JUTEKS - JURNAL TEKNIK SIPIL
E-ISSN: 2621-9786 | P-ISSN: 2527-5496 | DOI prefix: 10.32511

Use of Web-GIS Database Model to Accommodate Public Participation in the Improvement of Sustainable Road and Bridge Management: A Conceptual Idea

Stephanus Ola Demon[1], Paulus Sianto[2], Paskalis Andrianus Nani[3], Don Gaspar N. da Costa[4*]
[2,3,4]Study Program of Civil Engineering, Faculty of Engineering, Universitas Katolik Widya
[1]Study Program of Computer Science, Faculty of Engineering, Universitas Katolik Widya Mandira,

[*)]corresponding author: dnoesaku@unwira.ac.id

Abstract

Sustainability is usually associated with energy source, ecological, soil and environmental aspects. Periodical road and bridge preservation is required to ensure the increasing of accessibility and mobility level, to increase regional economics' growth, to minimize unplanned or unpredicted environmental consequences and to improve institutional arrangement capability as well. Road and bridge preservation is commonly managed based on its level of damage and constrained in budgeting. Poor public policy makes it worst. Therefore, the issue of strengthening the capacity of regional road and bridge management institutions is deemed important and urgent not only to reduce roads and bridges preservation cost but also to increase regional economics' growth. Therefore, a proper road preservation type and priority should be determined based on technical, socio-economics, environment and public policy consideration. However, annual road and bridge functional condition data collection took high cost because it has been carried out by engineering consultant. The aim of this study is resolve it by providing a public participation portion in a road and bridge data base model. They are simply asked to send a real time condition of road s or bridge nearby to the local authority. The results strongly indicate that cost saved obtained from it could be focused to road and bridge preservation cost.

Keywords: *Accessibility index; Geotagging picture; Institutional arrangement capability; Preservation cost*

Abstrak

Issue keberlanjutan seringkali dikaitkan dengan aspek sumber daya energi, lahan dan lingkungan. Preservasi jalan dan jembatan secara periodic diperlukan untuk memastikan terciptanya terkendalinya tingkat aksesibilitas dan mobilitas, untuk meningkatkan pertumbuhan ekonomi regional, untuk meminimalkan dampak yang tak terduga, serta untuk meningkatkan kapasitas institusional. Pengelolaan aspek preservasi jalan biaanya didasarkan pada level kerusakan jalan dan ketersediaan dana preservasi. Kebijakan public yang lemah memperburuk kondisi tersebut. oleh karena itu kemampuan institusi pengelola jalan dan jembatan kan isu penting dan mendesak, tidak saja untuk memperkecil biaya preservasi namun juga untuk meningkatkan struktur ekonomi regional.oleh karena itu, tipe dan prioritas preservasi jalan harus ditentukan dengan mempertimbangkan aspek teknis, social-ekonomi dan lingkungan. Sayangnya, pengumpulan data kondisi fungsional jalan dan jembatan yang dilakukan setiap tahun membutuhkan biaya mahal karena menggunakan jasa konsultan. Tujuan studi ini adalah untuk menyelesaikan persoalan ini dengan menyiapkan mekanisme pelibatan peran serta Masyarakat berbasis model data base. Mereka cukup mengirimkan data kondisi jalan dan jembatan disekitarnya secara kontekstual utnuk selanjutnya divalidasi oleh otoritas. Hasil penelitian ini sangat mengindikasikan bahwa penghematan biaya akibat penggunaan model partisipatif ini dapat dialihkan ke biaya preservasi jalan dan jembatan. .

Kata kunci: *Indeks aksesibilitas; gambar geotagging; pengelolaan kapasitas institusi, biaya preservasi*

Introduction

Generally, most of road and bridge located in sub-urban arterial and collector roadway is in poor category level as can easily be found in East Nusa Tenggara Province, Indonesia. It may be caused by limited ability in providing and/or managing road and bridge's preservation cost distributed in hundreds of islands. Nevertheless, every year the government always carries out data base strengthening activities and surveys on functional conditions of roads and bridges to determine which sections of roads and/or bridges need priority handling. Due to the repetitive nature of the process, it has an impact on the high cost of providing and managing data.

In Indonesia, data collection and processing services are carried out by the engineering consultant firms. Before being recorded, the results of data collection are first assisted with the technical team including the suitability of the names and dimensions of roads, geotagging photos of damaged roads, as well as determining the value of the level of damage based on the damage conditions in each section of the road or bridge. Furthermore, the data on the condition and location of damaged roads are displayed in the form of tables and GIS maps electronically. Since photos of damaged roads or bridges are taken in geotagging format, the location can be easily checked or showed on the map. Unfortunately, this important and strategic information has not been fully used as the main basis for determining the type or priority of preservation. Even the information cannot be easily accessed by policy makers because it was recorded in specific computer server. It remains full air conditioner services continuously. Therefore, it usually broken due to electricity power supply constraints. The data has to be collected and updated again and again.

This study aims to improve the current regional road database management model through the use of a Web-GIS-based digital database management model so that the resulting data collection and validation format saved in cloud system is able to be open accessed anytime. It is also designed to accommodate community participation in online data collection. This model allows updating data in real time so that the role of planning consultants can be minimized. In other words, the planning consultant only take detail data on roads or bridges that are recommended to be preserved. This may reduce the updating database cost significantly.

Method

Research Variables

General information about road functional condition. Such information is classified into good, and slight, medium as well as heavy damage based on the surface distress index/SDI value, whilst the bridge level of damage is determined based on the average value of damage occurred on upper and/or lower structure. The assessment criteria for each type of damage can be seen in Table 1 (Setiadji et al., 2019). The greater the value of SDI the worst the condition of the road segment.

Table 1. Road Condition Assessment Criteria

Type of Failure	Scoring of Failure Condition			Remark
	Weight	Condition	SDI value	
Crack Area	1	None	$SDI_1 = 0$	
	2	≤10%	$SDI_1 = 5$	
	3	10-30%	$SDI_1 = 20$	
	4	>30%	$SDI_1 = 40$	
Crack Width	1	None	$SDI_2 = SDI_1$	∑SDI <50
	2	Smooth <1mm	$SDI_2 = SDI_1$	= Good Condition
	3	Medium 1-3 mm	$SDI_2 = SDI_1$	50 > ∑SDI < 100
	4	Wide >3mm	$SDI_2 = SDI_1 x 2$	= Light Damage
Number of Potholes	1	None	$SDI_3 = SDI_3$	100 > ∑ SDI < 500
	2	>10/100 m	$SDI_3 = SDI_2 + 15$	= Medium Damage
	3	10-50/100 m	$SDI_3 = SDI_2 + 75$	∑SDI > 150
	4	>50/100 m	$SDI_3 = SDI_2 + 225$	= Heavy Damage
Average depth of wheel rutting	1	None	$SDI_4 = SDI_3$	
	2	> 1 cm (X = 0.5)	$SDI_4 = SDI_3 + 5X$	
	3	1-3 cm (X = 2)	$SDI_4 = SDI_3 + 5X$	
	4	> 3 cm (X = 4)	$SDI_4 = SDI_3 + 5X$	

In addition, road segment started to damage as well as observed damaged road that has not been handled are also reported.

Meanwhile, data of the functional condition of bridge is undertaken using a bridge inventory form where the damage condition of each bridge's element is assessed using the Bridge Management System/BMS method (Pratama et al., 2015). As previously stated, the score of damage of each bridge's structural element is then summarized so that the level of damage could be determined based on the average value, as can be seen in Table 2.

Table 2. Bridge Condition Assessment Criteria

Name of bridge	Length (m)	Carriage Width (m)	Scoring* (0-5)					Total score	Average	Level of Damage*
			Upper Structure			Lower Structure				
			Type of construction	Floor condition	Guard rail	Pile cap	Column			
			0-5	0-5	0-5	0-5	0-5	0-25	0-5	

* 0= none, 1= light damage, 2= required maintenance, 3= immediate action, 4= critical condition, 5= disfunction elements

Thus far, the determination of road functional condition is undertaken by planned consultant because the constraint in number as well as human capability in the concerned technical institution.

This responsibility could be transformed to local trained citizen in each district and/or sub district.

Road condition and scale of damage. Information on the name of the road segment, starting point and ending point must be disseminated to each surveyor so that photos of the damage condition are sent to include information about the position or station of the damage from the direction of the starting point to the end of the relevant road segment. In this particular case, the type of damaged that should be observed and reported are cracks, potholes, etc. as can be seen in Table 1. It also shows that the score of damaged (1 to 4) is depending on its scale (light, medium or heavy) identified based on the crack's width or the dimension as well as the number of potholes in each road segments.

Coordinates of the location of the damaged road and/or bridge. Examples of photo-taking techniques (left and right side as well as at the middle of road lane) and the information contained in the damage photo (name of road and village, UTM coordinates of the observed station) must be ensured so that the type and scale of damaged in each location could be correctly recorded.

The characteristics of local activities. The type, number, scale and density of socio-economic activities (including open space and/or empty land area) along the observed roadside should be identified so that the correlation between land use and transport activities (including public transport services quality) as well as the correlation between land use and road preservation capability could be discussed comprehensively. In this particular case, the discussion would be made based on the accessibility level of the main road link that connecting the tourism objects.

Existing road handling system. The determination of roads and/or bridges that must be handled has not been published, but based on the results of discussions with a number of technical team members for the road and bridge data base work in the last 3 years, it is indicated that the determination of priority for handling roads and/or bridges is influenced by a number of things:

1. From the technical aspect it is based on the percentage of the length of the road that is heavily damaged. The higher the percentage, the higher the priority ranking.
2. From the socio-economic aspect, it is based on the condition of the physical and functional connectivity of the road. The cut off road gets the highest priority.
3. From the political aspect, it is based on the position and role of the road segment. Roads that cross electoral base areas and/or policy-making villages receive the highest priority. Similarly, the main connecting road to the center of the tourist area, agriculture and/or the center of the leading socio-economic area.

Collection and Validation Data

Visual observation about road and bridge functional condition is captured using geotagging type of camera such as *Timestamp*, etc., which could be installed in android. It may inform coordinate location of each type of damage and name of region as well as data of observation concurrently. Therefore, the picture's resolution should be high so that the damaged condition could be identify and/or crosscheck clearly later. In this particular case, if the initial database should be previously provided then according to previous data, then a change in road and/or bridge condition could be clarified more easily. Subsequently, the data collected is used to determine the SDI value based on each type and scale of damages.

Consequently, since the data produced is referred to distance range of observed station of 200 m, then each type and scale of damage in such range of distance should be gathered in the same folder of field data. Therefore, the land use data in each road segment should also be informed so the correlation among them could be discussed.

The physical connectivity

Identifying the location of damaged road and bridge is required to identify whether the location of damaged bridges is in the same damaged road or not. If they are located in the same road link then the accessibility level is additional reduced. In this case, the accessibility index is calculated using the following equation:

$$Accessibility\ Index\ (AI) = \frac{\sum P_{rl}}{T_{rl}} \qquad (1)$$

P_{rl} = total road length within poor categories (km)
T_{rl} = total road length (km)

Therefore, the road segments within light to heavy damage area categorized in the poor condition. In this particular case, it could be understood that the AI value could be applied for evaluating the road link performance as well as road network performance.

The following points could be identified from the mapping of damage roads and bridge's location: 1) interconnected roads (travel chains) between sub-districts which are the center of leading sector activities 2) the number of bridges and/or river crossing areas on the main connecting road to the center of the leading economic sector activity. This information could be used to determine priorities for handling damage to roads and/or bridges (Irawan et al., 2016; Sudradjat et al., 2015)..

Result and Discussion

Road and bridge functional condition

In this study, the road surface condition survey only conducted on the road link that connecting the main tourism objects around the island of Semau as can be seen in Fig.1 below. It is a small and dry island located nearby the island of Timor in which the location of capital city of East Nusa Tenggara province, Indonesia. Since the main socio-economic activities were based on dry land agriculture and tourism activities then it is thought that it may be used as an object study to describe the role of a digital database system in the development of their regional economic growth based on sustainable road infrastructure management system.

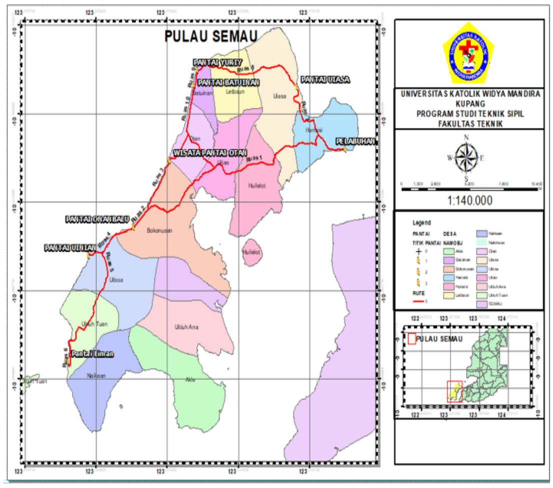

Figure 1. Observed road link

Currently, the display of road functional condition data is intended to inform the total length of roads that are in good or damaged condition. This data is usually used to determine the accessibility index and priority determination strategies for road and bridge handling. The accessibility index is mainly used to indicate the percentage of sections of the road that are difficult to pass because they are in a heavily damaged and/or difficult to cross condition. Similarly, the bridge accessibility index is used to describe the difficulty level of crossing the river crossing area due to variations in the level of bridge damage, or even due to the unavailability of a bridge in the river crossing area in question.

Unfortunately, until now, the data and/or information that can be generated from the database of functional conditions of the roads and bridges are only displayed in the form of tables and maps and can only be accessed by the Technical Team or Commitment Making Officials in the relevant agencies. Consequently, important and strategic issues related to the management strategy (priority determination and form of handling) of roads and bridges are relative, perhaps only known by planning consultants and/or related technical teams. The aspect of determining the priority of handling the damage so far is not the responsibility of the planning consultant because the substance and output of data base strengthening activities as stated in the Terms of Reference for the activity is only intended to produce data on the condition of road and bridge damage, the percentage level of damage to roads and bridges and the distribution of damage to roads and bridges. the location.

Table 1 below shows that the ratio of road length within in poor category to the total of the observed road length is usually used to describe the accessibility level. Therefore, although each location of socio-economic activities has been connected by road link but if the road functional condition is in the poor category, then the number of trips is usually less because it may increase not only the time travel but also the travel cost. The accessibility index value is around 31.965% where is 21.571% of them are in a heavy damaged category. This may confirm the very low traffic volume identified during the field survey period, particularly to the Pantai Liman and other tourism objects located far enough from the main transfer point of Hansisi port.

Table 1 Report form of functional conditions of roads

Number of Link	Number of Districts	Length (Km)	Type of Pavement					Functional Condition							
			Hot Rolled Sheet	Penetration Asphalt	Concrete Asphalt	Telford/ Gravel	Soil	Good		Medium		Light Damage		Heavy Damage	
								Km	%	Km	%	Km	%	Km	%
11	2	107.43	62.105	61.543	0	7.217	0.03	73.09	68.035	7.885	7.34	3.28	3.05	23.175	21.572

Moreover, the number and distribution of damaged roads have occurred in an irregular pattern. Therefore, priority of handling should be given to the handling of damage to roads segment, especially the main connecting roads to the center of tourism activities, or other leading socio-economic activities in the region. For this reason, this study proposes the use of Web-GIS based model to show not only the location but also the visual condition of the level of damage to roads at each location of damage. Meanwhile, from the result of field observation it was found that all small bridges are in good condition so that only routine preservation type is required.

Land Used and Road Network Characteristics

Since the island of Semau is categorized in small and dry island then the common type of activities is predominantly by dry land agriculture and natural as well as cultural tourism objects, especially based on offshore tourism facilities such as restaurant, bungalow, swimming beach, etc. In order to achieve such tourism location, there are several main roads that could be used to access them. However, although each exotic beach could be accessed using motorcycle and light vehicle but the functional condition should be increased. In addition, there was no public transport services.

Figure 2 below clearly shows that all Tourism Beach locations could be accessed using light vehicle as well as motorcycles. It could also be seen that the functional condition of some road segment is in poor condition category level. From the result of visual observation along the road link that connecting all tourism object's location it was found an interesting phenomenon as follows:

1) The type of land use is dominated by empty land (savanna), local residential (segmented), horticultural yards, and grassland. Further, the density of such activity is in low category and the distance between them is also faraway. Therefore, the local daily trip is dominated by social trips using private and/or rent motorcycle. This explains the absence of public transport services.
2) The main type of economic activities is dry land agriculture, and tourism-based activity such as offshore tourism (swimming, exotic sunset viewing, local culinary), restaurant, and cultural objects.

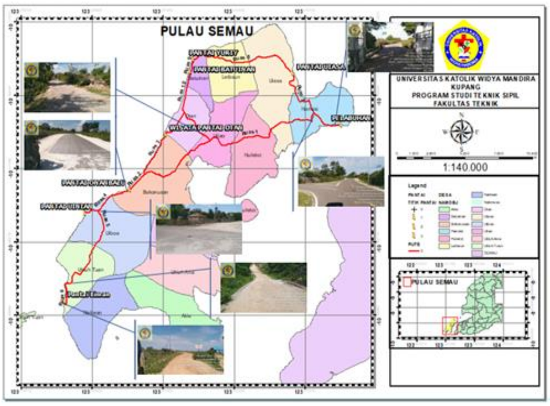

Figure 3. The dispersion location of tourism object at the island of Semau

Unfortunately, such economic activities have not been adequately supported by strategic arrangement. For example, since the location of activities are sporadic then their trip attractiveness is low. Consequently, the presence and/or growth of derived socio-economic activities such as mini-restaurant, hotel or guesthouse are also low. This may occur due to lack of local resident involvement in tourism activities. Therefore, it is required a diffusion of innovation so that local resident should be part of such social-economical changes, in accordance with (Robert, 2015). Therefore, it is though that an appropriate road preservation effort should be support by suitable land use intervention.

Challenge in Road Construction

a. Budget Constrain
The dependency on General Fund Allocation and/or Specific Fund Allocation from National Fund due to the inadequacy of Novel Local Earning from taxes strongly influence not only the road infrastructure preservation capability but also tourism object's facilities.

b. Construction materials availability
Semau Island is a small and dry land. The highest altitude is around 200 msl so that the presence of big river is very limited. Consequently, the unavailability of crushed stone used to construct the road pavement layer (base, sub base and road pavement surface) should be substituted by suitable alter material. A concerned previous study by Naikofi, et.al. reported that the use of local coral as a crushed stone substitute could be applied as long as the minimum standardized value of California Bearing Ratio is accepted. However, the use of such local material cannot

be instantly implemented because it has not been validated and/or calibrated. Therefore, it is required further studies to ensure the legal aspect of its usage, including by considering the potential environmental degradation due to the exploitation of such local coral.

c. Sustainable issue
Although lime stone and/or local coral could be found elsewhere in the island of Semau but a large scale of use of such substituted material in the road infrastructure activities should be monitored systematically and curiously so that each vegetation (trees) that have been departed during the land clearing stages should be replaced or converted and maintenance during the construction stages. This should be anticipated so that the potential environmental problems as reported by previous research (Karas & Bohatkiewicz, 2015; Puodziukas et al., 2016) could be avoided.

d. Strategic management in regular annual Village Fund should be appropriately considered by adding the road preservation fund so that the road functional condition could be maintained by local authority. Therefore, it is required a systematic and online road infrastructure database system. The use of such digital database model may answer it. The current road preservation funding allocation model is much depending on the availability of suitable priority program. Therefore, it was much influenced by the political bargaining effort, rather than the technical and/or economic aspects.

Accordingly, the determination of road infrastructure priority program should consider the effect of physical and functional connectivity concurrently based on the accessibility index level and/or the mobility level as follows:

a. The key strategies to implement a transit system (a concept that can integrate land use and transport systems) is to recognize the viable centers of socio-economic activity, in accord with (Natalia, 2021)
b. The time travel and/or travel cost should be improved so that it may trigger the increasing of trip attractiveness.
c. The socio-economic activities should be spread out along the main tourism road so that it may trigger the increasing of socio-economic trips. It is hoped that the presence of various socio-economic activities along the main tourism roadway may increase the regional attractiveness. In turn, it may increase internal and/or external trips such that the improvement of public transport services could be achieved.

Improvement of road and bridge management strategy

Since the availability of pavement material is limited then the use of crushed stone as the foundation and/or surface layers can be replaced by coral stone as long as the standardized CBR and Marshall values are met. Therefore, the following aspects should be considered:

a. Use of alternative materials (solid textured rock/rock)
A number of studies have been conducted to use solid coral / rock as an alternative material. The results of this study indicate that the use of rock as an alternative to crushed stone is only suitable for use in the subbase layer. Apart from that, the results of this study indicate that the level of dependence on imported materials can be reduced so that production costs become more affordable.
However, although the use of rock as an alternative to crushed stone is only allowed but its extraction should be limited due to environmental degradation possibility as can be seen in Fig.2 below. It strongly indicates the requirement of another type of environment friendly technology.

a. Rocky-coral quarry at Holain – Uiasa Village	b. Crushed stone quarry at Uibua – Uiasa Vullage	c. Rocky-coral quarry at Uibua – Uiasa Vullage

Figure 4. Land degradation due to the extraction of local crushed stone and rocky-coral

b. Use of soil-cement technology
Many studies have been conducted which aim to use a mixture of soil and cement (soil-

cement) as the basic material for forming roads. Soil-cement is a mixture of soil and type I pozzolan cement and a number of additives such as Difa-soil, and the like. The use of additive materials is not only to speed up the hardening process but also to increase the stability value of the road coating. The use of soil-cement technology is a profitable alternative because the composition of cement and additives is largely determined by the type of subgrade soil around the road construction site. Therefore, the use of a mixture of soil and cement (soil-cement) as the basic material for forming roads is strongly recommended because it may affect less land and/or environmental degradation.

The two alternative technologies are oriented towards the use of local materials as basic materials for road construction. This may support the environmental sustainability in logistic aspect (Mckinnon et al., 2010). Therefore, tactical and strategic efforts are needed to prevent disruption/damage to the natural environment due to the exploration/mining of these alternative materials.

The forms of environmental damage that are most likely to occur include:

a. changes in the form of land cover due to loss/reduced vegetation in the mining area
b. soil erosion in the mining area and sedimentation of material carried from upstream to downstream of the mining area

On the other hand, the scarcity of crushed stone for the construction of the bridge's concrete structural elements is overcome by: 1) using as little concrete material as possible 2) optimizing the use of steel materials/construction as the main structural element of the bridge.

Recommendation (Implication of Study Result)

In order to improve road and bridge infrastructure services quality, local authority should consider its relationship with land use and transport means characteristics as well as institutional arrangement capability, proportionally. Aspects of management that must be improved should be focused on how to increase: 1) the accessibility and mobility level 2) socio-economic activities 3) environmental quality 4) institutional arrangement capability, in accord with the proposed basic concept to improve the transportation system quality (Colonna et al., 2012; da Costa et al., 2021), by conducting the following aspects:

1. Road infrastructure management strategy:
    a. Technical assistance for soil-cement technology-based road construction, including assistance in the provision and use (operation and maintenance) of soil-cement production equipment intended for the implementation of soil-cement-based road works. This part of the work is the responsibility of the Kupang District Government, particularly the Public Works Service, and can collaborate with academics/universities.
    b. Technical assistance in determining strategic road corridors that need to be prioritized for handling roads and bridges. This part of the work is the responsibility of the Kupang Regency Government, especially the Regional Development Planning Agency, and can work together with academics / universities
2. Land use intervention focused on the determination of suitable type, number or density, scale of activities, in accord with (da Costa et al., 2019). This may be implemented if the local authority provides a kind of zoning regulation and promote suitable land use policy such as the use of progressive tax for new related investment.
3. Socio-economic activities focused on how to increase the number of trips or trip attractiveness. These should confirm the land use pattern or type and number of activities that could be built in a specific area. The presence of high scale activity such as hotel, or restaurant, or minimarket may trigger derived activities surrounding which in turn may increase their trip attractiveness.
4. Political (institutional arrangement) focused on providing and managing a regular road infrastructure fund and determination of priority projects by considering the occurrence of possible consequential environmental impacts produced.

Conclusion

The conclusions that can be drawn from the results of this study are:
Although the use of soil-cement based technology and/or local alter material for road and bridge presentation devices may reduce the construction (logistic) cost and trigger the proceed of road and bridge's regular funding so that the accessibility and mobility level might be increased, but a land and/or environmental degradation possibility due to its extraction should be curiously managed. Consequently, it required technical assistance during the construction or in the provision and use (operation and maintenance). This is the responsibility of the Public Works Department of Kupang District Government, and can collaborate with academics/universities.

An increasing in accessibility level along the main road that connecting the primary tourism object locations may trigger tourisms as well as other socio-economic trips attractiveness. which in turn may affect the increasing of derived socio-economic activities surrounding. Therefore, it could be inferred that a technical assistance in determining strategic road and bridge corridors that need to be prioritized is required.
Since the growth of socio-economic activities is influenced by region attractiveness and trip purposes then a land use intervention focused on the determination of suitable type, number or density, scale of activities should be taken, including providing specific policy for the presence of high scale of activities' investment. Consequently, the local authority should provide a kind of zoning regulation and promote suitable land use policy such as the use of progressive tax for a new high trip attractiveness objects investment.

Acknowledgements

Thank is conveyed to the group of Student Research Community of Transport Infrastructure, Study Program of Civil Engineering, Faculty of Engineering, Universitas Katolik Widya Mandira Kupang who has helped the process of collecting and compiling data on the condition of roads.

References

Colonna, P., Berloco, N., & Circella, G. (2012). The Interaction between Land Use and Transport Planning : a Methodological Issue. *Procedia - Social and Behavioral Sciences (SIIV - 5th International Congress - Sustainability of Road Infrastructures)*, *53*, 84–95. https://doi.org/10.1016/j.sbspro.2012.09.862

da Costa, D. G. N., Rayawulan, R. M., Bela, K. R., Naikofi, M. I., Seran, E. N. B., & Hendrikus, R. (2021). Use of Train Transport to Bridge Social-Economic Activities Between Indonesia and Timor Leste Along the Northern Coast of the Island of Timor: A Preliminary Study. *Advances in Engineering Research*, *199*(ICoSITEA 2020), 6–10. https://doi.org/https://doi.org/10.14716/ijtech.v9i4.941

da Costa, D. G. N., Rayawulan, R. M., & Seran, S. S. L. M. F. (2019). Penentuan Jenis, Jumlah, Skala dan Kerapatan Aktivitas di Kawasan Perkotaan berdasarkan Tarikan dan Bangkitan Perjalanan. *Prosiding Simposium Forum Studi Transportasi Antar Perguruan Tinggi Ke-22*, 1–10.

Irawan, H., Ismiyati, I., & Pudjianto, B. (2016). Penentuan Skala Prioritas Penanganan Jalan Kabupaten di Kabupaten Kudus Dengan Metode Analytical Hierarchy Process. *TEKNIK*, *37*(2), 72–77. https://doi.org/10.14710/teknik.v37n2.8411

Karas, S., & Bohatkiewicz, J. (2015). Sustainable Bridge Design . Zrównowa ż one projektowanie mostów. *PROBLEMS OF SUSTAINABLE DEVELOPMENT*, *10*(November (1)), 123–132.

Mckinnon, A., Cullinana, S., Browne, M., & Whiteing, A. (2010). *Green Logistic: Improving the environmental sustainability of logistics*.

Natalia, V. V. (2021). *Supporting the Integrated Planning for Land Use and Transport Systems by Examining the Distribution of Urban Centres and Public Transit Networks* (Issue August). an der Fakultät VI - Planen Bauen Umwelt der Technischen Universität Berlin.

Pratama, R. P., Vaza, H., Irawan, R. R., & Halim, H. A. (2015). *Pengembangan Sistem Manajemen Jembatan Terpadu*.

Puodziukas, V., Svarpliene, A., & Braga, A. (2016). Measures for Sustainable Development of Road Network. *Transportation Research Procedia*, *14*, 965–972. https://doi.org/10.1016/j.trpro.2016.05.076

Robert, H. (2015). Integrating transport and land-use planning ? How steering cultures in local authorities affect implementation of integrated public transport and land-use planning. *Transportation Research Part A:*

Policy and Practice, *postprint:*, 1–13.

Setiadji, B. H., Supriyono, & Purwanto, D. (2019). Surface Distress Index Updates to Improve Crack Damage Evaluation. *11th Asia Pacific Transportation and the Environment Conference (APTE 2018) Advances in Engineering Research*, *186*(APTE 2018), 48–55.

Sudradjat, H., Djakfar, L., & Zaika, Y. (2015). Penentuan Prioritas Penanganan Jembatan pada Jaringan Jalan Provinsi Jawa Timur (Wilayah UPT Surabaya: Kota Surabaya , Kabupaten Sidoarjo dan Kabupaten Gresik). *Rekayasa Sipil*, *9*(3), 219–228.