Modeling and Determining Urban Road Priority Rank for Maintenance Program Based on Multi-Criteria Decision Making in Makassar City, Indonesia

by Sakti Adji Adisasmita Unhas

Submission date: 21-Sep-2022 10:33PM (UTC+0300)
Submission ID: 1905602370
File name: 10.1.1.736.72_2.pdf (630.95K)
Word count: 3637
Character count: 19157

International Journal of Scientific and Research Publications, Volume 5, Issue 10, October 2015
ISSN 2250-3153

Modeling and Determining Urban Road Priority Rank for Maintenance Program Based on Multi-Criteria Decision Making in Makassar City, Indonesia

M. Asad Abdurrahman[*], **Lawalenna Samang**[*], **Sakti A. Adisasmita**[*], **M. Isran Ramli**[*]

[*] Civil Engineering Department, Hasanuddin University, Indonesia

Abstract- The gap between financing need and the fund allocated brings governments difficult to manage the road maintenance, thus a ranking procedure is required to optimize this limited fund. Determining the road maintenance priority is considered as a multi-criteria decision making problem. Recent priority procedure offered by the Department of Public Works and previous researches only consider technical aspects such as pavement condition and daily traffic. However, non-technical factor such as political intervention plays a significant role in determining priority. This paper suggests a comprehensive assessment framework that enables to take a number of technical and non-technical factors into consideration. Analytic Hierarchy Process (AHP) is used to evaluate these roads with respect to prescribed criterions. Five proposed road which funded by provincial government were subjected into criterions with diverse metrics that serve as multi-objective decision environment where AHP play an appropriate role and consistently lead toward the final decision.

Index Terms- priority, maintenance, multi-criteria decision-making, analytical hierarchy process

I. Introduction

Road management should be supported by adequate funding. In Indonesia, roadwork funding is allocated by government which falls into 3 categories: state funded roads, provincial funded roads, and municipal funded roads. However, recent situation shows that the allocated funds always do not meet with the financing needs. In other words, there is a lack of funding for effective road management. Empirical evidence shows that the government's ability to provide necessary fund is inadequate over the years. The budget for the management of state roads, provincially roads and municipally roads continues to decline (Tamin, 2002) whereas the price of construction materials is constantly increasing.

The gap between financing need and the fund allocated brings governments difficult to manage the road maintenance, thus a ranking procedure is required to optimize this limited fund. Determining the road maintenance priority is considered as a multi-criteria decision making problem. Recent priority procedure offered by the Public Works Department (2005) only considers technical aspects such as pavement condition and average daily traffic. In addition, several procedures have been suggested by Saputro (2011), Putri (2011), Moazami (2011), dan Munthe (2012) regarding these problems. However, these procedures did not take non-technical factors into consideration such as political influences. Since, a study by Alie (2006) reveals that the legislature politicians have strong intervention in determining the road maintenance program in Indonesia.

This paper suggests a comprehensive assessment framework that enables to take a number of major technical and non-technical aspects into consideration. The Analytic Hierarchy Process (AHP) (Saaty, 2001) is used to evaluate and rank these roads with respect to prescribed criterions. The AHP seems to be a flexible decision making tool for multiple-criterion problems. It enables decomposition of a problem into hierarchy and ensures that both quantitative and qualitative aspects of a problem are included in evaluation process.

II. METHODOLOGY

The assessment for determining road priority is a complex process. Many aspects should be taking into consideration. The proper solution to this complex and multi-criteria problem is to segregate the problem into a number of smaller sub-problems and solve them individually.

The Simple Multi-attribute Rating Technique (SMART) is one of the methods in dealing with the multi-objectives problems. Its main strength is its relative simplicity; however, the cost of its simplicity is that the method may not capture all the detail and complexities of the real problem (Goodwin and Wright, 2004). Decision tree is a valuable tool for people to obtain a deeper understanding of complex problems, but it deals with decision problems that consist of multi-stages. In addition, it involves continuous probability distribution that makes it difficult to use in practice. ELimination Et Choix Traduisant la REalité (ELimination and Choice Expressing REality) (ELECTRE) is another way of evaluating decision options which widely used and applied for many practical problems. However, since the method does not provided a way of obtaining weights and score, the numbers are accepted unchallenged as inputs to a complicated algorithm. Moreover, it compares alternatives but does not produce a single index of performance (Watson and Buede, 1987)

In our evaluating framework, we proposed to utilize analytic hierarchy process (AHP). It offers a number of strength over methods pointed out previously. Its widespread use has verified its popularity among decision-makers. The relative strengths of

AHP include: (a) formal structuring of problem; (b) simplicity of pair-wise comparisons; (c) redundancy allows consistency to be checked; and (d) having great diversity or variety. AHP offers an alternative approach when a decision-maker is dealing with a problem that involving multiple criteria. The method that was originally developed by Thomas Saaty (2001) has been commonly used in decision problems in areas such as project selection, economics and planning, material purchasing and handling, and transportation. The process consists of the following steps: (1) Set up the decision hierarchy, (2) Conduct pair-wise comparisons of criteria and alternatives, (3) Convert the comparisons into weightings and check the consistency of the comparisons, and (4) Use the weightings to gain scores for the different options and make a decision.

The study conducted in five road funded by provincial government as shown in table 1. The roads are located in Makassar city.

Table 1: Study Location

Code	Street Name	Length (m)
Link 1	Jend. Sudirman	1400
Link 2	Dr. Ratulangi	2200
Link 3	Dr. J. Leimena	1800
Link 4	Antang Raya	1500
Link 5	Tamangapa	4700

This decision hierarchy takes into account a number of tangible and intangible factors in the assessment. These factors and the hierarchy were identified by repetitively interviewing, discussing, and consulting with a number of professional and government staffs. They included officials from the Public Works Department, and Regional Planning Development Agency. Seven criterions with their sub-systems have been identified for the model as listed below:

A. Traffic characteristic
    A.1. Traffic volume (passenger car unit/hour)
    A.2. Traffic velocity (km/hour)
B. Land zone
    B.1. Residential zone ratio
    B.2. Commercial zone ratio
    B.3. Industrial zone ratio
C. Pavements condition
    C.1. Good
    C.2. Average
    C.3. Poor
D. Preferences
    D.1. Political intervention
    D.2. Fair funding

Traffic characteristic data is obtained through traffic survey based on the procedure in Indonesian Road Capacity Manual 1997. Land zone value is gained from observation to determining the percentage ratio of residential, commercial and industrial zone along the road. Pavement condition is obtained by visual survey based on the procedure in Manual of Road Maintenance Program 1990. Lastly, preference criterion is measured by questionnaire interview and fair-funding aspect is calculated by its fund allocated. For example, if maintenance budget for Link 1 is $X in this year therefore fair-funding value is 1/X. Pairwise comparison was carried out among these criterions whereas sub-criterions rating are measured using Likert scale.

AHP assists capture both objective and subjective evaluation measures, providing a useful mechanism for inspecting the consistency of the evaluations therefore reducing bias in decision making. When making complex decisions involving multiple objectives, the first step is to decompose the main goal into its constituent sub-goals or sometimes called objectives or criteria, progressing from the general to the specific. This structure contains a goal, criteria or objective and alternative level. Each set of criteria would then be further divided into an appropriate level of detail as illustrated in figure 1.

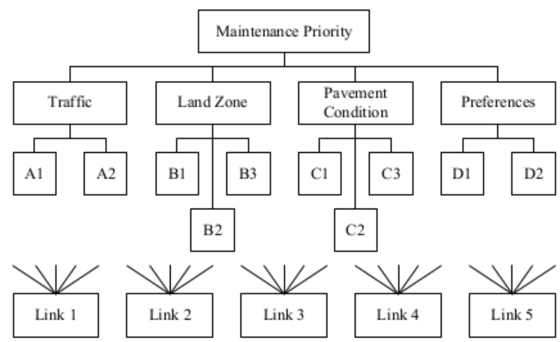

Figure 1: AHP hierarchy of goals, criterions, and alternatives

Generally, the main goal is placed on the top hierarchy while the decision alternatives are at the bottom. The relevant attributes of the decision problem such as the selection criteria and objectives lay between the top and bottom levels reside. Relative weights to each item in the corresponding level are assigned. Each criterion has a local and global priority. The sum of all the criteria beneath a given parent criterion in each layer of the model must equal one. The global priority shows alternatives relative importance within the overall model.

After the criteria factors are identified, scoring of each level with respect to its parent is conducted using a relative relational basis by comparing one option to another. Relative scores for each option are computed within each leaf of the hierarchy. Scores are then synthesized through the model, yielding a composite score for each option at every layer, as well as an overall score.

This relative scoring within each level will result in a matrix of scores, say a(i, j). The matrix holds the expert judgment of the pair-wise comparisons. Nevertheless, the judgment should be consistent. Therefore, inconsistency test is necessary to validate it. The inconsistency measure is useful for identifying possible errors in judgments data entry as well as actual inconsistencies in the judgments themselves. Inconsistency measures the logical inconsistency of the judgments. For instance, if we say that "A" is more important than "B" and "B" is more important than "C" and then say that "C' is more important than "A", we are not being consistent. A somewhat less inconsistent situation would occur if we would say that "A" is 4 times more important than "B", "B" is 3 times more important than "C", and that "C" is 7 times more important than "A". In broad-spectrum, the inconsistency ratio should be less than 0.1 be considered as reasonably consistent. Particularly, a matrix a(i, j) is said to be consistent if all its elements follow the transitivity and reciprocity rules below:

$$a_{i,j} = a_{i,k} \cdot a_{k,j} \quad (1)$$

$$a_{i,j} = \frac{1}{a_{j,i}} \quad (2)$$

where i, j and k are any alternatives of the matrix. For instance if "A" is considered 3 times more important than "B", then "B" should be 1/3 times more important than "A". The relational scale used in ranking is presented in Table 2.

Table 2: AHP importance scale

For any pair of objectives i, j:	
Score	Relative importance
1	Objectives i and j are of equal importance.
3	Objective i is weakly more important than j.
5	Objective i is strongly more important than j.
7	Objective i is very strongly more important than j.
9	Objective i is absolutely more important than j.
Note: 2, 4, 6, 8 are intermediate values.	

The pair-wise comparison matrices are able to be represented as:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \vdots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} = \begin{bmatrix} w_1/w_1 & \cdots & w_1/w_n \\ \vdots & \vdots & \vdots \\ w_n/w_1 & \cdots & w_n/w_n \end{bmatrix} \quad (3)$$

for a consistent matrix, it can be demonstrated that:

$$A = \begin{bmatrix} w_1/w_1 & \cdots & w_1/w_n \\ \vdots & \vdots & \vdots \\ w_n/w_1 & \cdots & w_n/w_n \end{bmatrix} \times \begin{bmatrix} w_1 \\ \vdots \\ w_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ \vdots \\ w_n \end{bmatrix} \quad (4)$$

where A is the comparison matrix, w is the eigenvector and n is the dimension of the matrix. The equation above can be treated as an eigenvalue problem. For a slightly inconsistent matrix, the eigenvalue and the eigenvector are only slightly modified. Saaty (2001) demonstrated that for consistent reciprocal matrix, the largest eigenvalue is equal to the number of comparisons, or $\lambda_{max} = n$. Then he gave a measure of consistency, called Consistency Index as a deviation or a degree of consistency using the following formula:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (5)$$

The average random Consistency Index of a sample size of 500 matrices is shown in the table 3 (Saaty, 2001). Other researchers have conducted simulations with different numbers of matrices (Tummala, 1994; Alonso, 2006). Their indices are different but similar to Saaty's.

Table 3: Random index (RI) for the factors used in the decision making process

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.58

A Consistency Ratio is a comparison between Consistency Index and Random Consistency Index, or in formula:

$$CR = \frac{CI}{RI} \quad (6)$$

If the value of Consistency Ratio is smaller or equal to 10%, the inconsistency is acceptable. Alternately, if the Consistency Ratio is greater than 10%, the judgment should be revised.

III. RESULTS AND DISSCUSSION

According to the above assessment framework, a weighting was assigned to each of the factors, and scores were given with respect to each of these factors. The weightings were obtained through a purpose-designed questionnaire completed by 32 experts. These data are listed in table 4.

Table 4: Data recapitulation

Sub Criteria	Weight	Link 1	Link 2	Link 3	Link 4	Link 5
Traffic volume (pcu/hour)	71.2%	1981	1748	1240	1048	1114
Traffic velocity (km/h)	28.8%	22.47	25.12	24.2	25.4	20.45
Residential	34.3%	2.3%	6.1%	65.2%	51.2%	35.1%
Commercial	36.5%	97.7%	93.9%	25.1%	29.4%	36.2%
Industrial	29.2%	0.0%	0.0%	9.7%	19.4%	28.7%
Good	9.2%	54.2%	69.4%	45.2%	65.1%	75.4%
Average	31.8%	44.1%	29.4%	41.4%	25.4%	14.2%
Poor	59.0%	1.7%	1.2%	13.4%	9.5%	10.4%
Political intervention	54.0%	5.00	5.00	2.00	2.00	2.00
Fair funding (1/$)	46.0%	0.09	0.13	0.20	0.41	0.17

A scale of verbal assessments is used in the questionnaire, namely: Extreme, Very strong, Strong, Moderate and Equal importance along with their corresponding scale of importance (Finan, 1999). Table 5 shows pairwise comparison between main criteria which obtained by expert judgment

Table 5: Pairwise comparison of main criteria

Criteria	A	B	C	D
A	1	4.8	0.48	1.04
B	0.21	1	0.52	0.32
C	2.10	1.94	1	0.99
D	0.96	3.12	1.01	1

Then if the columns of the above table are normalized and the resulting rows are averaged we acquire the corresponding weights of each criterion as demonstrated below:

$$\begin{bmatrix} 0.23 & 0.44 & 0.16 & 0.45 \\ 0.05 & 0.9 & 0.17 & 0.14 \\ 0.49 & 0.18 & 0.33 & 0.43 \\ 0.23 & 0.29 & 0.34 & 0.43 \end{bmatrix}$$

Therefore, the row averages are $(0.32\ 0.11\ 0.36\ 0.32)^T$ or normalized as $(0.28\ 0.09\ 0.32\ 0.29)^T$ which explains the priority weight of main criteria.

Consider $\left[Ax = \lambda_{\max} x\right]$ where x is the eigenvector

$$\begin{bmatrix} 1 & 4.8 & 0.48 & 1.04 \\ 0.21 & 1 & 0.52 & 0.32 \\ 2.1 & 1.94 & 1 & 0.99 \\ 0.96 & 3.12 & 1.01 & 1 \end{bmatrix} \begin{bmatrix} 0.32 \\ 0.11 \\ 0.36 \\ 0.32 \end{bmatrix} = \begin{bmatrix} 1.35 \\ 0.46 \\ 1.56 \\ 1.33 \end{bmatrix} = \lambda_{\max} \begin{bmatrix} 0.32 \\ 0.11 \\ 0.36 \\ 0.32 \end{bmatrix}$$

Hence, the largest eigenvalue is

$$\lambda_{\max} = average\left(\frac{1.35}{0.32}, \frac{0.46}{0.11}, \frac{1.56}{0.36}, \frac{1.33}{0.32}\right) = 4.24$$

The consistency index with n = 4 as calculated using equation 5 is equal to 0.08. Whereas, the random index of a 4 criterion matrix = 0.9 as listed in Table 3; therefore consistency ratio is 0.089 ≈ 8.9%. The similar result is found using software package Expert Choice® as shown for this particular criterion in Figure 2. As stated above, a CI ratio that is less than 10% is acceptable and the judgments are considered to be consistent.

Figure 2. Priority weights of main criteria

For quantitative data, it is allowed to directly assign priorities without having to make paired comparisons. The values of the factors are normalized into dimensionless relative values with a range between 0 and 1. Synthesis which is the process of weighting and combining priorities throughout the model after judgments are made to yield the final result. Global priorities are obtained for nodes throughout the model by applying each node's local priority and its parent's global priority. The global priorities for each alternative are then summed to yield overall or synthesized priorities. The most preferred alternative is the one with the highest priority. Figure 3 presents the synthesis with respect to main goal. It shows that LINK 4 has the highest priority which expresses the most recommended road to be maintained, followed by LINK 1, LINK 3, LINK 2, and LINK 5 respectively. A complete hierarchy of goals and objectives with the corresponding aggregate weights is shown in Figure 4. It shows that multi-modal aspect factor contributes for the most weight in the hierarchy.

Figure 3: Synthesis with respect to main goal.

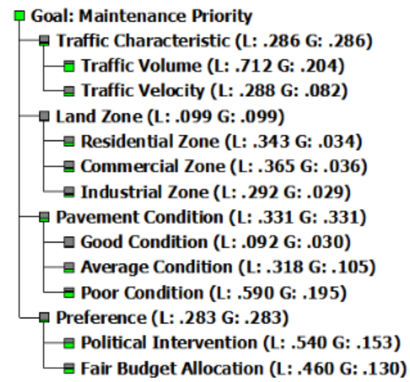

Figure 4: Importance of each factor with respect to the main goal and parent criterion

Lastly, sensitivity analysis is used to investigate the sensitivity of the alternatives to changes in the priorities of the objectives. What-if analysis can be performed with the sensitivity analyses graphs to determine how the overall result would change if the priorities of the objectives were changed. Figure 5 shows the current weights of each main criterion and alternatives with respect to the main goal. Noticeably, the results are in favor of the LINK 4. Now that the optimum option has been identified, how the model would respond to any changes in the weights of the listed criteria.

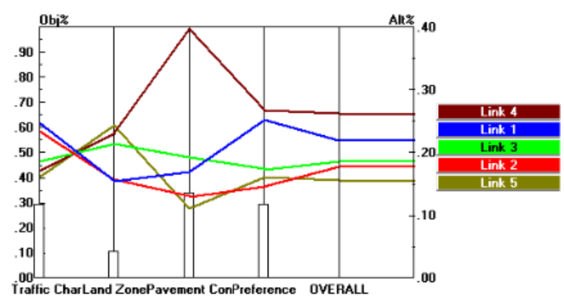

Figure 5: Sensitivity graph of the main factors and alternatives with respect to the main goal.

First, consider the land zone, by increasing the share of this criterion to an extreme of 50% of the main goal, leaving 50% for the others while keeping the proportionality between each, it has been noticed that the model is still in favor of LINK 4 with a score of 24.7% (Figure 6). The same conclusion can be drawn for the pavement condition and preferences criterions, where the LINK 4 stays as the optimum alternative with a score of 31.7% (Figure 7 and 8).

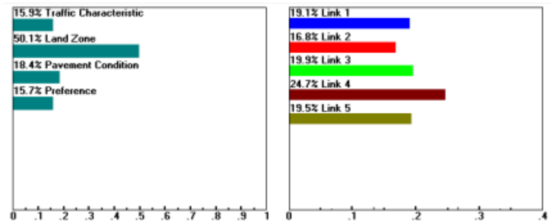

Figure 6: Sensitivity analysis of land zone, the new assigned weights (left) and the resulting scores of the alternatives (right).

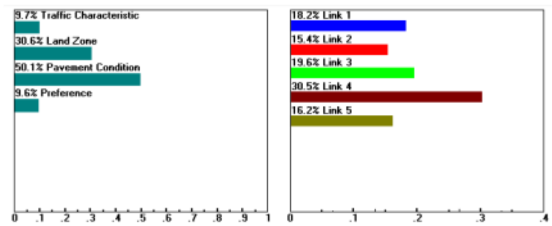

Figure 7: Sensitivity analysis of pavement condition, the new assigned weights (left) and the resulting scores of the alternatives (right).

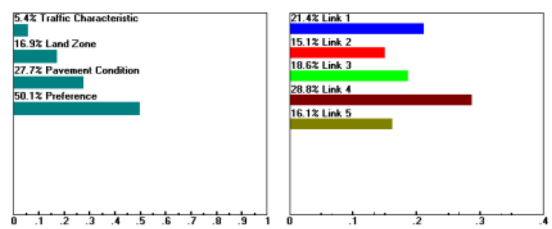

Figure 8: Sensitivity analysis of preference, the new assigned weights (left) and the resulting scores of the alternatives (right).

IV. CONCLUSION

It was observed that the developed analytic hierarchy process (AHP) model works sufficiently and yields adequate results as well as providing accurate decisions. This paper proposes a comprehensive framework, which takes a number of major technical and non-technical factors into consideration in determining urban road priority for maintenance program. Among the major criteria that guide decision maker in the evaluation, the main considerations are pavement condition traffic characteristic, and preference.

Application of this framework which is based on the AHP method and a survey among government officials and transportation experts in a study case with data in 2014 reveals that Dr. J. Leimena Street (LINK 4) has significant value; therefore, it is considered has the highest priority to be maintained.

REFERENCES

[1] Alie, Asmawi, 2006, Identification of Road Maintenance Financing Policy in Sungailiat City, Magister Thesis, Postgraduate Program, Diponegoro University

[2] Alonso, J. and T. Lamata (2006), Consistency in The Analytic Hierarchy Process: A new approach, International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems 14(4): 445-459.

[3] Finan, J. S., and Hurley,W. J. (1999). Transitive Calibration of the AHP Verbal Scale. European Journal of Operational Research, 112: 367–372.

[4] Goodwin, P., and Wright, G. (2004), Decision Analysis for Management Judgment. 3rd Ed. Chichester: John Wiley & Sons Ltd.

[5] Moazami, D., R. Muniandy, H. Hamid, and Z M. Yusoff, 2011, The Use of Analytical Hierarchy Process in Priority Rating of Pavement Maintenance, Scientific Research and Essays Vol. 6(12), pp. 2447-2456.

[6] Munthe, S., 2011, Prioritizing Road Maintenance in Manokwari, Magister Thesis, Postgraduate Program, Institut Teknologi Sepuluh Nopember

[7] Public Works Department, 1990, Manual of Urban Road Maintenance Program, Directorate General of Highways, Jakarta.

[8] Public Works Department, 1997, Indonesian Road Capacity Manual, Directorate General of Highways, Jakarta.

[9] Public Works Department, 2005, Road Management Techniques, Centre for Research and Development of Transport Infrastructure, Jakarta.

[10] Putri, I. D., 2011, Determining Road Handling Priority in Bangli, Magister Thesis, Postgraduate Program, Udayana University

[11] Saaty, T. L. (2001), The Analytical Hierarchy Process: Planning, Priority Setting, Resource Allocation. London, England: McGraw-Hill International Book Co.

[12] Saputro, D.A., Ludfi D. dan Arief R., 2011, Evaluating Road Condition and its Maintenance Priority, Jurnal Rekayasa Sipil, Vol. 5, No. 2, ISSN 1978 – 5658

[13] Tamin, O.Z. (2002), Concept for development of state and provincial road network in East Nusa Tenggara, 7th Regional conference of road engineering; Indonesian Road Development Association, 18 – 19 Juli 2002, Denpasar, Bali. (in Indonesia)

[14] Tummala, V. and Y. Wan (1994), On The Mean Random Inconsistency Index of the Analytic Hierarchy Process (AHP), Computers & Industrial Engineering 27(1-4): 401-404.

[15] Watson, S. R., and Buede, D. M. (1987), Decision Synthesis: The Principles and Practice of Decision Analysis. Cambridge: Cambridge University Press.

AUTHORS

First Author – M. Asad Abdurrahman, Doctoral Student, Civil Engineering Department, Hasanuddin University, INDONESIA, muh.asad@yahoo.co.id

Second Author – Lawalenna Samang, Professor, Civil Engineering Department, Hasanuddin University, INDONESIA, samang_l@yahoo.com

Third Author – Sakti A. Adisasmita, Professor, Civil Engineering Department, Hasanuddin University, INDONESIA, adjiadisasmita@yahoo.com

Fourth Author – M. Isran Ramli, Associate Professor, Civil Engineering Department, Hasanuddin University, INDONESIA, muhisran@yahoo.com

Correspondence Author – M. Asad A., muh.asad@yahoo.co.id

Modeling and Determining Urban Road Priority Rank for Maintenance Program Based on Multi-Criteria Decision Making in Makassar City, Indonesia

ORIGINALITY REPORT

8%	5%	4%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.ajer.org Internet Source	2%
2	Submitted to University of Leicester Student Paper	<1%
3	acikerisim.pau.edu.tr:8080 Internet Source	<1%
4	www.citethisforme.com Internet Source	<1%
5	www.shophyperformance.com Internet Source	<1%
6	R. M. K. Sandamal, H. R. Pasindu. "Applicability of smartphone-based roughness data for rural road pavement condition evaluation", International Journal of Pavement Engineering, 2020 Publication	<1%
7	Safa Azaat Al Mustafa, Mehmood Khan, Matloub Hussain. "Implementing Barcode	<1%

Medication Administration Systems in Public Sector Medical Units", International Journal of Decision Support System Technology, 2018
Publication

8	uobrep.openrepository.com Internet Source	<1%
9	H.H. Goh, B.C. Kok. "Application of Analytic Hierarchy Process (AHP) in load shedding scheme for electrical power system", 2010 9th International Conference on Environment and Electrical Engineering, 2010 Publication	<1%
10	Submitted to Luiss Guido Carli University Student Paper	<1%
11	Niemira, M.P.. "An Analytic Network Process model for financial-crisis forecasting", International Journal of Forecasting, 200410/12 Publication	<1%
12	Shankha Shubhra Goswami, Dhiren Kumar Behera, Dr Soupayan Mitra. "A Comprehensive Study of Weighted Product Model for Selecting the Best Product in Our Daily Life", Brazilian Journal of Operations & Production Management, 2020 Publication	<1%

13	Kamal M.Al-Subhi Al-Harbi. "Application of the AHP in project management", International Journal of Project Management, 2001 Publication	<1%
14	International Journal of Clothing Science and Technology, Volume 25, Issue 3 (2013-05-27) Publication	<1%
15	Submitted to University of Portsmouth Student Paper	<1%
16	MURAT TARIMCILAR. "On Sensitivity Analysis in the Analytic Hierarchy Process", IMA Journal of Management Mathematics, 1991 Publication	<1%
17	Management Decision, Volume 50, Issue 7 (2012-07-21) Publication	<1%
18	S. Nima Mirabedini, Hossein Iranmanesh. "A scheduling model for serial jobs on parallel machines with different preventive maintenance (PM)", The International Journal of Advanced Manufacturing Technology, 2013 Publication	<1%

Exclude quotes Off

Exclude bibliography Off

Exclude matches Off