INTEGRATING MMS AND GIS TO IMPROVE THE EFFICIENCY AND SPEED OF MAPPING OF URBAN ROAD DAMAGE CONDITIONS IN MATARAM, INDONESIA

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ABSTRACT :
An effort to maintain roads still in condition in Mataram City required maintenance even reconstruction. Related matter that, necessary information fast about condition surface road. This is important so can make decisions in handling the road. Information in the form of a map showing the condition and location of road damage is very helpful in speed of handling. Making maps relies heavily on data readiness to calculate road damage. Using application Mobile Mapping System (MMS) for damage data collection through photo tagging and Geographic Information Systems (GIS), can speed up making maps. The method used in the analysis of damaged roads is method Surface Distress Index (SDI). Based on the application This obtained the type of damaged road and at the same time position with synchronization location using GPS. The result of is novelty study is a map condition of surface roads in the city of Mataram spread out over 6 sub-sub-districts It is in condition good until damaged heavily. Based on the total length of Mataram City roads (312,529 km), the conditions and handling patterns provided are: (1) Good (85%): Routine maintenance (light green); (2) Medium (9%): Light rehabilitation (green); (3) Minor damage (3%): Heavy rehabilitation (yellow); and (4) Heavy damaged (3%): Reconstruction (red).

Key-words: *GIS, Mobile Mapping System, Surface Distress Index, Rehabilitation, Reconstruction, Maps Information*

1. INTRODUCTION

Road service performance decreases as the road ages, until one day the road surface becomes disturbed. Road damage is a condition where a road is damaged unable to serve traffic optimally (D, Sharma and Gogi, 2022). Driving comfort and safety are affected due to damage such as roads holes, cracks and collapses (Van Der Horst, Lindenbergh and Puister, 2019). So, maintenance is something that needs attention so that roads have an excellent level of service for accessibility between regions.

Along with the speed of the development program, it is demanded speed in readiness information. When the road management agency will to repair damage, clear information is needed regarding the type of damage so that effective action can be taken. The data obtained must be accurate (valid) and precise (reliable) in order to obtain information that meets needs (Kabir, 2016). Because of this, a lot of research has been carried out regarding the detection of road surface damage using image processing techniques, resulting in quite high detection accuracy (Maeda *et al.*, 2018). Automatic detection with a focus on identifying road damage is a challenging topic in road maintenance (Zhang *et al.*, 2022). Road conditions must be known for maintenance purposes by conducting field surveys in the form of information maps. However, surveys require a long time and a large number of personnel if there are a large number of roads or areas. Effective data acquisition techniques are needed with minimal effort and time to obtain maximum spatial data requirements (Furlaneto, Santos and Hara, 2012).

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The main process is Geographic Information System (GIS) -based asset mapping and geospatial analysis (Azeem *et al.*, 2020). This is where the Mobile Mapping System (MMS) method emerged which utilizes instrument development in mapping activities. MMS is increasingly used among technologies in the context of mobile platforms, combining sensors and measurement systems designed to provide a 3D position of the platform and, at the same time capable of obtaining geographic data without the help of control points in the field (Dardanelli *et al.*, 2015). MMS is a mobile platform and uses a Direct Georeferencing System (DGS) and remote sensors for the synchronization process, connecting with time, data, and to obtain the position and orientation of the platform. This MMS is able to provide fast, efficient, cost-effective and complete data collection. Its development was motivated by the desire to overcome this problem with alternative methods of collecting spatial data (El-Sheimy, 2005).

Spatial modeling is a GIS product that can be used as a reference in developing future policies for effective spatial management (Antomi *et al.*, 2023). The use of sensors in mapping and GIS applications is becoming very interesting. This was triggered by the progress achieved in the Mobile Multi-sensor System with the concept of multisensory integration and aspects of its implementation. These advances are in terms of sensor resolution, data speed and operational flexibility (El-Sheimy, 2000). The use of MMS for data acquisition and updating in road management with a spatial framework system is used in Switzerland. This simple system is very efficient for data retrieval. This system is an evolution of survey techniques and technology in the form of the development of a low-cost mobile mapping system (Gilliéron *et al.*, 2001). The evolution of MMS has received attention because it was facilitated by the availability of low-cost sensors (Taymanov and Sapozhnikova, 2020), advances in computing resources, maturity of mapping algorithms, and the need for accurate and on demand GIS and digital map data (Elhashash, Albanwan and Qin, 2022). The advantages provided by MMS include: 1) it can be applied to areas that are difficult to access by terrestrial surveys; 2) produce data that can be processed in the office; 3) has variable parameters and flexible data acquisition; 4) requires a relatively short time; 5) have accurate data quality including altitude information; and 6) reducing field work (Madeira, Gonçalves and Bastos, 2013). This method is effective and practical in recording road conditions and inventory data. The data obtained from MMS is processed using software called tracker, then analyzed using the SDI method. The results of SDI calculations are integrated into GIS to obtain spatial information data. This activity carries out the creation of products in the form of information system applications. This product utilizes GIS technology. The information system displays road conditions which are used as reference information to facilitate government work. In this case it can be used in planning, checking and programming road conditions periodically and continuously.

The government needs new breakthroughs in accelerating road management and repair. The application of MMS and GIS to prepare road condition maps is one option because it provides acceleration in data collection. Research that offers high productivity with a combination of navigation and videogrammetry tools (Ishikawa *et al.*, 2006), minimizes the personnel energy used in field data collection. Flexible use of vehicles in field data collection results in reduced survey costs. This method obtains photo data with coordinates so that it is precisely at the location of the road damage. Furthermore, the data can be analyzed using the *Surface Distress Index (SDI)* method to obtain the type of damage that occurred, such as good, moderate, light and heavy damage (Hamdani and Pujiastuti, 2022).

The urgent need for road maintenance management means MMS must be chosen to be applied for data collection. The combined navigation system displays of GPS Dead Reckoning, GPS-Gyro Inertial Measurement Unit, laser scanner, camera, and measurement data logger with high accuracy, can measure the center and side lines of the road (Ishikawa *et al.*, 2006). The GPS receiver works in point positioning mode, with deviations of several meters in planimetry and even higher altitudes. This accuracy is not sufficient to be representative for creating or updating large-scale road network maps (Baiocchi, Domenica and Vatore, 2017), integration with other applications is required. This can speed up the acquisition of information on road surface conditions when making maps.

This map is very useful in road maintenance management as a treatment database. Information from this map is used as a reference in selecting handling locations for preparing the Detail Engineering Design (DED). This research needs to be carried out to anticipate damage handling in order to maintain stable road conditions. The availability of accurate and up-to-date data on the condition of all road sections in the database system is very helpful for related parties in preparing road plans properly.

2. RESEARCH METHODS

2.1. Research area location data

Research was conducted on all roads in Mataram City, Lombok Island, Indonesia. **Fig. 1** shows a map of the research location.

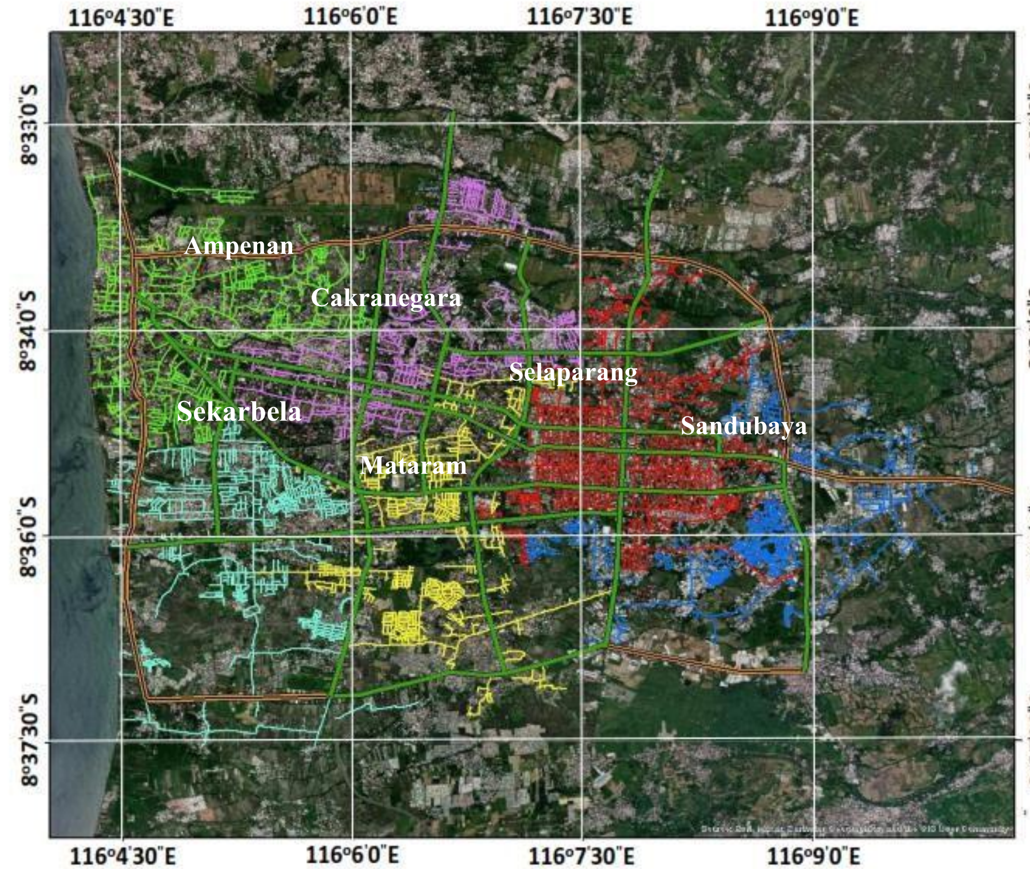

Fig. 1. Map of the Mataram City Road network spread across 6 sub-districts, current condition.

2.2. Equipment, work methods and approaches

Data collection was carried out by surveying road conditions using *the MMS method, which is* one option to speed up data collection. Data collection using *the MMS method* can be used as a reference for assessing the initial condition of road damage. The tool used is a multisensor system application modified from several components placed on a motorbike for mobile data collection (see **Fig. 2**).

Fig. 2. A set of road condition survey equipment.

The selection of sensors for such systems clearly depends on system requirements, such as accuracy, reliability, operational flexibility and application range. The data acquisition module contains navigation sensors and imaging sensors. Navigation sensors are used to solve georeferencing problems. Different systems on general navigation. This combination offers considerable redundancy and does not require additional sensors for reliability purposes. The addition of an odometer type device for short-range applications is necessary for operational reasons, for example maintaining a constant distance between camera exposures. The data acquisition module must be designed with the application and transport vehicle in mind.

MMS has become an emerging trend in mapping applications because it allows the application of task-oriented geodetic concepts at the measurement level (El-Sheimy, 2000). These systems have a common feature in which the sensors required to solve a particular problem are installed on the same platform. By accurately synchronizing data streams, solutions to specific problems can be achieved using data from a single integrated measurement process. Mission integration results from a number of discontinuous measurement processes and the inevitable errors inherent in those processes are avoided. This results in conceptual clarity, task-oriented system design, and data flow optimization. A more important application that offers the potential for real-time solutions in many cases.

The MMS measurement trend is driven by the demand for fast, cost-effective data acquisition and the development of technologies that meet this demand. Two developments are particularly important in this context: Digital imaging and precision navigation. Digital imaging sensors greatly reduce data processing efforts by eliminating the digitization step. The relatively cheap price of digital frame cameras is the reason for their redundancy as a primary design tool (Elhashash, Albanwan and Qin, 2022) (Madeira, Gonçalves and Bastos, 2012) (Hassan *et al.*, 2006).

In the form of pushbroom scanners, they provide an additional layer of information, which is not available from optical cameras. Because the results are available in digital form, combining the data with imaging data is easy and real-time applications are in principle possible. Operational flexibility is improved in all cases where a block structure is not required. Costs will be greatly reduced, especially in areas where little or no ground control is available (Ellum and El-Sheimy, 2000). Current accuracy is sufficient for many mapping applications (Chiang, Tsai and Chu, 2012).

A consideration for its use for mapping applications that use digital frame cameras, push sweep scanners, or laser scanners as imaging components is the incorporation of the concept of georeferenced images as the basic photogrammetric unit. Each image with its georeferenced parameters, namely three positions and three orientations, can be combined with other georeferenced images of the same scene using geometric constraints. The parameters of each image are obtained directly through independent measurements. The direct method does not require connectivity information in a single image block to solve the georeferencing problem. So that can offer much greater flexibility.

2.3. Data collection

Surveys are carried out using photo tagging which produces photos with coordinates attached to the documentation data. This data can be depicted on a GIS map to make it easier to check field conditions.

The process of collecting field data begins with preparing equipment from the MMS tool, namely a set of camera equipment integrated with GPS. The condition of the vehicle used for the survey must also be in good condition (Ellum and El-Sheimy, 2000) (see **Fig. 2**). Road condition inspection form to record special conditions on the road surface. The survey was carried out on the road section from the start point to the end point of the road section.

The application is carried out starting from small kilometer benchmarks to large kilometer benchmarks. Survey officers observe road conditions from vehicles traveling no more than 30 km/h and fill out the specified supporting form. Survey officers determine conditions that are representative of the 200m road section surveyed. In special conditions and cannot be observed from the vehicle, the survey officer must get out of the vehicle and carefully observe the road conditions and take measurements of the existing damage.

2.4. The analysis method to determine the type of damage that occurred is to use the SDI method

Surface Distress Index (SDI) is used to provide an assessment of road pavement conditions. This value can be used as a reference in maintenance efforts (Hamdani and Pujiastuti, 2022). The analysis uses data from visual observations using data from photo surveys using the MMS method. The operator fills out the form then enters it into the SDI table to process road segment data which is divided into several segments (Direktorat Jendral Bina Marga, 2011).

Pavement assessment consists of (Direktorat Jendral Bina Marga, 2011): 1) Pavement surface condition, 2) Cracks, 3) Other damage. Pavement surface assessment consists of: a) Surface arrangement conditions (**Table 1**), b) Pavement surface condition (**Table 2**), c) Value based on surface settlement area (**Table 3)**

A patch is a pavement surface condition where holes, slopes and cracks have been repaired and leveled with asphalt and stone or other aggregate materials. Calculations are made based on the percentage of patch area to the total road surface area along 200 m (Direktorat Jendral Bina Marga, 2011) (see **Table 4.** Value based on patch area).

Surface subsidence is a local decrease in an area of pavement that usually occurs in an erratic form. Included in the reduction category is a reduction in vehicle wheel load marks. The calculation is based on the percentage of area that has decreased to the total surface area along 200 m (Direktorat Jendral Bina Marga, 2011) (see **Table 5.** Value based on crack area).

Table 1. Struture surface conditions.

Surface condition	Explanation	Value
Good/ meet/ dense	Smooth and even, like a new coating from what was mixed in a mixing place, for example a layer of asphalt concrete. The small stones visible on the surface are well arranged in the binder.	1
Rough	Rough with stones that stand out compared to the binding material (asphalt)	2

Table 2. Pavement surface condition.

Surface condition	Explanation	Value
Good	The road surface is flat without deformation or slope	1
Excessive asphalt	The road surface is smooth, shiny, and there are no visible rocks. On hot days, this type of surface becomes soft and sticky	2
Leave	This situation occurs on pavement surfaces where there is a lot of asphalt binder that does not bind the stone aggregate so that a lot of stone comes loose without the asphalt binder.	3
Destroyed	The road surface was destroyed and almost all of the asphalt binder was missing. There are lots of loose rocks of various sizes on the road surface and it looks like a gravel road with a little bit of the surface still paved.	4

Table 3. Value based on surface settlement area.

Settlement area	Value
None	1
<10%	2
10 - 30%	3
>30%	4

Table 4. Value based on patch area.

Patch area	Value
None	1
<10%	2
10 - 30%	3
>30%	4

Crack Width is the distance between two crack areas measured on the pavement surface. Crack assessment includes (Directorate General of Highways (Direktorat Jendral Bina Marga), 2011): a) crack area (**Table 5**), b) crack width (**Table 6**), c) type of crack (**Table 7**). Cracked Area, is the area of the road surface that has cracks, calculated as a percentage of the surface area of the 200 m surveyed road section. The value of the crack area factor can be seen in **Table 5**.

Table 5. Value based on crack area.

Crack area	Value
None	1
<10%	2
10 - 30%	3
>30%	4

Table 6. Value based on crack width.

Crack width	Value	Condition
None	1	-
<1mm	2	Good
1 – 3mm	3	At the moment
>3mm	4	Wide

Table 7. Value based on surface crack type.

Crack Type	Explanation	Value
None	-	1
Not-connected	-	2
Interconnected (wide area)	These interconnected cracks form a pattern with a wide area including transverse and longitudinal crack patterns	3
Interconnected (narrow field)	Interconnected cracks form patterns with narrow or small areas, including crocodile skin cracks and similar cracks.	4

Table 8. Value based on the number of holes.

Number of holes	Value
None	1
<10/200m	2
10 – 50/200 m	3
>50 / 200 m	4

Table 9. Value based on the width and depth of the hole.

Width and depth	Size	Value
Small	< 0.5m	1
Wide	≥ 0.5m	2
Shallow	< 0.5cm	3
Depth	≥ 0.5cm	4

Other damage assessment includes (Directorate General of Highways (Direktorat Jendral Bina Marga), 2011): a) Holes, namely the number of holes (**Table 8**), width and depth of the hole (**Table 9**) and b) wheel marks (**Table 10**). The number of holes on the road surface surveyed was 200 m long. The hole size is an estimate of the average hole size representing a 200 m long surveyed road section.

Table 10. Value based on wheel marks.

Wheel marks	Value
None	1
< 1cm	2
1 – 3 cm	3
>3cm	4

Table 11. Surface Distress Index Value (SDI Value).

Road Conditions	SDI
Well (W)	<50
Moderate (M)	50 – 100
Light Damage (LD)	100 – 150
Heavy Damage (HD)	> 150

Wheel ruts are depressions that occur on the road surface due to the weight of vehicle wheels. Vehicle wheel arches can be in the form of protrusions and rutting that are widely distributed on the road surface.

From the results of the observations above, values are obtained for each type of damage identified. The road condition value is obtained by adding up all the values of pavement damage that occurred. It can be seen that the greater the cumulative damage number, the greater the value of the road condition. This means that the road is in poor condition and requires better maintenance (Setiadji, Supriyono and Purwanto, 2019).

For the SDI method calculation, there are 4 main variables which will later be included in the calculation, namely the percentage of crack area (%), average crack width (mm), number of holes per 200 m and average rutting depth (cm). The SDI index calculation is carried out in an accumulation manner based on road damage so that road conditions can then be determined as shown in **Table 11**.

The stages in calculating the SDI value carried out are: 1) Determining the initial SDI_1 based on the total area of cracks, 2) Determining SDI_2 based on the average crack width, 3) Determining SDI_3 based on the total number of potholes, 4) Determine SDI based on average depth of vehicle wheel rutting. The SDI_1, SDI_2 , and SDI_3 values are obtained from **Table 12**.

Table 12. The SDI value is based on the Total Crack Area, Average Crack Width, Number of Holes and Average Wheel Depth.

SDI_1	SDI_2	SDI_3	SDI is based on rutting depth
None	None	None	None
Crack area: <10% = 5	Average crack width: Fine <1 mm; $SDI_2 = SDI_1$	Number of holes: <10 /200m; $SDI_3 = SDI_2 + 15$	Rutting depth: <1 cm; X=0.5; $SDI = SDI_3 + 5*X$
Crack area: 10-30%=20	Average crack width: Med 1-3 mm; $SDI_2 = SDI_1$	Number of holes: 10 - 50/200m; $SDI_3 = SDI_2 + 75$	Rutting depth: 1-3 cm; X=2; $SDI = SDI_3 + 5*X$
Crack area: > 30% = 40	Average crack width: Width>3 mm; $SDI_2 = SDI_1 *2$	Number of holes: > 50 /200m; $SDI_3 = SDI_2 + 225$	Rutting depth: > 3 cm; X=5; $SDI = SDI_3 + 4*X$

2.5. Method for drawing road condition maps

Road damage conditions obtained from SDI calculations are mapped using GIS to make it easier to see the distribution of road conditions. The map is drawn by combining the results of calculating road conditions (with SDI) and location (with GPS). In this road survey, the navigation system is satellite-based to notify users of its location, namely with GPS. By combining the system with the equipment used, geospatial data used during tracking can be recorded based on certain coordinates (waypoints). Waypoints can be used to identify the start and end locations of a section, intersection points, locations of culverts, bridges and other objects whose coordinates are considered important for storage.

GIS in principle, it is a special information system that is used to process geographic data (spatial data) to produce information. GIS data consists of spatial (location-based) and non-spatial (attribute) data that are interconnected (integrated). GIS is a computer system for capturing, storing, examining, and displaying data relating to positions on the earth's surface. By connecting seemingly unrelated data, GIS can help individuals and organizations better understand spatial patterns and relationships. By analyzing and visualizing data, GIS helps individuals and organizations uncover patterns, trends, and relationships that might not be apparent when looking at the data individually. With this concept, spatial data in the form of road locations is integrated with road damage conditions according to the survey location. All of these combinations will depict a map of pavement surface conditions throughout the research area, namely Mataram City, Indonesia.

3. DATA ANALYSIS AND RESULTS

3.1. Data collection results

Data on road surface conditions in Mataran City was taken using the MMS method. Examples of survey data collection results can be seen in **Fig. 3**, location of the Jalan Batu Bolong section (Mataram Sub-district) and **Fig. 4**, location of the Jalan Karang Duntal section (Sandubaya Sub-district).
Images of road surface conditions were taken at every 25-meter distance.

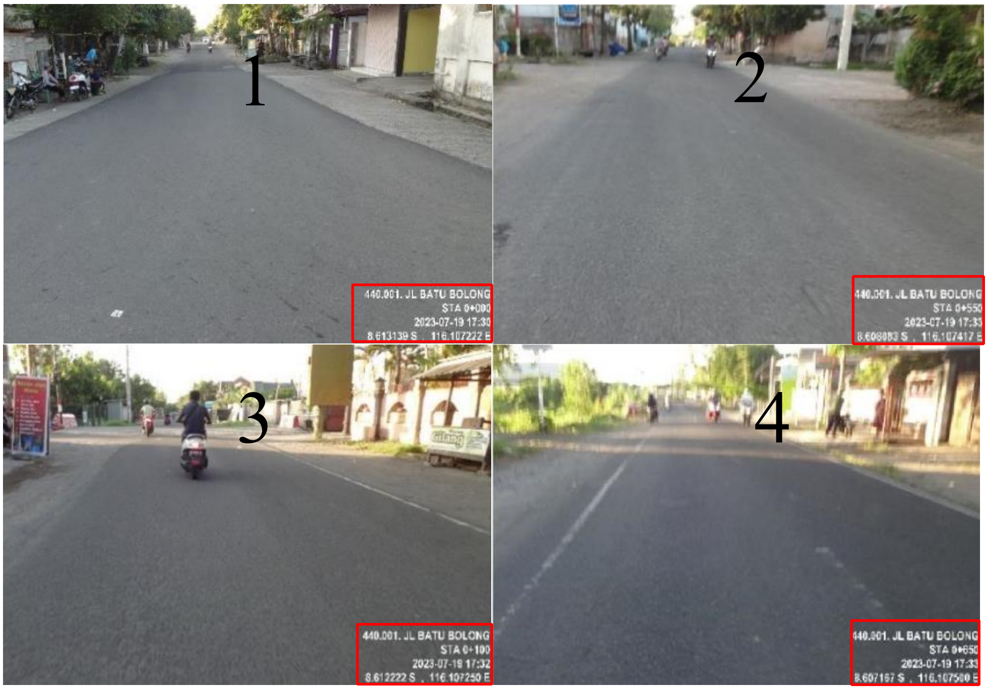

Fig. 3. Photo results of the road surface using the MMS method for the Batu Bolong Road section.

Fig. 4. Pictures of Road Surface Conditions on Karang Duntal Road.

3.2. Analysis of road surface damage conditions using the Surface Distress Index (SDI) method.

Detailed calculation of road surface conditions using the SDI method, based on data collection (photos of road surface conditions) using the MMS method. The surface conditions of the Batu Bolong Road Section (Mataram Sub-district) and the Karang Duntal Road Section (Sandubaya Subdistrict) are based on data taken using the MMS method as in **Fig. 3** and **Fig. 4**. These road sections are divided into several segments with a length of 200 meters. Based on the appearance of the road surface, the condition of the road surface can be calculated. Including the type of damage due to photo tagging, as road condition data. Road condition data is then used to obtain SDI.

a) Example of SDI calculation for Jalan Batu Bolong Road Section I (0+000 – 0+200):
Based on the results of photo documentation using the MMS method (see **Fig. 3**), it shows that the composition of the asphalt pavement is smooth and even, in **Table 1** the value is 1. Based on **Table 2** the condition value is 1 (flat surface, without changes in shape). Visually, the condition is good, where there are no: subsidence, road surface spots, cracks, so the overall value is 1 based on **Table 3-9**. There were no holes and rutting found on this section of road, so the value of other damage was 1.
The calculation of SDI values based on **Table 12** is:
   - Establish initial SDI_1 based on total crack area: None, $SDI_1 = 0$
   - Set SDI_2 based on average crack width: None, $SDI_2 = 0$
   - Set SDI_3 based on number of holes: None, $SDI_3 = 0$
   - Determine SDI based on average wheel rutting depth: No rutting conditions were found on the surveyed road sections, so the SDI value = 0. SDI value < 50, based on **Table 11**, shows the road surface is in Well (W) condition.

b) Example of SDI calculation for Jalan Karang Duntal Road Section (0+000 – 0+200):
Based on the results of photo documentation using the MMS method (see **Fig. 4**) it shows the composition of asphalt pavement in rough condition, value 2 (based on **Table 1**).

Tabel 13. Example of Road Condition Calculation Sheet using the SDI Method and recommendations for handling

INPUT IS BASED ON SKJ FORM PER 200M																	Calculation of SDI Value/200 m				SDI Value	Type	Condition	Handling
Road section number	Sub-section road number	Name of road section	Kilo-meter bench-mark	Length (meters)	Pavement surface				Cracks			Other damage					Crack area	Crack width	Number of holes	Wheel marks		A: asphalt; B: concrete; K : gravel; T: land road		
					Structure	Condition	Settlement	Patch	Type	Wide	Area	Number of Holes	Hole Size	Wheel Marks	Edge Damage									
															Left	Right								
			from-to		(1-2)	(1-4)	(1-4)	(1-4)	(1-4)	(1-4)	(1-4)	(1-4)	(1-5)	(1-4)	(1-3)	(1-3)								
521	-	Batu Bolong I Road	0+000	200	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	A	**Well**	**Routine Maintenance**
			0+200	13	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	A	**Well**	**Routine Maintenance**
522	-	Batu Bolong II Road	0+000	200	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	A	**Well**	**Routine Maintenance**
			0+200	65	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	A	**Well**	**Routine Maintenance**

a) Batu Bolong Road Section

INPUT IS BASED ON SKJ FORM PER 200M																	Calculation of SDI Value/200 m				SDI Value	Type	Condition	Handling
Road section number	Sub-section road number	Name of road section	Kilo-meter bench-mark	Length (meters)	Pavement surface				Cracks			Other damage					Crack area	Crack width	Number of holes	Wheel marks		A: asphalt; B: concrete; K : gravel; T: land road		
					Structure	Condition	Settlement	Patch	Type	Wide	Area	Number of Holes	Hole Size	Wheel Marks	Edge Damage									
															Left	Right								
			from-to		(1-2)	(1-4)	(1-4)	(1-4)	(1-4)	(1-4)	(1-4)	(1-4)	(1-5)	(1-4)	(1-3)	(1-3)								
526	-	Jalan Karang Duntal	0+000	200	2	3	2	1	4	4	4	3	4	1	1	1	40	80	155	155	155	A	**Heavy damaged**	**Recon-struction**
			0+200	200	2	3	2	1	4	4	4	3	4	1	2	1	40	80	155	155	155	A	**Heavy damaged**	**Recon-struction**
				14	2	3	1	1	4	4	4	3	4	1	1	1	40	80	155	155	155	A	**Heavy damaged**	**Recon-struction**

b) Karang Duntal Road

The condition of the aggregate occurs loosely on the road pavement, based on **Table 2**, the value of condition 3 is obtained. There is no visible decrease in visual documentation, on direct observation, the settlement is less than 10%, based on **Table 3**, the value of condition 2 is obtained. There are no visible patches on the road surface, based on **Table 4** condition value 1. There are cracks with an average crack width of more than 3 mm (value 4, **Table 6**) which are interconnected (**Table 7**, value 4) and the crack area is more than 30%, based on **Table 5** the condition is found value 4.

Other damage that occurred as seen between 10-50 holes (value condition 3, **Table 8**) with an average size of more than 0.5 m with a shallow depth based on **Table 9** obtained a value condition of 4.

The calculation of SDI values based on **Table 12** is:

- Establish initial SDI_1 based on total crack area crack area: > 30%; $SDI_1 = 40$
- Set SDI_2 based on average crack width: Width > 3 mm; $SDI_2 = SDI_1 \times 2 = 40 \times 2 = 80$
- Set SDI_3 based on Number of Holes Number of holes: 10-50/200 m; $SDI_3 = SDI_2 + 75 = 80 + 75 = 155$
- Determine SDI based on average wheel rutting depth: No rutting conditions were found on the surveyed road sections, so the SDI value = 155. SDI value > 150, based on **Table 11**, shows the road surface is in Heavy Damage (HD) condition.

Complete calculations of all road sections are carried out in tables using the Excel application. Examples of SDI calculations for the Karang Duntal Road Section (shade) in Sandubaya Sub-district and the Batu Bolong Road Section (shade) in Mataram Sub-district can be seen in **Table 13**.

Recapitulation of road condition calculations based on the results of road condition surveys using *MMS* and data analysis using the *SDI method* shows that the road condition values for 312,529 km are in the well category (85%), 32,225 km are in moderate condition (9%), light damage conditioned along 13,799 km (3%) and heavy damaged along 11,296 km (3%). Details of the results for each sub-district are presented in **Table 14**.

Table 14. Results of analysis of road conditions per sub-district in Mataram City.

Condition	Sub-district Sandubaya		Sub-district Cakranegara		Sub-district Mataram	
	(km)	(%)	(km)	(%)	(km)	(%)
Well	36,887	86	67,155	91	55,737	88
Moderate	3,214	8	4,757	6	4,822	8
Light Damage	2,208	5	1,910	3	2,152	3
Heavy Damage	374	1	161	0	613	1
Condition	Sub-district Selaparang		Sub-district Ampenan		Sub-district Sekarbela	
	(km)	(%)	(km)	(km)	(%)	(km)
Well	47,609	84	53,037	84	41,344	73
Moderate	4,172	7	7,542	12	7,117	13
Light Damage	3,160	6	2,104	3	1,874	3
Heavy Damage	1,726	3	631	1	6,120	11

3.3. Synchronization analysis of road positions into GIS maps

From condition data obtained using *MMS* and analyzed using *the Surface Distress Index (SDI) method,* the condition of road surface damage in Mataram City was obtained. Furthermore, the conditions and types of road treatment are regulated in **Fig. 5**. The conditions and treatment patterns provided are: (1) Well: Routine maintenance (light green); (2) Moderate: Light rehabilitation (green); (3) Light damage: Major rehabilitation (yellow); and (4) Heavy damaged: Reconstruction (red).

Sandubaya Sub-district

Cakranegara Sub-district

Mataram Sub-district

Selaparang Sub-district

Ampenan Sub-district

Sekarbela Sub-district

Fig. 5. Map of road conditions in 6 sub-districts in Mataram City based on SDI calculation results.

4. DISCUSSION

4 .1. Speed, precision and accuracy of the MMS method in obtaining data on road surface conditions

MMS is a new method to speed up the measurement process with positional accuracy and dimensional accuracy values that meet the accuracy criteria (Teo, 2018) provided in the Urban Road Geometry Inventory Survey Guidelines by the Ministry of PUPR. The use of web-based information system technology created using secondary data in the form of data obtained using MMS, sub-district administrative boundary data, and road section list attribute data, can make it easier for the government and the public to obtain information about roads. conditions more effectively. MMS can obtain a road database with a combination of navigation tools, and videogrammetry, validly and effectively with a location error within 100 [mm] even on sloping roads (Ishikawa *et al.*, 2006). This becomes evident when the validation results carried out in field conditions match the results of the images produced with MMS.

4.2. Map depiction of road surface conditions as a guide for road maintenance management

The novelty of this research is determining treatment priorities based on the level of road damage by integrating the MMS method with the Surface Distress Index (SDI) method to obtain a data base in the form of a road pavement condition map.

Based on survey results using tagging photos, photos are produced with coordinates attached to the documentation data, which can be depicted on a GIS map, to make it easier to check existing field conditions. This GIS map can also show the connectivity of City roads with higher status road networks. Data from GIS maps can also display information on existing road conditions with attribute tables containing section numbers, road section names, road section lengths and display condition maps according to existing conditions in the field (see **Fig. 6**).

Fig. 6. Image of phototagging display in GIS.

The pattern for handling any road damage is, if the road is in good condition, routine road maintenance is still carried out, for roads in moderate condition, light rehabilitation is carried out, and for lightly damaged roads, heavy rehabilitation is carried out. exit or periodic maintenance of damaged roads and conditions. Massive handling of road repairs or road reconstruction is carried out in order to return the road to its original function (See **Fig. 5**).

5. CONCLUSIONS AND FUTURE WORK

Conclusions based on the discussion of the analysis results are as follows:

1) *MMS* produces photos that show the type of road damage and its location (along with coordinates), so that it can be used as a reference for initial assessment of road surface conditions.
2) Recommendations for handling each road section refer to maps produced based on MMS data using *the Surface Distress Index (SDI) method.* The handling pattern is in the form of routine maintenance carried out on roads in good condition. On lightly damaged roads, light rehabilitation treatment is carried out. On damaged roads, massive rehabilitation is carried out (periodic maintenance). Meanwhile, repairs (reconstruction) are carried out if the road is in a heavy damaged condition. This is done to restore the function of the road.

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