Implementation of Web-based Analytic Network Process for Highway Maintenance Planning

Noldy Sinsu
Department of Information System
Diponegoro University
Semarang – Indonesia

Eko Sediyono
Department of Information System
Satya Wacana Christian University Salatiga – Indonesia

Aris Puji Widodo
Department of Informatics
Diponegoro University
Semarang – Indonesia

ABSTRACT
The Maintenance of highway as an important role in the reliability of the conditions can be affected positively the economic sector, government, and society. which will be the priority of highway maintenance planning is to pay attention to the supporting parameters standards that affect the highways segment. These parameters as a variable in Analytic Network Process method. In this research, the first step is to identify problems, data collection, form parameters, data processing parameters before to the next step of the ranking process. After grouping the highway segment, the next step is assessing its highway segment using Analytic Network Process (ANP) method. The results of the ranking process are stored into the database and then represented by displaying the graphs and tables. The final result of the information shows the rankings 27 highways and the result of the accuracy of 80% of the system results. And field data that are shown from one national highway and five provincial highways. From the test results, the system is able to provide information about highway maintenance that will be a priority ranking which one the top list that needed to be maintenance.

General Terms
Method Analytic Network Process

Keywords
Analytic Network Process (ANP), Maintenance, Highway, Web-Based and ANP

1. INTRODUCTION
The availability and the reliability of highway conditions will positively affect the economic sector, government, and society. The highways have an important role in realizing the national development so that people need the comfort and smoothness of highway facilities in carrying out daily activities [1]. There is the close relationship between highways transport and economic development because strong economics foundation provides stabilization in highway transport demand and also affects the economic development. An adequate highway can provide the comforts for its users. many highways are unrecognizable because of the absence the construction or the regular maintenance [2]. Therefore, it is necessary to excellent handlings, such as highways maintenance or highways improvement, it is intended that the highway conditions will be in accordance with the planned age of highways [5].

ANP methods have been widely used for various qualitative studies, such as decision making, forecasting, strategizing, mapping, evaluations, resource allocation and so on. To assist decision-makers in evaluation and synthesis any number of factors in the hierarchy or network [4], in general in prioritizing decision problems using a network approach without setting the level [3]. As a multi criteria decision-maker with a decision-making approach appropriately related to the selection of transport infrastructure projects [7], the overall risk priority of the project supply network is to initiate a timely mitigation strategy against the cost consequences and the timing significance of the risk of major project performance steps [10].

In this study, the focus of the problem is maintaining the highway. This is because of the highway as a media that liaison one and another location and the highway maintenance process needed some criteria that must be considered to the smoothness of the highway maintenance itself, ie, highway conditions, volumes traffic, economics and land use. Minister of Public Works adopted the government regulation [5]. The scope of arrangements in ministerial regulations includes technical requirements and maintenance technical criteria of highway that applied to the national highways, provincial highways, district highways, and the urban highways [5]. The study was conducted using the ANP method to determine road maintenance based on roadside ranking results against its criteria [6], [7], and using a web-based system to facilitate access intended to provide information on road projects in detail, informative and accessible by the community [11], the web-based system is also used to categorize and analyze incident addressing [11], the web-based system facilitates online access, image visualization, and analysis, as well as additional data and maps [13]. The researcher chose ANP as a multi criteria ranking method, therefore assumption and justification theories based on assumptions, and can assist decision-making involving multiple decision makers [8], [9]. The main criterion will require the adoption of multi criteria of decision making so that it can provide a reference for planning the maintenance of Semarang City highway for the future.

2. METHODOLOGY
2.1. Data Collection
In this research, the data that used is field data obtained from the office of the highway of Central Java, the questionnaire result and interview result about influencing of criteria against to the road maintenance planning. The criteria that used according to Regulation of Minister of Public Works No.13/2011 (PMPU 2011). The proposed system framework starts from the input data is highway data (data list of highway, data of highway conditions, traffics volume data, economic data, and land use data) which is then performed by expert assessment of the proposed criteria (15 criteria)). The data on the results of the experts processed by the method of Analytic Network Process (ANP) that proposed for more detail can be seen in Figure 1. The final result is the ranking information of prioritization of highway maintenance and all highways ranking.

The data that used is data obtained from 27 roads, which is spread into 6 national road segments and 21 provincial road segments in Semarang city.

Data criteria were taken 27 roads segment (Table 1 and Table 2), the criteria as follows:

[1] Road condition consisting of C1 is a good road, C2 is a medium road, C3 is a damaged road, C4 is a heavy damaged road,

[2] traffic volume consisting of C5 is a lightweight truck, C6 is a medium truck, C7 is a heavy truck, C8 is BUS, C9 is a car, C10 is a motorcycle,

[3] C11 is the economy (road maintenance fund),

Land use consisting of C12 is agriculture, C13 is education field, C14 is the socio-cultural, C15 is trade and service.

Table 1. Data parameter 27 highways

Roads Name	**Criteria**								
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
Jl. Cangkiran - ungaran bts.kodya	10,202	13	1	0	713	474	0	752	371
Jl. Pandanaran	216	2	300	0	360	27	0	25,250	126
Jl. Bunderan simpang lima	100	1,047	100	0	391	10	0	70,406	232
Jl. A. Yani	60	600	200	0	88	0	0	23,435	128
Jl. Brigjend katamso	0	480	0	0	184	26	0	18,966	249
Jl. Brigjend sudiarto	300	92	800	0	1,380	442	0	34,984	556
Jl. Anton sujarwo	2	4	0	0	3,282	2,263	7	2,027	1,554
Jl. Setia budhi	3	700	200	0	1,528	3,393	618	3,548	4,749
Jl. Teuku umar	540	400	0	0	1,641	3,879	68	4,793	3,189
Jl. Dr. Wahidin	2	440	0	0	2,928	1,400	52	1,023	734
Jl. Mt. Haryono	875	0	0	0	2,459	944	16	691	762
Jl. Kompol maksum	400	240	0	0	1,701	657	23	870	662
Jl. Dr. Cipto	3	310	0	0	880	554	43	534	338
Jl. Widoharjo	0	400	0	0	2,895	2,617	38	2,195	2,170
Jl. Raden patah	110	1	0	0	3,252	2,683	2	828	2,175
Jl. Kaligawe	600	5	517	0	3,610	1,640	5	430	1,299
Jl. Usman janatin	100	1	100	0	8,873	6,477	339	1,406	3,127
Jl. Arteri utara (martadinata,fly over,yos sudarso)	7	8	430	100	4,552	2,573	384	2,526	976
Jl. Tugu muda	100	200	0	0	4,588	2,274	84	2,117	1,680
Jl. Dr. Sutomo	1	200	0	0	4,602	2,406	44	2,207	2,011
Jl. S. Parman	2	670	0	0	6,038	3,099	5	1,576	2,094
Jl. Sultan agung	1,385	500	0	0	3,837	1,279	19	492	1,123
Jl. Mgr. Sugiyopranoto	830	100	0	0	7,177	3,390	21	2,923	1,941
Jl. Jendral sudirman	1	700	0	0	7,350	3,140	26	2,407	1,948
Jl. Siliwangi	200	1,565	800	0	5,589	2,765	20	865	2,021
Jl. Walisongo	1	5,915	2	100	5,712	3,197	18	1,837	2,328
Bts. Kota kendal - bts. Kota semarang	4	4,138	1	100	5,450	3,624	81	2,949	3,046

* Source: Office of Public Works-Human Settlements and Spatial Planning of Central Java

Table 2. (Continued)

Roads Name	**Criteria**					
	C10	**C11**	**C12**	**C13**	**C14**	**C15**
Jl. Cangkiran - ungaran bts.kodya	7,847	16,750,000,118	10	20	0	30
Jl. Pandanaran	62,877	9,504,451,000	8	15	4	50

Roads Name	**Criteria**					
	C10	**C11**	**C12**	**C13**	**C14**	**C15**
Jl. Bunderan simpang lima	124,526	2,065,858,000	23	11	7	40
Jl. A. Yani	67,967	3,065,858,000	12	20	8	35
Jl. Brigjend katamso	55,887	2,340,000,000	10	60	10	27
Jl. Brigjend sudiarto	79,003	2,340,000,000	9	30	7	20
Jl. Anton sujarwo	487	4,110,707,000	30	35	0	25
Jl. Setia budhi	2,432	4,913,772,000	25	27	20	20
Jl. Teuku umar	1,862	9,000,028,000	10	20	15	35
Jl. Dr. Wahidin	766	4,636,500,000	8	25	17	25
Jl. Mt. Haryono	963	4,122,705,000	9	19	0	0
Jl. Kompol maksum	342	4,701,513,000	20	20	18	30
Jl. Dr. Cipto	368	4,689,641,000	60	10	16	35
Jl. Widoharjo	874	8,800,023,000	30	11	25	27
Jl. Raden patah	372	4,748,883,000	35	15	20	20
Jl. Kaligawe	148	7,215,030,000	27	20	28	17
Jl. Usman janatin	1,903	8,130,599,000	20	27	15	14
Jl. Arteri utara (martadinata,fly over,yos sudarso)	64	4,642,960,000	17	30	0	15
Jl. Tugu muda	763	4,501,894,000	14	20	10	10
Jl. Dr. Sutomo	1,958	1,730,730,000	15	9	25	11
Jl. S. Parman	1,155	1,734,241,000	20	30	20	0
Jl. Sultan agung	172	4,714,330,000	27	25	8	30
Jl. Mgr. Sugiyopranoto	625	4,793,957,000	30	10	10	25
Jl. Jendral sudirman	597	6,174,118,000	20	8	0	10
Jl. Siliwangi	500	3,900,898,000	25	15	15	25
Jl. Walisongo	174	5,411,511,000	30	20	20	0
Bts. Kota kendal - bts. Kota semarang	1,428	7,106,814,000	40	21	0	10

* Source: Office of Public Works-Human Settlements and Spatial Planning of Central Java

2.2. Research Step

The research steps are problem identification, data collection, parameter formation, and data processing parameters. Data modeling is a step that must be completed first before doing the next process, which needs to be considered in the data modeling step is the classification of data that has been collected into criteria for the ANP process.

The next step is coding PHP programming language with the steps as follows:

a) Develop problem structures and develop linkage models Criteria control, and determine alternative options. If there are elements that have the equivalent quality then grouped into a similar component.

b) Forming pairwise comparison matrix
ANP assumes that the decision maker must make a comparison of interests between all elements for each level in pairs. The comparison is transformed into the matrix form A. Value α_{ij} represents the relative importance value of the element on the line to *-i* against the elements in the column to *-j*. for example $\alpha_{ij} = \frac{wi}{wj}$. If any *n* elements are compared, then the comparison matrix A is defined as:

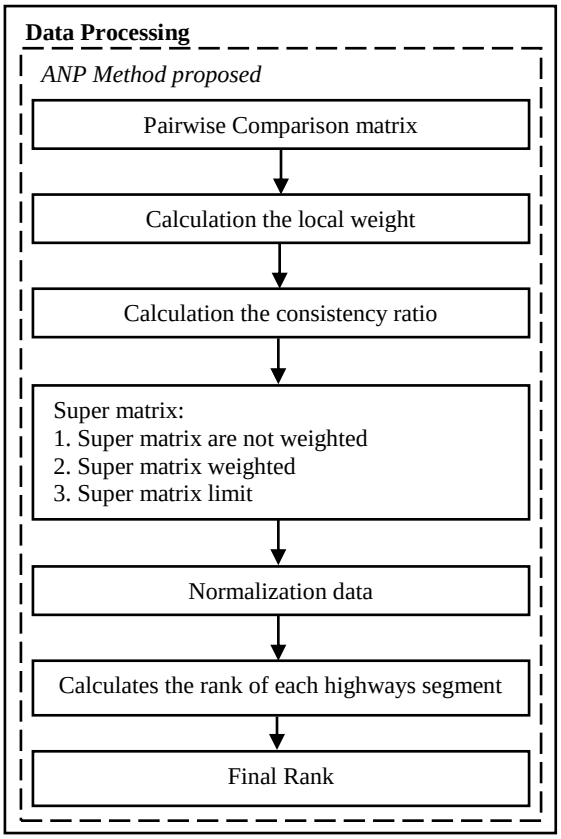

Fig 1. ANP Method that proposal

$$= \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \cdots & \cdots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_2} \end{bmatrix} = \begin{bmatrix} 1 & \alpha_{12} & \cdots & \alpha_{1n} \\ \alpha_{21} & 1 & \cdots & \alpha_{2n} \\ \vdots & \cdots & \cdots & \vdots \\ \alpha_{n1} & \alpha_{n2} & \cdots & 1 \end{bmatrix} \quad (1)$$

c) Calculates the element weights
If pairwise comparisons are complete, the priority vector w referred to as the eigenvector is calculated by. Where A is a pairwise comparison matrix, w is an eigenvector, and λ_{maks} is the largest eigenvalue of A.

The eigenvector is the priority weight of a matrix which is then used in the preparation of super matrix.

$$A \cdot w = \lambda_{maks} \cdot W \quad (2)$$

d) Calculates the consistency ratio
Consistency has two meanings, the first is similar objects can be grouped according to uniformity and relevance. Second, it concerns the level of relationship between objects based on certain criteria. In making decisions, it is important to know how good the consistency is. Therefore it is necessary to check the value of consistency by using a random index list (RI) which can be seen in Table 2. Consistency ratio should be worth 10 percent or less. If the value is more than 10 percent, then the assessment of decision data should be corrected. In practice, such consistency is not possible. In the consistency matrix, practically λ_{maks}=n, whereas in the matrix, not every variation of W_{ij} will bring changes to the value λ_{maks}. Deviation λ_{maks} from *n* is a consistency index parameter as follows.

$$CI = \frac{\lambda_{maks} - n}{n-1} \quad (3)$$

Where CI is the consistency index, λ_{maks} is the value *eigen* greatest, and *n* is the number of elements that are compared. By comparing CI and RI there is a benchmark for determining the consistency level of a matrix, called the Consistency Ratio (CR). To calculate the consistency ratio is used the following equation.

$$CR = \frac{CI}{RI} \quad (4)$$

Where CR is the consistency ratio, CI is the consistency index, and RI is the random index. Table 3. shows the size of the matrix and the random index value that can be used as a benchmark to determine the consistency level of a matrix [7].

Table 3. Random Index Value

Matrix Size	Value
1	0
2	0
3	0.5247
4	0.8816
5	1.1086
6	1.2479
7	1.3417
8	1.4057
9	1.4499
10	1.4854
11	1.514
12	1.5365
13	1.5551
14	1.5713
15	1.5838
16	1.5978
17	1.6086
18	1.6181
19	1.6265
20	1.6341
21	1.6409
22	1.647
23	1.6526
24	1.6577
25	1.6624
26	1.6667
27	1.6706
28	1.6743
29	1.6777
30	1.6809

If the value of CR = 0 then a comparison matrix can be said to be consistent if CR ≤ 0.1 then the matrix is quite consistent, and if CR> 0.1 then it is said to be very inconsistent [6].

e) Making Supermatrix
Super matrix are the result of eigenvectors of a pairwise comparison matrix between clusters, criteria, and alternatives. Assuming a system has an N cluster in which elements in each cluster interact or have an effect on some or all of the existing clusters. If the cluster is denoted with *ch* where *h = 1,2, ... , N* with as many elements denoted as $e_{h1}, e_{h2}, \ldots, e_{hn_h}$. The effect of one element in a cluster on another element in a system can be recipe toned by a ratio-scale eigenvector taken from a pairwise comparison matrix.

f) The final stage of the ANP method in which the rank of each criterion is obtained by calculating the final weight of each criterion. There are three kinds of weights that will be calculated that is raw weight, normal weight, and weight idea. The raw weight will be calculated by summing every normalized line of super matrix limit, while the normal weight is calculated by dividing the highest value by the number of criteria. So that the ideal weight hung by dividing the value of the normal weight with the highest value of the normal weight, then we get the highest weight of the ideal weight of one (1).

3. RESULT AND ANALYSIS

To achieve the research objectives discussed earlier, there are several steps that must be done. The stages are divided into several processes including, evaluation criteria that are part of data modeling to determine criteria to be used in ANP, comparisons of pairwise comparisons between criteria form the criteria matrix, data normalization, eigenvalue calculation, calculation of largest eigenvalue (λ_{maks}), testing consistency ratio, super matrix calculation, and ranking.

3.1. Application of Analytical Network Process

The process of applying the ANP is the weighting of the 15 criteria used to calculate the matrix of pairwise comparisons, data normalization, the calculation of eigenvalues, the calculation of the largest eigenvalues (λ_{maks}), the consistency ratio test, and the super matrix calculations (unweighted super matrix, super matrix weighted, and super matrix limits) determination of raw weights, normal weight and ideal weight of each priority road segment.

The final step of applying ANP method is to determine the rank of each segment by calculating the final weight of each criterion. Where the weight to be used in the calculation process consists of raw weights, normal weight, and ideal weight. For calculation of raw weights done by summing every line of normalized super matrix limit. Furthermore, in calculating the normal weight is done by dividing the value of the raw weights by the number of criteria. Then the calculation of the ideal weight is calculated by dividing the normal weight value with the highest value of the normal weight so that the highest value of the ideal weight = 1. The roads segment that gets the value = 1 on the ideal weight is the roads segment that will be a priority in maintenance planning. The ranking results are shown in Table 4.

Table 4. Result of final 27 roads segment

No	Roads Name	Weight	Ranking	Precentage (%)
1	Jl. Usaman janatin	0.033	1	3.25%
2	Jl. Brigjend sudiarto	0.031	2	3.13%
3	Jl. Bunderan simpang lima	0.031	3	3.13%
4	Jl. A. Yani	0.031	4	3.13%
5	Jl. Pandanaran	0.028	5	2.84%
6	Jl. Brigjend katamso	0.026	6	2.55%
7	Jl. Arteri utara (martadinata, fly over, yos sudarso)	0.026	7	2.55%
8	Bts. Kota kendal - bts. Kota semarang	0.023	8	2.30%
9	Jl. Walisongo	0.023	9	2.25%
10	Jl. Mgr. Sugiyopranoto	0.022	10	2.21%
11	Jl. Siliwangi	0.021	11	2.08%
12	Jl. Kaligawe	0.019	12	1.90%
13	Jl. Setia budhi	0.019	13	1.89%
14	Jl. S. Parman	0.019	14	1.88%
15	Jl. Jendral sudirman	0.018	15	1.83%
16	Jl. Cangkiran - ungaran bts.kodya	0.018	16	1.81%
17	Jl. Sultan agung	0.017	17	1.71%
18	Jl. Teuku umar	0.017	18	1.71%
19	Jl. Tugu muda	0.017	19	1.71%
20	Jl. Kompol maksum	0.017	20	1.71%
21	Jl. Raden patah	0.015	21	1.54%
22	Jl. Dr. Wahidin	0.015	22	1.53%
23	Jl. Dr. Cipto	0.015	23	1.53%
24	Jl. Dr. Sutomo	0.015	24	1.50%
25	Jl. Widoharjo	0.015	25	1.50%
26	Jl. Mt. Haryono	0.012	26	1.22%
27	Jl. Anton sujarwo	0.012	27	1.18%

Based on the calculation obtained the highest weight is 0.0325, as well as the ideal value = 1 with the percentage of 3.25% located on the Jl. Usman janatin. And the weight of the lowest value is 0.0118, and the ideal value = 0.3631 with the percentage of 1.18% located on the Jl. Anton sujarwo. The graph results are shown in Figure 2.

3.2. Analysis of Accuracy

Accuracy analysis is done to get the level of accuracy, the way is calculating the number of the appropriateness of alternative rankings of road segments that generated by the

system based on real data. The process of calculating the accuracy test is determined using the accuracy equation.

$$\text{Accuracy } (\%) = \frac{\sum \text{correct test data}}{\sum \text{total test data}} \text{ x } 100\%$$

Comparison of system rankings and rankings on real data is shown in Table 5.

Table 5. Accuracy system results

No	System Results	Data From Minister of Public Works	Information
1	Jl. Bunderan simpang lima	Jl. Bunderan simpang lima	Suitable
2	Jl. A. Yani	Jl. Brigjend Katamso	Unsuitable
3	Jl. Brigjend Sudiarto	Jl. Brigjend Sudiarto	Suitable
4	Jl. Pandanaran	Jl. Pandanaran	Suitable
5	Jl. Brigjend Katamso	Jl. A. Yani	Unsuitable
6	Jl.Cangkringan-unggaran bts.kodya	Jl.Cangkringan-unggaran bts.kodya	Suitable
7	Jl. Setia budi	Jl. Setia budi	Suitable
8	Jl. Mt. Haryono	Jl. Dr. Sutomo	Unsuitable
9	Jl. Dr. Cipto	Jl. Dr. Cipto	Suitable
10	Jl. Tugu muda	Jl. Tugu muda	Suitable
11	Jl. Dr. Sutomo	Jl. Mt. Haryono	Unsuitable
12	Jl. Usman janatin	Jl. Usman janatin	Suitable
13	Jl. S. Parman	Jl. S. Parman	Suitable
14	Jl. Siliwangi	Jl. Siliwangi	Suitable
15	Jl. Walisongo	Jl. Walisongo	Suitable
16	Jl. Dr. Wahidin	Jl. Dr. Wahidin	Suitable
17	Jl. Sultan agung	Jl. Sultan agung	Suitable
18	Jl. Mgr. Sugiyopranoto	Jl. Mgr. Sugiyopranoto	Suitable
19	Jl. Jendral sudirman	Jl. Jendral sudirman	Suitable
20	Jl. Anton sujarwo	Jl. Anton sujarwo	Suitable

Based on Table 5. It can be seen that from 6 provincial roads there are 3 road segments that become the priority of maintenance, the test of accuracy as follows:

$$\text{Accuracy } (\%) = \frac{16}{20} \text{ x } 100\% = 80\%$$

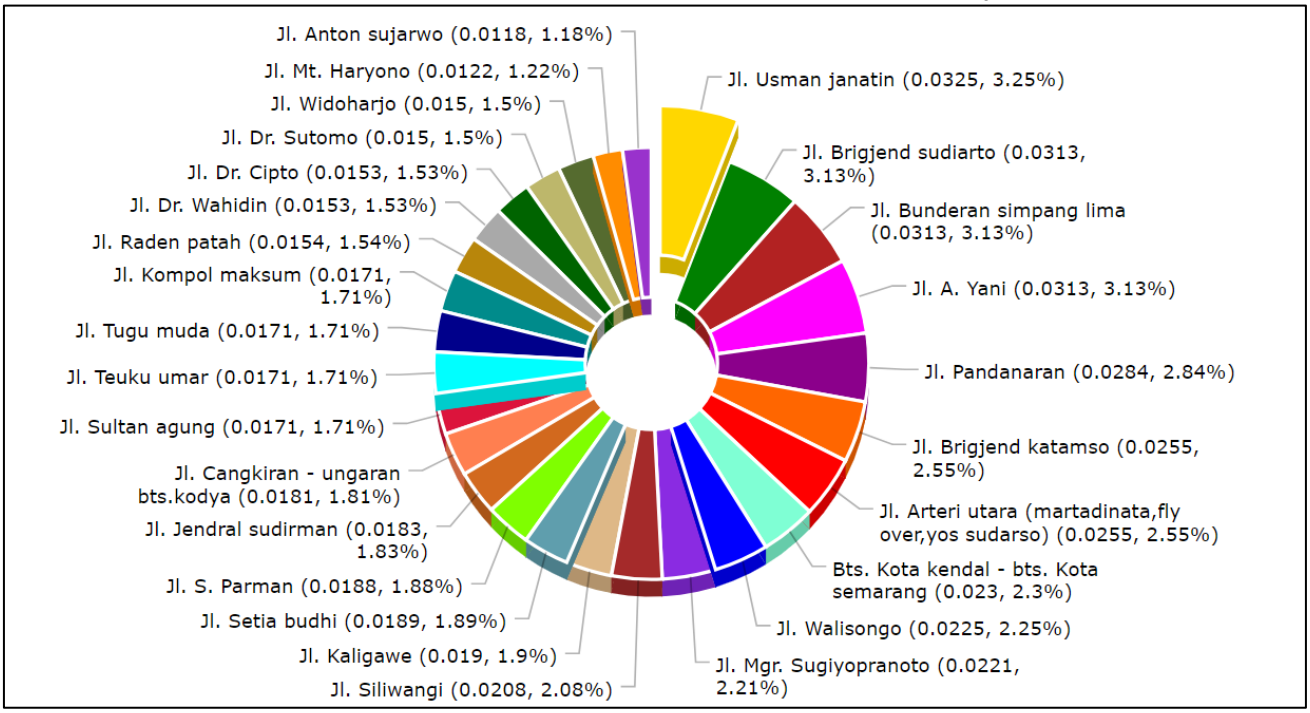

Fig 2. The graph result

The result of the analysis has calculated the percentage of accuracy level indicating that the system built using ANP method has an accuracy level of 80% which means either based on priority ranking between field data and system output. The resulting rating system uses the ANP method by considering the 15 criteria (C_1-C_{15}), the weight of each criterion, and the calculation of super matrix. From the test results obtained that the system designed by combining ANP and web-based methods can be applied to assess the extent of highway damage and determine the priority of highway maintenance appropriately.

4. CONCLUSION

Based on the results of research and discussion, the system built is a combination of ANP and web-based methods can be applied in the highway maintenance planning process, with

the following conclusion that the alternatives ranking can be accessed online so that the decision can be taken quickly and accurately. Based on the accuracy result obtained from the system is 80% with field data from the Minister of Public Works consisting of six (6) provincial roads and fourteen (14) national road segments. And the real value of each parameter used on each road segment is very influential in the ranking process for priority in highway maintenance.

The results of this study still restricted. It can be expanded by integrating sensors and systems in realtime in particular places for the measurement of the vehicle capacity parameters of the number of vehicles on highway section. This research is also useful for road users, with the maintained road the oxidant will be decreased.

5. ACKNOWLEDGMENTS

The author would like to express his sincere thanks to all those who have helped in this research. Particularly to the Office of Public Works-Human Settlements and Spatial Planning of Central Java because it has been willing to be the source of data for this research.

6. REFERENCES

[1] Law of the Republic of Indonesia Number 38 Year 2004 Concerning the Highway.

[2] Ibeto, I., and Justine, C., 2012. Issues And Challenges In Local Government Project Monitoring And Evaluation In Nigeria: The Way Forward. European Scientific Journal, Vol. 8, No.18, ISSN: 1857 – 7881.

[3] Tanjung, H., and Devi, A., 2013, *Metodologi Penelitian Ekonomi Islam*, Gramatika, Bekasi.

[4] T.L. Saaty, 2004, Fundamentals Of The Analytic Network Process – Dependence And Feedback In Decision-Making With A Single Network, *Journal of systems science and systems engineering, Vol. 13, No. 2, pp129-157.*

[5] Regulation of the Minister of Public Works No. 13 of 2011 on Procedures for Maintenance and Highway Ownership.

[6] T.L. Saaty and L.G. Varga, 2006, Decision Making with the Analytic Network Process: Economic, Political, Social and Technological edisi 2, Springer, New York.

[7] Ivanovic, I., Grujicic, D., Macura, D., Jovic, J., Bojovic, N., 2013. One Approach For Road Transport Project Selection. Transport Policy 25 (2013) 22–29.

[8] M.M. Senante, T. Gomez., R. Caballero and H.F Sancho, R.S. Garrido., 2015, Assessment of wastewater treatment alternatives for small communities: An analytic network process approach, *Science of The Total Environment* 532, *1* 676–687.

[9] Cai, S. H., Yao, X. G., and Ping, T., 2007. Evaluation of the Design Alternatives of Emergency Bridge by Applying Analytic Network Process (ANP). Systems Engineering - Theory & Practice. Volume 27, SETP, 2007, 27(3): 63–70.

[10] Prince, B., Zhen, C., and Stephen, O. O., 2015. An Analytical network process Model For Risks Prioritization In Megaprojects. International Journal of Project Management, (2015) No of Pages 17.

[11] Landicho, J. A., 2017. A Web-Based Geographical Project Monitoring And Information system For The Road And Highways. Journal of Electrical Systems and Information Technology (2017) No of Pages 10.

[12] Kannan, P., Flechas, T., Mendez, E., Angarita, L., and Chaudhari, P., 2016. A web-Based Collection And Analysis Of Process Safety Incidents. Journal of Loss Prevention in the Process Industries 44 (2016) 171-192.