Web-GIS Application using Multi-Attribute Utility Theory to Classify Accident-Prone Roads

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***Abstract*—Traffic accidents are greatly influenced by several factors. Some of the factors are the condition of the roads, the density of the roads and the number of accidents occurring on the road. Web Geographical Information System (Web-GIS) can assist the society to identify the accident-prone points with Multi-Attribute Utility Theory (MAUT) Method. The Web-GIS was built using the architecture concept of client-server, where the application could act as the server. The Web-GIS system thematic using ArcGIS Desktop 10.2 software, linked to the database of Microsoft SQL Server Management Studio. It was then carried on to the Web-GIS technology and ArcGIS Viewer for Silverlight. The green thematic layer with the category classification of low-risk accident prone-roads was 24%. The yellow thematic layer with the category classification of accident prone-roads was 58% and the red thematic layer with the category classification of high-risk accident prone-roads was 18%.**

***Index Terms*—WEB-GIS; MAUT; Thematic-Layer; Traffic-Accident; Prone-Roads.**

I. INTRODUCTION

The objects of the discussion on this paper were Gresik Regency and Bawean islands, East Java Province, Indonesia as shown in Figure 1. According to the data from the Traffic Police corps of Indonesia in 2010, out of 31.234 people lost their lives due to traffic accidents in Indonesia. More than 4.500 victims died in East Java. Gresik Regency in East Java, Indonesia was the 8th with casualties out of 38 regencies in East Java.

Figure 1: The Location of Gresik – East Java Indonesia

The area which had the highest traffic accident rate was the south part. It was 35.78 % with 273 accidents. The west part was 23.73 % with 181 accidents. The middle part was 23.6 % with 180 accidents. The north part was 16.64 % with 127 accidents. Bawean islands were 0.26 % with 2 accidents [1].

The rate of traffic accidents in 2013 was increasing. There were 52 accidents in August 2013. Up to the middle of September, there had been 26 accidents. According to the traffic Accident Unit of the Police Office at Gresik, there were 52 accidents in August 2013, 22 of them died, 2 of them were badly hurt, and 61 of them were slightly hurt, with material loss reached up to IDR52,9 million. In September up to Friday, Sept 20, 2013, the number of accidents reached up to 26 accidents with 5 persons died, none were badly hurt, 38 persons were slightly hurt with material loss reached up to IDR 21,5 million [2].

GIS has become an aided tool to manage, keep, analyze and make the decision by combining spatial and non-spatial data [3]. Web-GIS is a part of GIS, by applying web and internet to provide interaction between data and visual presentation and prepare web server in publishing the spatial data, attributed data and thematic geospatial processing layer by allowing the users taking out information from what has been published by the web server [4].

Similar research has been conducted as in [5]–Accident Mapping and Analysis Using GIS to map the road, in which the road was classified into 3 categories: State Highway, Metal Roads, and Non-Metal Roads. The Research was using Kernel Density method as it was a very effective method for setting the cluster location, using spatial autocorrelation in determining data point and preparing the GIS basis data for all accident location. Another research conducted was in [6]–Identification of Traffic Accident Risk-Prone Areas under Low-Light Conditions. The Relation between Spatial Data Distribution of Traffic Accident and the Condition of the Light, where the Accident Prone-area in town was identified based on the calculation of the level of injury for an area of 0,5 km2 was based on the speed of driving of the users of the road and low-light conditions. This mapping was functioning to reduce the rate of traffic accidents by increasing the lamp roads, decreasing the speed of driving of the road users and by providing traffic signages. The research as in [7]–Accident Analysis System by Integration of Spatial Data Mining with GIS Web Services with Geocoding Algorithm was to identify the address associated with this latitude and longitude. The research as in [8]–Integration of GIS and Multicriteria Evaluation for School Site Selection: A Case Study of Belgut Constituency, the Combination of GIS Tools and Multi-Criteria Evaluation (MCE) Methods to determine the dense location of the incidents and dangerous by locating physically for any school. The overlay method using ArcGIS tool was used to combine all criteria identified. The result showed that there were suitable economically to build a new school. Based on all research references, this research was developed using MAUT method to map the accident prone-roads.

MAUT method was used to do the calculation to produce geospatial processing layer processed using *ArcGIS Desktop*

10.2 software to classify the accident-prone roads. The parameter used were (1) weight criterion of road layer which was the category of heavily damaged road, medium damaged road and good road; (2) weight criterion of dense traffic lanes layer on daily average day and (3) weight criterion of traffic accident layer [9].

The result of geospatial processing layer was processed to produce the thematic which will be transferred to web-GIS based technology with a database connection using Microsoft *SQL Server Management Studio*, Web-GIS *ArcGIS Server 10.2* Implementation and framework design of web-GIS with *ArcGIS Server 10.2*, *Arc GIS API 3.2 for Silverlight* and *Arc GIS Viewer for Silverlight*.

II. Material and Methods

The data used for Web-GIS system processing was using the data of the traffic accidents based on the condition of the density of the road. The purpose was to produce the thematic layer of the spatial data and attribute data by classifying the un-accident prone-roads, the accident prone-roads and heavily accident prone-roads.

A. Material On Traffic Accident Roads

The result of geospatial processing layer of the accident-prone road was obtained from the road layer processing of Gresik Regency and Bawean Island, East Java Province of Indonesia. The result was overlaid by the layer of the number of accidents at certain roads points, which was also overlaid further with the layer of dense road layer lanes. With the average yield of low-risk accident-prone roads as of 58%, 24% were low-risk accident-prone roads and 18% were high-risk accident-prone roads [9]. The result of the road mapping can be viewed at Figure 2.

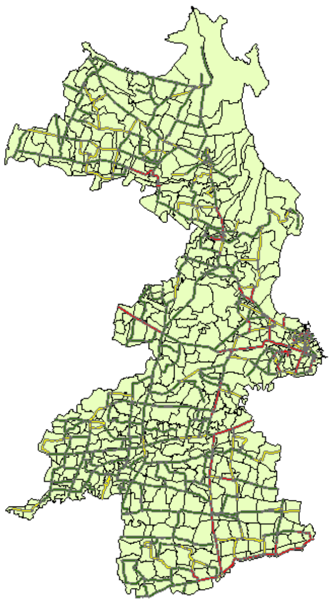

Figure 2: Materials Spatial Data of Accident-Prone Roads [1]

B. Method Data Thematic Layer

Multi-Attribute Utility Theory (MAUT) Method was used to do the calculation of the total value from the alternative selections at sub criteria by setting the weight value and priority value at each parameter. The processing of spatial and attribute data to produce the thematic layer mapping of accident-prone roads was based on the parameter of road layer, the condition of the road and the density of the traffic using MAUT method [9]. This process was to do the calculation of the whole value of the choice alternatives at a sub-criterion by setting the weight value and priority value at every parameter [10].

The capability of GIS to process the spatial and attribute data was to combine the artificial intelligence method which was able to do the data saving, taking, manipulating and analyzing data. The spatial layer using MAUT method was used to combine the geographical data capability and preference of the decision makers to become one dimension of the alternative decision value [11], with reference to the following formula 1.

$$U(A_i) = \sum_{k=1}^{K} w_k \, u_k(x_{ik}), \quad (1)$$

Multi-criteria were used to process the thematic layer to give the score criteria, by giving some alternative possibilities. The alternatives were rated based on the total calculation value (formula 1). The total value of the alternatives of the sub-criteria was calculated and accommodated into a U (Ai) variable. The total value was calculated by giving priority weight of criteria or sub-criteria by making compare matrix for each criterion or sub-criterion. Then each column in the comparison matrix of criteria or sub-criteria was summed up and accommodated at the Σ variable by summing up each line divided by the total comparative matrix. The next step was to give priority weight to the sub-criterion, accommodated into w_k u_k variable, giving choice alternatives value of each sub-criterion, described to be accommodated into x_{ik} variable, where i was the assigned alternative choice and k was the assigned sub-criteria.

The classification of accident prone-roads category was based on some parameter as shown in Table 1 to Table 3 [9] and the parameter priority value used is shown in Table 4 [9].

Table 1
Weight Criterion of Roads Layer

Road Condition	Weight
Heavily Damaged Road	5
Medium Damaged Road	3
Good	1

Table 1 is weight criterion of road layer with categories of heavily damaged road with a weight of 5, medium damaged road with a weight of 3 and good road with a weight of 1.

Table 2
Weight Criterion of Dense Traffic Lanes Layer

Density Level (on average per day)	Weight
0.91-0.1	5
0.81-0.90	4
0.71-0.80	3
0.61-0.70	2
0.51-0.60	1

Table 2 is weight criterion of dense traffic lanes layer on average per day between 0.91-0.1 with a weight of 5; between 0.81-0.90 with a weight of 4; between 0.71-0.80 with a weight of 3; between 0.61-0,70 with a weight of 2 and between 0.51-0.60 with a weight of 1.

Table 3
Weight Criterion of Traffic Accident Layer

Total Accident Rate (death)	Weight
≥101	5
76-100	4
51-75	3
26-50	2
1-25	1

Table 3 is weight criterion of traffic accident layer consisting of the total accident rate (death) ≥ 101 victims with a weight of 5; 76-100 souls with a weight of 4, 51-75 victims with weight 3, 26-50 victims with a weight of 2 and 1-25 victims with a weight of 1.

Table 4
The Priority Value Parameter

Parameter	Priority Value	Total Criterion
Road Layer	20	3
Traffic Density Layer	50	5
Traffic Accident Layer	30	5

Table 4 is the priority value at each parameter was as follows: the category of parameter with the road condition with 3 total criteria had priority value of 20; the parameter on traffic density layer with 5 total criteria had priority value of 50 and parameter of traffic accident layer with 5 total criteria had priority value of 30.

The geospatial processing overlay layer obtained from the spatial data and attribute data layer of the condition of the road, accident incident layer and dense traffic lane, were processed by calculating (formula 1) where,

$$U(A_i) = \sum\left(\left(\frac{weight\ of\ the\ road\ condition}{total\ criterion}\right) * priority\ value\right) + \left(\left(\frac{weight\ of\ the\ traffic\ density}{total\ criterion}\right) * priority\ value\right) + \left(\left(\frac{weight\ of\ the\ traffic\ accident}{total\ criterion}\right) * total\ priority\right) \quad (2)$$

The result of the sum up was then compared with the following criteria. If $U(A_i) \geq 1$ && $U(A_i) \leq 25$ then it belonged to the low-risk accident prone-roads category, if $U(A_i) \geq 26$ && $U(A_i) \leq 50$ then it belonged to the Accident prone-roads category and if $U(A_i) \geq 51$ && $U(A_i) \leq 100$ then it belonged to the high-risk accident prone-roads category [9].

III. Application Architecture

The architecture of the WEB-GIS application was at the client server side. The application program could also act as the client that can be connected to the society. It communicated with GIS server functioning as the data provider from the process of the spatial data layer and attribute data table geospatial processing using GIS web server. The GIS web server was responsible to serve the request from the client server to send the information needed from the Web-GIS application, as described at Figure 3.

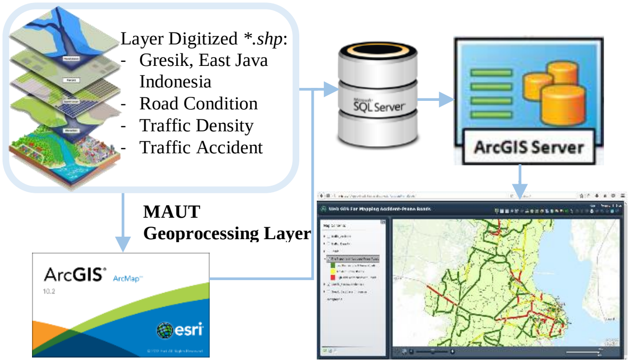

Figure 3: The Architecture of Web-GIS System

The activity started by developing a database connection using *Microsoft SQL Server Management Studio* software. The identified decision on the result of the analyzed layer [1] was implemented into the framework design application program using *Arc GIS API 3.2 for Silverlight* and *Arc GIS Viewer for Silverlight*. The implementation of the Web-GIS development using *Arc GIS Server 10.2* was conducted by activating the web browser as shown in the flowchart system in Figure 4.

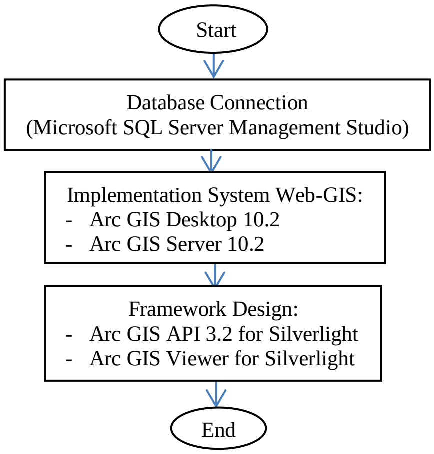

Figure 4: Web-GIS Information System

A. *Database Connection*

The database connection at the discussion of this paper was using the *Microsoft SQL Server Management Studio* basis data. The attribute database is very important on the geospatial data functioning as information, explanation or value of the spatial data. If a user has vector data as the spatial data, but not equipped with attribute data, then there will be a lack of information.

The vector data can be added attribute data. The table at the database was formed from importing spatial data or layer data formed at the software of *ArcGIS Desktop 10.2*. The Layer **.shp* which had been processed was transformed into the analysis layer from the process of union, buffer and intersect [9]. Then the file **.shp* was imported into the software of *ArcGIS Desktop 10.2* by developing a database into the software of *Microsoft SQL Server Management Studio*, as viewed in Figure 5.

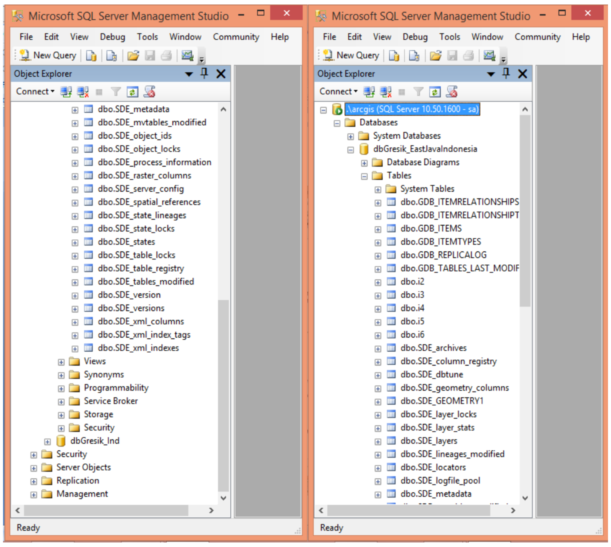

Figure 5: The *.*shp* Layer Spatial Data Connection into the attribute data

B. The implementation of Web-GIS System

The implementation of Web-GIS system using the software of *ArcGIS Server 10.2* was meant to publish the result of data processing of spatial layer and attribute data table using the connection that was going to be developed. At the menu on Catalog Software *ArcGIS Server 10.2*, the file *.*mdx* formed at the process of analysis was to combine several layers into a workspace [9].

The connection was summed from the web-server ArcGIS Server 10.2 into the web browser of Internet Explorer or Mozilla Firefox by writing the URL of the server: http://localhost:6080/arcgis/manager. The username and password formed were entered. The layer *.mdx, obtained from the analysis process was uploaded into the web browser by connecting the web server. The *.mdx service layer obtained from the process of geospatial processing layer was published into the publish service root that would be used to link between the ArcGIS Server 10.2 with the web browser that would be used by the client to access the application that was going to be published. An analysis should be conducted to make sure that there would be no mistakes in the process of layer upload. A preview was conducted to see the result of the upload layer. The ArcGIS Server Manager was run at the web browser, as seen in the following Figure 6.

Figure 6: The connection of ArcGIS Server

C. The Web-GIS System Framework Design

The framework was designed to connect ArcGIS into the web browser. It was meant to be the interface. This research was using Arc GIS API 3.2 for Silverlight and Arc GIS Viewer for Silverlight functioning as a plugin for the web browser at the operating system Microsoft Windows, Mac OSX and mobile device. The ArcMap server was connected, using Arc GIS Viewer for Silverlight, with the web browser by entering the address of the browser http://microsoft/Builder/Default.aspx. The result can be viewed at the following Figure 7.

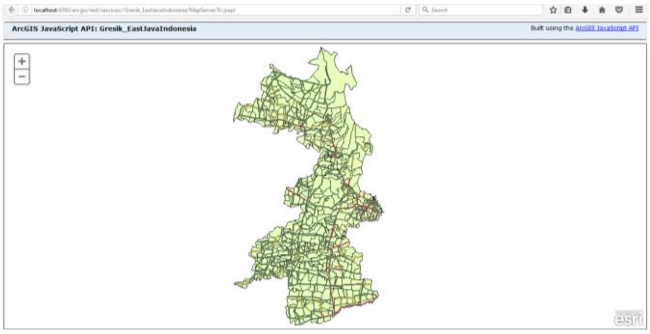

Figure 7: The connection of Arc GIS Viewer for Silverlight System

All layers processed at geospatial processing layer at the first year of the research [9], were uploaded and carried into the plugin Arc GIS API 3.2 for Silverlight from the web browser application. The proxy that had been developed was taken with the result as seen in the following Figure 8.

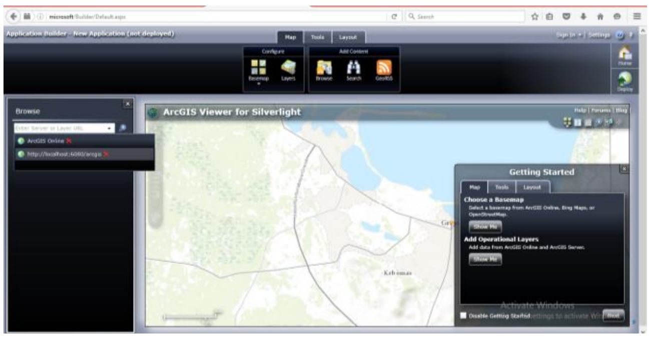

Figure 8: Proxy Web-GIS System

IV. RESULTS AND DISCUSSIONS

The Web-GIS thematic layer system was obtained from the Geospatial processing layer processing with the road condition parameter, dense traffic road lanes, and accidents at certain roads. There were 432 roads processed. They were province roads, regency roads, the roads at Gresik Regency and Bawean Islands in East Java Province, Indonesia. The test was using the sampling technique.

A. Web-GIS Layer thematic.

MAUT method (Equation 1) was used to present the information to the user in identifying the road points at a certain area and of which were accident-prone road points. There were 3 categories of thematic layer mapping being processed. They were the low rich accident prone-roads category, accident prone-roads, and high-risk accident prone-roads. The low-risk accident prone-roads with the thematic green layer category were 24 %. The accident prone-roads with thematic yellow layer category were 58 %. The high-risk accident prone-roads with thematic red layer were 18 %. The result can be seen in Figure 9.

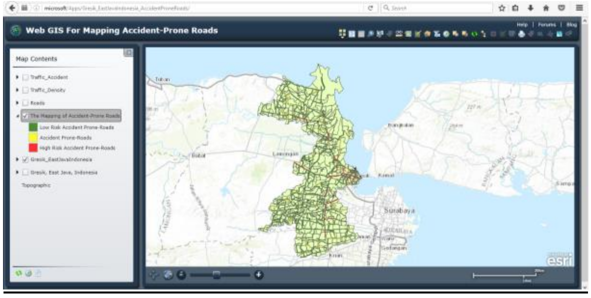

Figure 9: Thematic Web-GIS Layer

The data processing of spatial layer at the Web-GIS system was meant to know the whole content of analysis table (database) at each road in all area. The combined entities as an element data, attribute data, and item data were displayed in Figure 10.

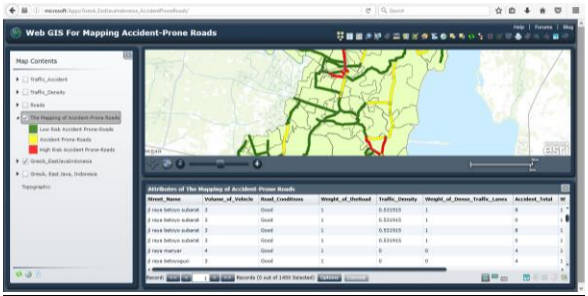

Figure 10: Spatial Data and Web-GIS System Attribute Data

B. Web-GIS Thematic Layer Classification of the Accident Prone-Roads Category

The first test to identify the Web-GIS thematic layer classification of the accident prone-roads category was conducted at Jalan Raya Palenwatu. The condition of the road was categorized as heavily damaged road with the weight of 5. The dense traffic lane at the road was 0,572772. The daily average with a weight of 1 and total accident incidents on the roads were 8 times with the weight of 1. After all, the parameter was entered, the calculation process was conducted using the MAUT method (Equation 1), where:

$$U(A_i) = \sum \left(\left(\frac{5}{3}\right) * 20 \right) + \left(\left(\frac{1}{5}\right) * 50 \right) + \left(\left(\frac{1}{5}\right) * 30 \right) \quad (3)$$

The result of the calculation $U(A_i) = 49.33333$ rounded into $U(A_i) = 49$, it was then concluded that Jalan Raya Palemwatu with that condition was considered as accident prone-roads with the yellow thematic layer, as seen at Figure 11.

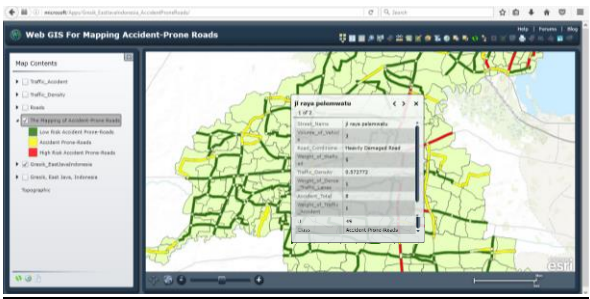

Figure 11: Classification of Accident Prone-Roads Category with Heavily Damaged Road Condition

The second test to identify the Web-GIS thematic layer with accident prone-roads category was conducted at Jalan Segoromadu. The condition of the road was categorized as medium damaged road with the weight of 3. The daily average of the dense traffic road lane was 0,670886 with the weight of 2. There were 14 accident incidents with a weight of 1. After all, the parameter was entered, the calculation process was conducted using MAUT method (Equation 1), where

$$U(A_i) = \sum \left(\left(\frac{3}{3}\right) * 20 \right) + \left(\left(\frac{2}{5}\right) * 50 \right) + \left(\left(\frac{1}{5}\right) * 30 \right) \quad (4)$$

The result of the calculation was $U(A_i) = 46$. It was concluded that Jalan Segoromadu with that condition was classified as accident prone-roads category with the yellow thematic layer, as seen in Figure 12.

Figure 12: Classification of Accident Prone-Roads Category with Medium Damaged Road Condition

The third test was meant to identify the Web-GIS thematic layer classification of the accident prone-roads category conducted at Jalan Raya Sembayat. The condition of the road was categorized as good with the weight of 1. The dense traffic lane at the road was 0.77419 of daily average with the weight of 3. There were 26 accident incidents on the roads with the weight of 2. After all, the parameter was entered, the calculation process was conducted using MAUT method (Equation 1) where,

$$U(A_i) = \sum \left(\left(\frac{1}{3}\right) * 20 \right) + \left(\left(\frac{3}{5}\right) * 50 \right) + \left(\left(\frac{2}{5}\right) * 30 \right) \quad (5)$$

The result of the calculation $U(A_i) = 48.66667$ was rounded into $U(A_i) = 49$. It was concluded that Jalan Raya Sembayat with that condition was classified as accident prone-roads category with the yellow thematic layer, as seen in Figure 13.

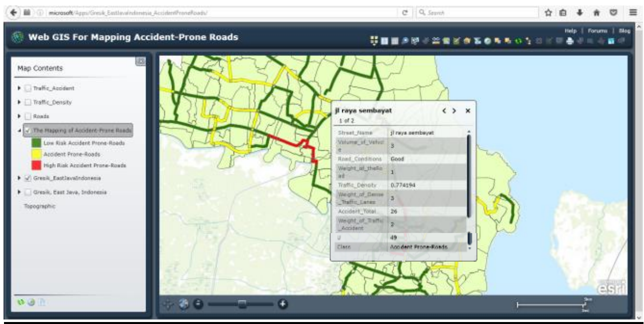

Figure 13: Classification of Accident Prone-Roads Category with the good condition of the road

C. Web-GIS Thematic Layer classification fn the High-Risk Accident Prone-Roads Category.

The first test to identify the Web-GIS thematic layer classification of high accident prone-roads category was conducted at Jalan Raya Kedamean. The condition of the road was heavily damaged road with the weight of 5. The dense traffic lane at that road was 0,793915 of daily average with the weight of 3. There were 26 accident incidents on the road with the weight of 2. After all, the parameter was entered, the calculation process was conducted using MAUT method (Equation 1) where,

$$U(A_i) = \sum \left(\left(\frac{5}{3}\right) * 20 \right) + \left(\left(\frac{3}{5}\right) * 50 \right) + \left(\left(\frac{2}{5}\right) * 30 \right) \quad (6)$$

The result of the calculation $U(A_i) = 75.33333$ was rounded into $U(A_i) = 75$. It was concluded that Jalan Raya Kedamean with that condition was classified as high accident prone-roads category with the red thematic layer, as seen in Figure 14.

Figure 14: Classification of High Accident Prone-Roads Category with Heavily Damaged Road Condition

The second test to identify the Web-GIS thematic layer classification of high accident prone-roads category was conducted at Jalan Raya Bringkang. The condition of the road was medium damaged road with the weight of 3. The dense traffic lane at that road was 0,800606 of daily average with the weight of 3. There were 32 accident incidents on the road with the weight of 2. After all, the parameter was entered, the calculation process was conducted using MAUT method (Equation 1) where,

$$U(A_i) = \sum \left(\left(\frac{3}{3}\right) * 20 \right) + \left(\left(\frac{3}{5}\right) * 50 \right) + \left(\left(\frac{2}{5}\right) * 30 \right) \quad (7)$$

The result of the calculation was $U(A_i) = 62$. It was concluded that Jalan Raya Bringkang with that condition was classified as high accident prone-roads category with the red thematic layer, as seen in Figure 15.

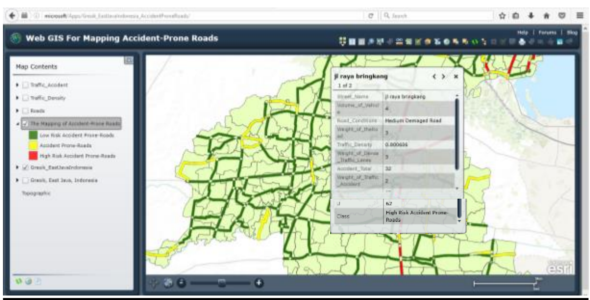

Figure 15: Classification of High Accident Prone-Roads Category with Medium Damaged Road Condition

The third test to identify the Web-GIS thematic layer classification of high accident prone-roads category was conducted at Jalan Raya Kepatihan. The condition of the road was good with the weight of 1. The dense traffic lane at that road was 0,894408 of daily average with the weight of 4. There were 24 accident incidents on the road with the weight of 1. After all, the parameter was entered, the calculation process was conducted using MAUT method (formula 1) where,

$$U(A_i) = \sum \left(\left(\frac{1}{3}\right) * 20 \right) + \left(\left(\frac{4}{5}\right) * 50 \right) + \left(\left(\frac{1}{5}\right) * 30 \right) \quad (8)$$

The result of the calculation $U(A_i) = 53.66667$ was rounded into $U(A_i) = 53$. It was concluded that Jalan Raya Sembayat with that condition was classified as high accident prone-roads category with the red thematic layer, as seen in Figure 16.

Figure 16: Classification of Accident Prone-Roads Category with Good Condition of the Road

D. Web-GIS Thematic Layer classification of the Low-Risk Accident Prone-Roads Category.

The first test to identify the Web-GIS thematic layer classification of low accident prone-roads category was conducted at Jalan Raya Pajangganan. The condition of the category of the road was medium damaged road with the weight of 3. The category of the road with a daily average of not dense traffic lane with the weight of 0. There were 2 accident incidents on the road with the weight of 1. After all, the parameter was entered, the calculation process was conducted using MAUT method (Equation 1) where,

$$U(A_i) = \sum \left(\left(\frac{3}{3}\right) * 20 \right) + \left(\left(\frac{0}{5}\right) * 50 \right) + \left(\left(\frac{1}{5}\right) * 30 \right) \quad (9)$$

The result of the calculation was $U(A_i) = 26$. It was concluded that Jalan Raya Pajangganan with that condition was classified as low accident prone-roads category with the red thematic layer, as seen in Figure 17.

The second test to identify the Web-GIS thematic layer classification on low accident prone-roads category was conducted at Jalan Raya Kedayang Raya. The condition of the category of the road was good with a weight of 1. The category of the road with a daily average of not dense traffic with a weight of 0. There were 8 accident incidents on the road with a weight of 1. After all, the parameter was entered, the calculation process was conducted using MAUT method (Equation 1) where,

$$U(A_i) = \sum \left(\left(\frac{1}{3}\right) * 20 \right) + \left(\left(\frac{0}{5}\right) * 50 \right) + \left(\left(\frac{1}{5}\right) * 30 \right) \quad (10)$$

The result of the calculation was $U(A_i) = 12.66667$, which was rounded into $U(A_i) = 13$ It was concluded that Jalan Raya Sembayat with that condition was classified as low accident prone-roads category with the green thematic layer, as seen in Figure 18.

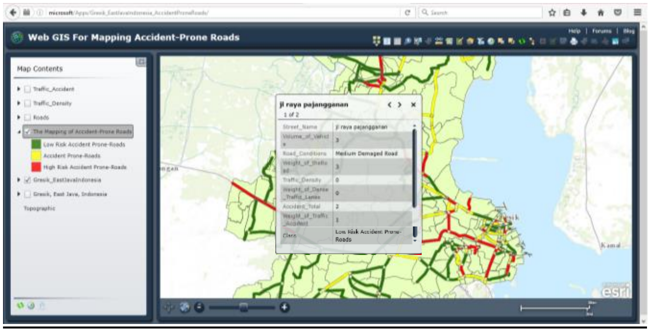

Figure 17: Classification of Accident Prone-Roads Category with Medium Damaged Road Condition

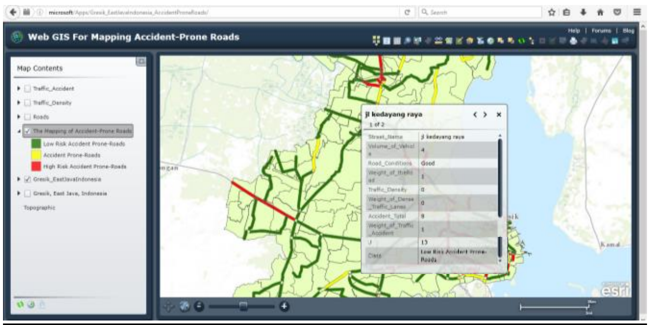

Figure 18: Classification of Accident Prone-Roads Category with Good Condition of the Road

The classification of low accident prone-roads category can be referred as a reference for the road users or society in choosing the roads to pass by. The Figure 17 and Figure 18 mark the green thematic layer as safe roads to be passed by.

V. Conclusion

The data related to the data of the road, the data of accident incidents, and the traffic density data used were eligible as originated from the Transportation and Police Department. The data gathering was considered as the data resources to collect information being mapped to be processed into the spatial layer data and attribute data table. The function of this process was to distribute the information in the form of WEB-GIS. It will be beneficial for the society who will pass the roads to be more careful if the road is predicted as included in the geospatial processing. The thematic accident-prone roads are classified as accident prone-roads category or high accident prone-roads category. The use of MAUT method is appropriate for the behavior of the data which can classify the thematic layer to do the mapping of accident prone-roads, high accident prone-roads or low accident prone-roads. There are other methods which can be applied to develop the further application, among others are spatial data mining method, Empirical Bayes. It is recommended that the use of technology can go further into the use of mobile Web-GIS application, which is making use of Location Based Service (LBS) to identify the position of the user when using the application and guide the user to the roads with the classification of low accident prone-roads category.

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