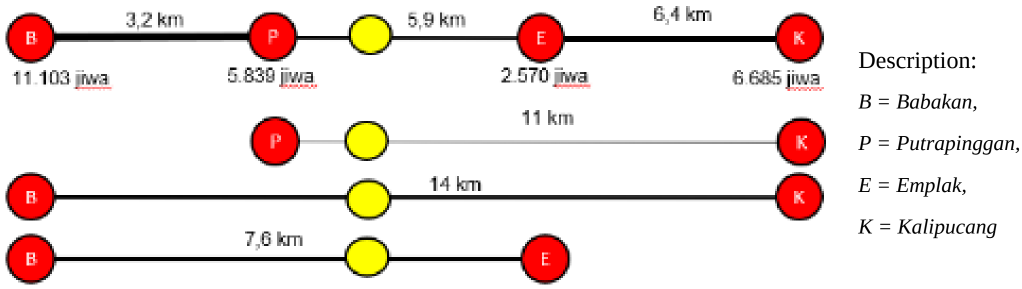

Fig. 4 **Area I interaction.**

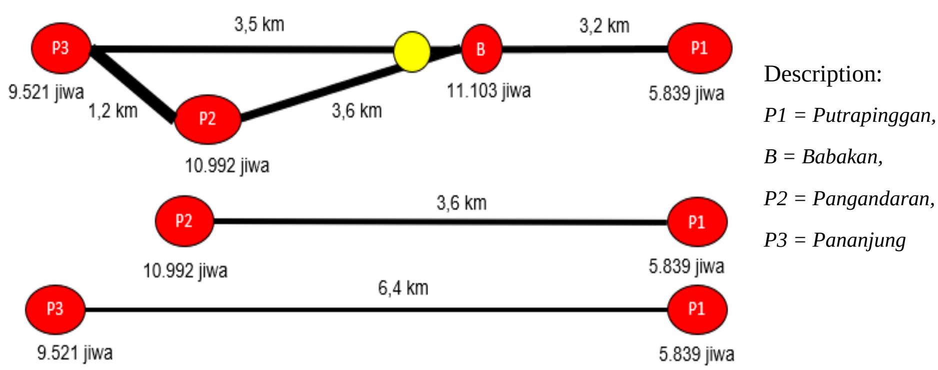

Fig. 5 **Area II interaction.**

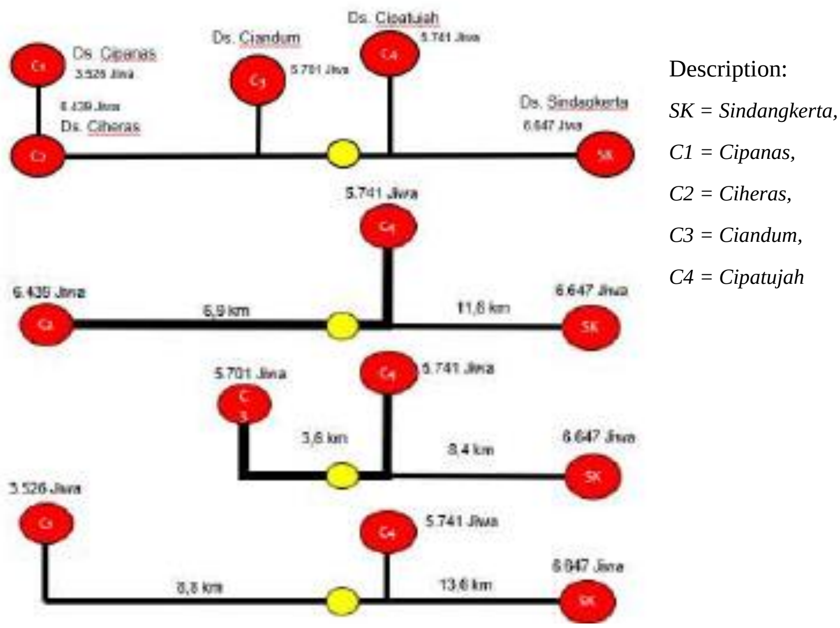

Fig. 6 **Area III interaction.**

5.3 Accessibility Level Analysis

From the results of the accessibility index analysis for the three regions, the best is in the trade and services sector because some of the regions from these three regions include leading tourist areas, either in the Pangandaran district or in the province of West Java. Region I Kalipucang sub-district, accessibility index = 6.00, area II Pangandaran sub-district = 174.81, and Region III Cipatujah sub-district = 19.00 and the best comparative accessibility index of the three regions are in region II, namely Pangandaran sub-district. This is understandable because in the Pangandaran sub-district there are more facilities for activities, namely as a tourist destination. The results of the analysis of the level of accessibility from the three regions (region I, II, and region III) are the highest on the Pananjung-Babakan road section, namely the accessibility level value = 20.77 while for the Putrapinggan-Babakan road section = 8.44 and area III on the Cipatujah Raya road, the accessibility level value is = 18.95. From the analysis of the strength of the interaction, the strongest of the three research areas is in region II Pangandaran sub-district = 1.8 because it is supported by the number of roads as transportation infrastructure, population movements, and the number of activity centers as levers of economic movement, especially trade and services and the tourism sector.

5.4 Level of Service (LOS)

The road service level analysis or Level of Service (LOS) is carried out on the National road (Banjar-Pangandaran) and the National road (Ciandum-Cipatujah) where the bridges are to be repaired/replaced are located. The results of this service level analysis can be seen in Table 5 below.

Table 5 Analysis of road service level (LOS)

Level of Service				**Level of Service**			
Kalipucang - Pangandaran			Interpretation	Cipatujah - Ciandum			Interpretation
Saturday	Sunday	Monday		Saturday	Sunday	Monday	
0,23146	0,226526	0,142644	B	0,157895	0,146681	0,137261	A
0,164624	0,276766	0,139504	B	0,110796	0,120216	0,078499	A
0,465612	0,17225	0,191089	C	0,057417	0,068182	0,060108	A

From the table above, it can be seen that V/C has a scope limit of 0.00 - 1, which means the value of A is free flow conditions at high speed, the driver can choose the desired speed without obstacles. While the current B value is stable, but the operating speed starts to be limited by traffic conditions, the driver has sufficient freedom to choose the speed. Then the value of C the current is stable, but the speed and motion of the vehicle are controlled, the driver is limited in choosing the speed.

5.5 Economic Analysis

This economic analysis uses the Benefit-Cost Analysis method. The results of the analysis show that the most affected road users are road users who pass Viaduck Putrapinggan, namely transportation costs N (normal) = Rp. 9,107,441,280 and TN transportation costs (not normal) = Rp. 29,781,332,986,-. The results of the B/CR (benefit-cost ratio) analysis of the most affected economic sector income is bridges located in Region II with N = 4.28/>1 TN = 4.27/>1, Region III with N = 2.55/>1 TN = 2.50/>1 and Region I with N = 4.7/>1 TN = 4.5/>.

6. Comparison of Analysis Results

The results of the analysis are then compared through the analysis of the comparison matrix for each region. This analysis is used as material in determining the decision to determine the priority scale, in terms of choosing the location for handling bridge damage based on considerations of function and space value. The comparison matrix between Areas I, II, and III is as follows, as shown in Table 6: Based on the results of the comparison analysis Table 6, it shows that both the results of the gravity analysis, graphic analysis, and accessibility analysis for region II, namely the Pangandaran sub-district, are more dominant in the priority level of importance than other regions, and the bridge in region II, namely the Cikidang bridge, is the main priority for repairs or replacements of existing bridges on the southern causeway of West Java because when viewed from the movement and level of interaction as well as the mobility of the strongest population activities are in region II, namely Pangandaran sub-district covering Babakan Village, Pananjung Village, and Pangandaran Village. The results of the comparison of the priority order for determining the location of the bridge in the framework of the bridge damage handling process show that there are differences in results, namely if using the BMS'92 method, the main priority result is the Viaduc Putrapinggan bridge. Meanwhile, the results of the BMS analysis by adding the analysis of the function and space value of the bridge were obtained as the main priority location for handling repairs, namely the Cikidang bridge. When viewed from the overall analysis stages obtained different results. The table of comparison results can be seen in the Table 7 and Table 8 [15] below.

The flowchart of the BMS'92 merging system with 2 new entities (function and space value) can be seen in the flowchart Fig. 7 [15] below.

Table 6 Comparison of analytical methods in Area I, II, and III.

AREA	BMS		GRAVITY	GRAPH	INDEX ACCESSIBILITY	ACCESSIBILITY LEVELS
	I	II				
AREA I	3	1	6.331.095 952.972	0.8	0.75 6.00	8.44
AREA II	3	1	72.676.976 9.416.989	1.8	114.21 15.83	20.77
AREA III	5	5	2.525.420 776.440	0.8	19.00 12.5	18.95

Table 7 Comparison of analysis calculation results.

BRIDGE	BMS’92/ INVI-J	Metoda BMS+				
		Gravity	Graph	Indeks accessibility	Accessibility level	Economic analysis
Viaduct Putrapinggan	1	6.331.095 952.972	0.8	0.75 6.00	8.44	3.4/>1
Cikidang	2	9.416.989 8.629.524	1.8	114.21 15.83	20.77	4.5/>1
Cipatujah	3	2.525.420 776.440	0.8	19.00 12.5	18.95	1.24/>1

Table 8 Comparison of analysis results for the priority of determining the location for handling bridge damage.

NO	Name of Method	Name of Bridge		
		Viaduck Putrapinggan	Cikidang	Cipatujah
1	BMS’92/ INVI-J	**1**	2	3
2	BMS+ method	2	**1**	3

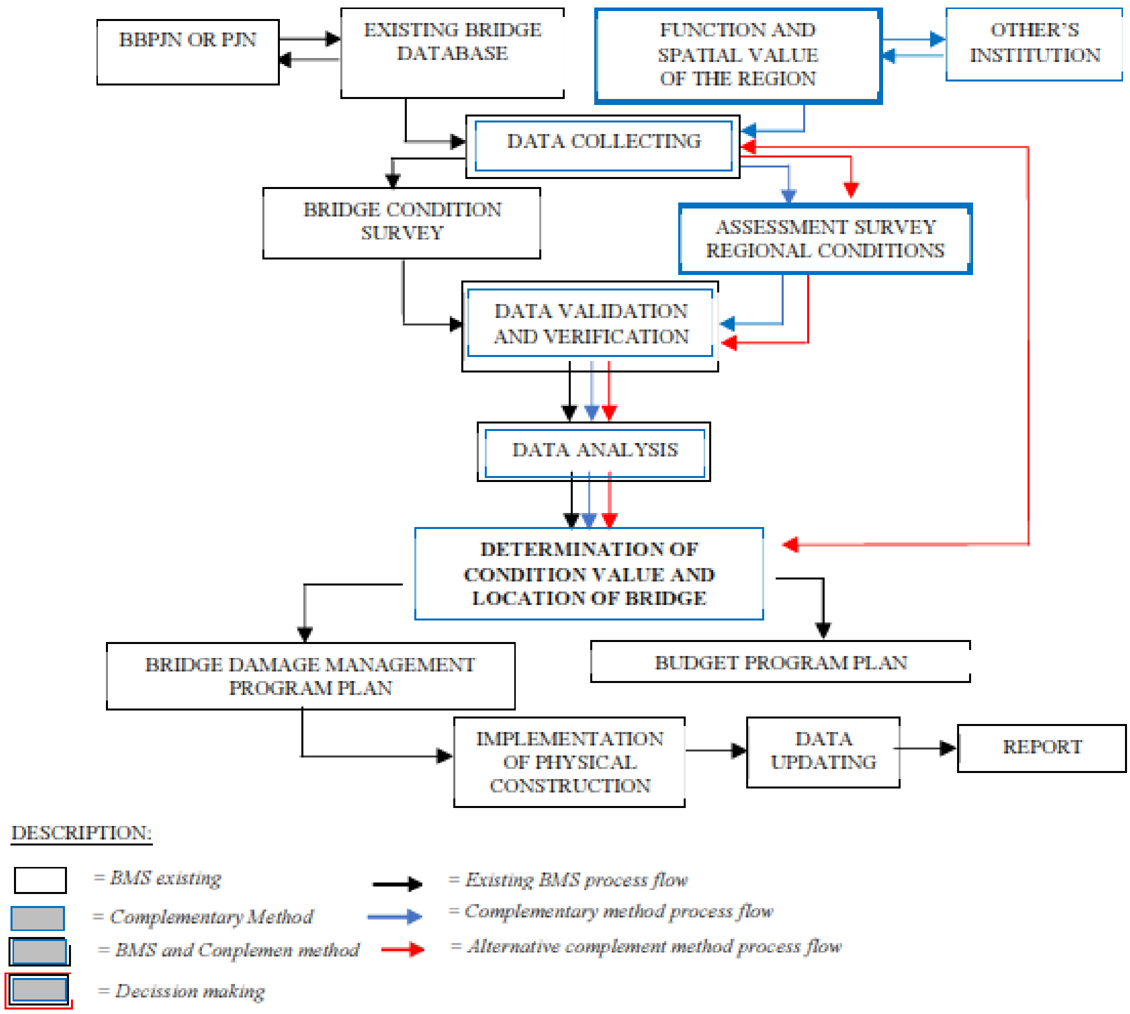

Fig. 7 Flowchart of the bridge inspection procedure with method BMS+.

7. Conclusion

From the results of this study it can be concluded as follows:

The assessment of the condition of the bridge using BMS'92 (Bridge Management System) and BMS+ with the addition of 2 (two) new entities or variables, namely the function variable and space value, produces differences in the results of the analysis, automatically influencing the determination of location priorities for bridge handling.

This research is useful for decision-makers in determining the priority location for handling bridge damage. The bridge assessment procedure resulting from the development of the BMS'92 method is shown in Diagram 8 which includes the function and value of space as a new entity that must be calculated and considered in making decisions on bridge handling because it greatly affects the socio-economic conditions of the community.

It is necessary to conduct trials to examine the value of the condition of the bridge in several other locations to test the consistency of the model tested in this study. It is necessary to disseminate information to agencies or agencies as well as related parties with an interest in issues related to inspection, planning, maintenance, and repair of bridges through publication media for further studies and research to obtain a standard method.

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