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PLANNING AND DEVELOPING A WEB BASED GROUP DECISION SUPPORT SYSTEM FOR PROJECT ORIENTED COMPANY USING ANALYTIC HIERARCHY PROCESS METHOD

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ABSTRACT

As the increasing of the organization's complexities, fewer decisions are made by one individual only. Facilities to support the process of decision-making are needed, and Group Decision Support System (GDSS) as a new face of Decision Support System can be used as an alternative. As an information media that might reduce the problem of time and space, internet can be used as a base of the GDSS development in order to create GDSS with ability in reducing the problem of time and space in decision-making process. This developed web based GDSS is specifically designed for project-oriented company, considering this kind of company is undoubtly facing various problems that need input from more than one individual. Analytic Hierarchy Process is used as engine in this GDSS, where the geometric mean method is utilized in grouping the judgments from all decision makers.

Key Words:
Group Decision Support System, Analytic Hierarchy Process, Web Based, Project-oriented company, geometric mean

1. Introduction

Decision Support System (DSS) could be thought as an evolution of computer types that can be used to enhance the decision making process. DSS might be defined as set of system, which can be used to help or support the decision making process in collecting data or in testing some alternatives of solution.

Based on early concept of Gerrity (1979), DSS might give benefits either to an individual or group of decision maker. But in practice, however, most DSS was designed for use by a single decision maker. Although DSS for a single user is an important thing in managerial function, but a lot of organizational decisions have to be made by group of decision makers, especially at the strategic or executive level. Moreover, as organizations become increasingly complex, fewer decisions are made by single individual (Ganon, 1979). Organizational responsibilities are getting wider, and cause more decision-making that involves input from more than one individual. This group decision-making concept was a trigger to the birth of new face of the DSS, that later known as Group Decision Support System (GDSS). GDSS was first introduced by Gerardine DeSanctics and Brent Gallupe in 1985. GDSS can be described as a system based on computer, which can support the decision making process of either semi-structured problem or unstructured one by a group of decision maker in an organization.

Either the complexities of an organization structure or the problems phenomena as described earlier, may occur in project-oriented companies. Those companies often have to deal with more than one project simultaneously, whereas each project needs different way in handling, different needs in sources, and also has different characteristics and problems.

In this case, the advance of information technology has made it possible for the exchange of information, which is not limited by time and space anymore, and one of those technologies is known as Internet that has opened wider chance for the GDSS development.

A group decision-making quality surely has connections with the method. Analytic Hierarchy Process (AHP) as a multi criteria decision-making method, which was developed by Thomas L. Saaty in early 1970's. By using AHP, a multi criteria decision can be done either based on quantitative or qualitative judgments. Besides, AHP also accommodates group decision-making process, by using geometric mean method.

2. Project Organizations Structures

Different companies might have different organization structure. In this case, The GDSS that was developed is specifically designed for organization structure that is often founded in company that dealt with Manufacturing-Engineering Construction Projects. This organization structure is known as project organization with Project Director (Soeharto, 1988). After this, the GDSS that is being developed will be called as GDSS-PO (Group Decision Support System for Project Organization).

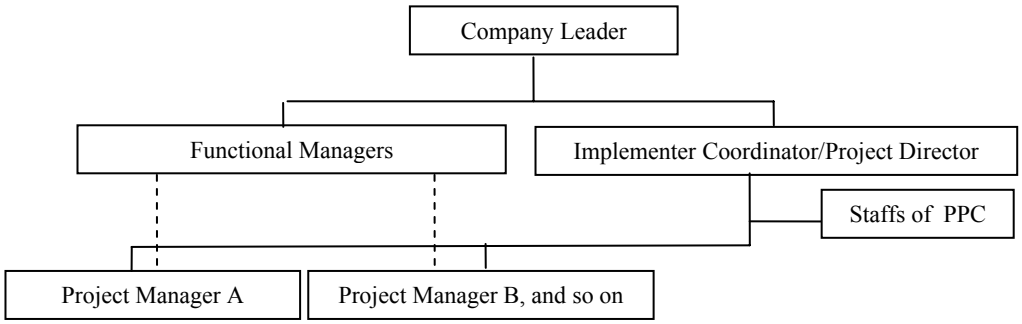

Figure 1. Structure of Project Organization with Project Director

3. The Architectures of GDSS-PO

Basically, components in GDSS architecture consist of hardware, software, people, and procedures (DeSanctics and Gallupe, 1985).

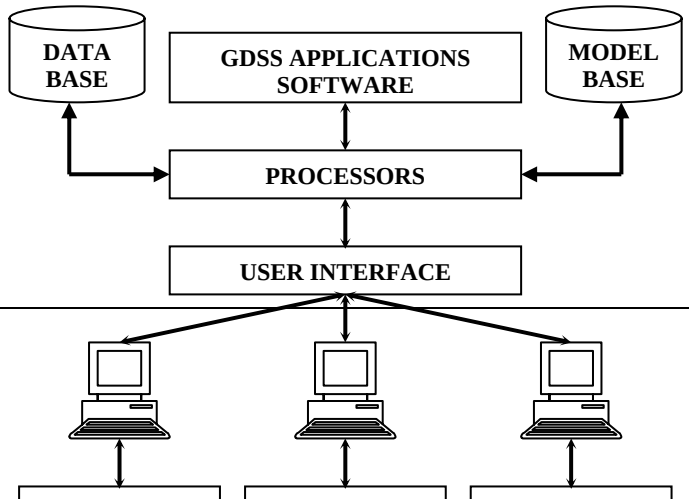

Figure 2. Design of GDSS-PO's model architecture

3.1 Hardware

Minimum requirements needed in using GDSS-PO generally cover computer server, Internet connection tools, and personal computer (PC).

3.2 Software

The software components of the GDSS include a database, a model base, specialized application program(s) to be used by the group, and an easy-to-use, a flexible user interface (DeSanctics and Gallupe, 1985). Software component of the GDSS should accommodate individual and group needs. So, the web based GDSS-PO is designed not only as a supporting tools in decision-making, but also accommodates individual jobs for users. Relating to that needs, the GDSS-PO should made it possible for every user to do either input or data retrieval process, which is suitable with their managerial levels and types of access they have.

3.2.1 Database Design

Before designing a database we should define the activities and flow of information that will happen. In this case, the structured specification method is used as an approach to elaborate process and data flows.

3.2.2 Model Base Design

The DSS approach to modeling requires a model base management system (MBMS) with capabilities analogous to Data Base Management System (DBMS). The most important things that should be included in GDSS:

a. Flexible mechanism for building models
   Mechanisms, which make it possible for users to build new decision models, are included in GDSS-PO. In other words, GDSS-PO is a general GDSS. GDSS-PO is designed to accommodate the ability to support decision of various problems by accepting AHP's decision model input from user beforehand.

b. Ease of use of the models to obtain needed decision support.
   GDSS-PO is designed to create ease of use for the users in re-using an AHP's decision model. After an AHP's decision model is made, users that are involved as decision maker automatically will be able to give their opinions/judgment about the problem. His/her judgment will be transferred in the database. As a result of using

AHP, a decision maker gives his/her input by giving his/her pair wise comparisons judgment for every hierarchy subsystem of the decision model.

c. Methods for saving models that will be re-used.
The GDSS-PO provides the ability to save models and their results. In this case, a decision model can be re-used again and again. GDSS-PO saves models and their results, whereas these models could be re-used again to solve another problem if the hierarchy structure of the model is still considered relevant as solutions for that problem.

d. Procedures for updating models
User, who has the access toward the decision model in GDSS-PO, can do changes and modifications of the hierarchy structure of certain AHP's decision models.

3.2.3 Application Programs

Developing GDSS-PO surely needs application programs, which should accommodate the decision-making process requirements. Internet utilization in GDSS-PO requires the using of web programming, those are HTML (Hypertext Markup Language), JavaScript, MySQL, PHP, and browser.

3.2.4 User Interface Design

GDSS-PO is designed for multi user, there are eight types of user with eight types of access; access type 1 to access type 8. In GDSS-PO, features designed for each user were done by building user menus. Generally, the menus for users can be divided into five parts:

1. Input Menu
   This menu is used for adding data in GDSS-PO database.
2. View Menu
   This menu is used for data retrieval or for displaying data from database of GDSS-PO.
3. Delete Menu
   This menu is used for deleting data from the database
4. Update Menu
   This menu is used for updating process or data changing from database of GDSS-PO.
5. Search Menu
   This menu is used for searching data of employees, models, or even projects, with flexible searching criteria, as the user wants and the access type of the user.

3.3 People

People as component in GDSS-PO covers all company's employee. In this case, those employee may be involved in a decision making process. Thus, the groups of decision maker are not consisting of a fixed group of people, but it might consists of different people for different kinds of problems and managerial level of those decision makers.

3.4 Procedures

Procedures are the last basic components of GDSS-PO that are connected with the use of GDSS-PO. Generally, there are several procedures implemented in this GDSS-PO:

1. Procedure for using menus for each type of user

2. Procedure for building decision model of AHP for certain types of problem in GDSS-PO.
3. Procedure for decision making process in group by using GDSS-PO

4. Types of User and Flow of Information in GDSS-PO

As described earlier, GDSS-PO is designed for multi user. The users may be categorized in several types of user based on the types of access he/she has. In this case, types of access that a user owns might not always consist of one certain type only, but rather can be various of types, depend on the condition and situation. For further details, here are the explanations of the access type and several technical terms, which are used in GDSS-PO:

- Access type 0
  This access type is used for a user to do his job as an administrator of GDSS-PO
- Access type 1
  Access type 1 is the type of access that has to be owned by a user to do his job as controller of all projects and as a decision maker in a group of decision makers of a project
- Access type 2
  Access type 2 is the type of access that has to be owned by a user to input decision model in GDSS-PO's database. Then, this user will be assumed as the decision model's owner.
- Access type 3
  This access type is the type of access that has to be owned by a user to do his job as a project manager.
- Access type 4
  This type of access has to be owned by a user for doing his job in processes of data input and updating or deletion of company profiles and employees who are the user of GDSS-PO.
- Access type 5
  Access type 5 is the type of access that a user should have whenever he is involved as a decision maker of certain problems in GDSS-PO's database.
- Access type 6
  Access type 6 is given for employees who are involved as project's personnel by the manager of the project.
- Access type 7
  This type of access is given to all employees. Thus, access type 7 has the most limited right that a user could have.

4.1 General Procedures to Access the GDSS-PO

In order to access the GDSS-PO, a user must give his/her login name and password for every access for each access type that he/she has. Generally, the procedures can be described as below:

1. First of all, the user has to enter his login name and password as user of type 7 to do the login process.
2. If the first login was a success, then the GDSS-PO will display first page that shows all menus owned by the user, which meets his type of accesses.

3. Then the user can click on the chosen menu to login as a user of certain types. Then, GDSS-PO will display certain login page that meets the user choice.
4. The next step is the login process as the holder of access type 0, 1, 2, 3, 4, or 5 (as what the menus are displaying to the user) by entering their login name and password for each type of user they want to access.
5. If the login process is successful, the GDSS-PO will then display menus page as the type of access that the user has.

5. Procedures of Multi criteria Group Decision Making By Using Analytic Hierarchy Process

Generally, the steps of Group Decision making are:

1. Problem Identification
2. The building and input process of AHP's decision model for certain types of problem by the user that has access type 1, 2, or 3 into GDSS-PO.
3. Determine people who will be involved as decision maker.
4. Decision model publication to the web or the session opening of the decision making.
5. Pair wise comparison judgment process for each hierarchy subsystem from the hierarchy decision model.
6. Uniting the pair wise comparisons judgment of each decision maker in order to obtain priority vector for each alternatives (last element in the hierarchy) from an AHP decision model by using geometric mean method.
7. Closing of decision-making session of a decision model.

5.1 Problem Identification

In this phase, identification process of existing problem that needs group decision making process will be done. Starting from this problem identification, then AHP's decision model is made.

5.2 AHP's Decision Model Building

GDSS-PO will provide the needs to input new AHP's decision model that meets the problem's requirements for user of type 1, 2 or 3. The modeler should give clear descriptions when entering the decision model in order to facilitate other users or decision makers in understanding the model. GDSS-PO also makes it possible for the user to re-use or modify his models. Moreover, when a model is stated as a free access one, then user of type 1, 2, or 3 can import the model and do some modifications.

In the building process of AHP's decision model, a problem is described in a hierarchical structure. Generally, the hierarchy can be divided into Goal as first hierarchy, then the criteria, sub criteria as the next hierarchy, until then the alternatives as the last hierarchy.

The simplest hierarchy structure of AHP's decision-model is shown as follows:

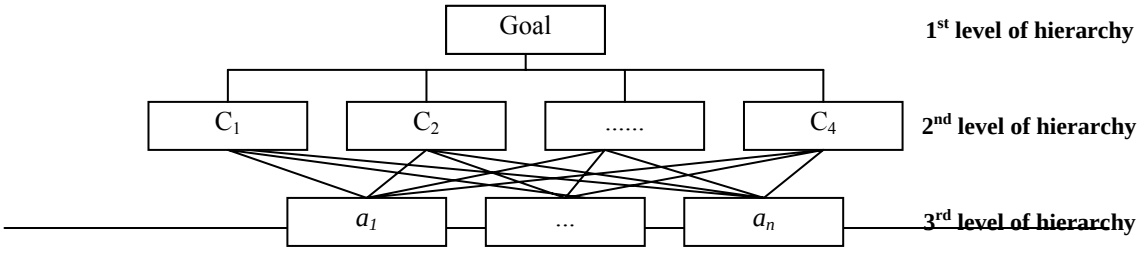

Figure 3. Model of AHP Hierarchy Structure

5.3 Determine people who will be involved as decision makers

In this step, a decision modeler is asked to choose the people that would be involved as decision makers.

5.4 Decision model publication to the web and Pair wise Comparisons Judgment for each subsystem of Hierarchy by Each Decision Maker

This GDSS-PO will accommodate the decision makers to do the judgment at anytime and anyplace they want it to be. Besides, GDSS-PO will automatically check the decision maker's consistency in their pair wise comparisons judgment, so that all data are consistent before they were entered to the database. Generally, the judgment processes are exhibited in Figure 3. The results of the pair wise comparison judgment will have a common form below:

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{bmatrix}$$

With:

$a_{ji} = 1/a_{ij}$ for each i, j=1, 2, 3,..., n

$1/a_{ij} = 1$ for each i=j (elements of matrix diagonal A)

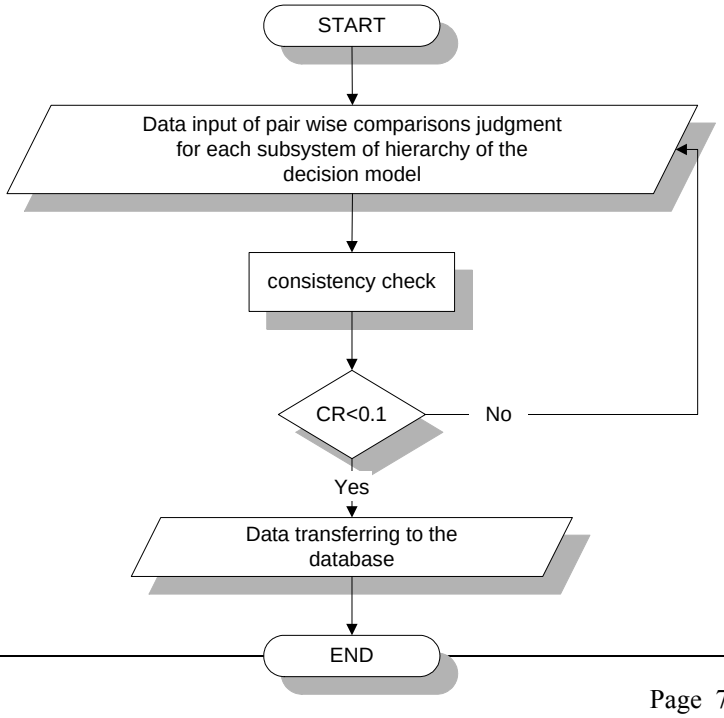

Figure 4. Flow chart of pairwise comparison judgments processes

Pair wise comparisons in AHP should be applied to pairs of homogenous elements. The fundamental scale of absolute values for representing the intensities of judgment is shown in table 1.

Table 1.Fundamental Scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contributes equally to the objectives
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between two close comparisons	These values are made if there are compromise between two choice
Reciprocal ($a_{ji} = 1/a_{ij}$)	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.	

The weight for each criterion is notated by W= (w_1,w_2,…,w_n). If AHP is used for choosing alternatives, then values of w_n are representing relatives weight of A_n toward the whole set of criteria of the subsystem.
As a result of a consistent judgment will appear as relation below:

$$a_{ik} = a_{ij}.\ a_{jk} \qquad \text{with } i, j, k = 1, 2, 3,.., n \tag{1}$$

In other words, the consistent judgment will result as a consistent matrix, so that a comparison matrix can be made by using the values in table 1, they are a_{ij} with $i, j = 1, 2, 3, n$. Whereas, the value of a_{ij} can be represented in vector W:

$$a_{ij} = w_i/w_j \tag{2}$$

thus, the equation below will be obtained:

$$\sum_{j=1}^{n} \frac{a_{ij} w_j}{w_i} = n \qquad i, j = 1,2,3...,n \tag{3}$$

or

$$\sum_{j=1}^{n} a_{ij} w_j = n \qquad i, j = 1,2,3...,n$$

(4)

that is equivalent with equation below:

$$Aw = nw \tag{5}$$

In matrix theorem, the formula is a characteristic equation with W as Eigen vector of A with Eigen value *n*. Commonly, there are several Eigen value and Eigen vector that meet the above equation. Variable n in the equation above may be replaced commonly by vector λ:

$$Aw = \lambda w \qquad \text{with : } \lambda = (\lambda_1, \lambda_2, ..., \lambda_v) \tag{6}$$

If matrix A is a consistent matrix, then all eigen values will have zero values except one eigen value that has the same value with *n*. If matrix A is an inconsistent one, then small variance towards a_{ij} will have value that near the largest eigen value, and λ_{max} will still be close to n, whereas the other eigen values will have values close to zero.

Value of λ_{max} can be obtained by this equation:

$$Aw = \lambda_{max} w \tag{7}$$

or

$$(A - \lambda_{max} I)w = 0 \tag{8}$$

whereas I is an identity matrix and 0 is a zero matrix. Value of weight vector W can be obtained by substituting the value of λ_{max} to equation (8).

After obtaining the priority vector, then the next things that should be questioned is the consistency of the decision maker in performing their pair wise comparisons judgment. In a consistent judgment, transitivity characteristic will be resulted, that is when an element A has larger intensity of importance than element B, and B is more important than C, then automatically A should has larger importance than C. In pair wise comparisons that involved more elements, it will be more difficult to achieve the consistent matrix. The AHP method will make it possible to identify the degree of consistency of the decision maker by a measure that called as *Consistency Ratio* and denote by CR. A comparison matrix is assumed consistent whenever its CR is smaller than 0.1 (10%).

Value of *Consistency Ratio* is obtained by:

$$CR = \frac{CI}{RI} \tag{9}$$

where:

CI= *Consistency Index*

RI= *Average random Consistency Index*

value of CI is counted by formula below:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{10}$$

Average Random Index (RI) itself is derived from a sample of generated reciprocal matrices using the scale 1/9,1/8,...,1,...,8,9.

Table 2. *Average Random Consistency Index* (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	.52	.89	.11	.25	.35	.40	.45	.49

If CR is larger than 0.1, then the decision maker is not consistent enough in performing his pair wise comparison judgment, and it would be better if he start his judgment all over again.

5.5 Uniting The Decision

In this case, GDSS-PO will unite the decision matrixes from all the decision makers into group pair wise comparisons judgment, so that the calculation process can be done to obtain the priority weight or vector from each alternatives/elements. The grouping method of the decision can be performed by using geometric mean method

$$MG = (x_1.x_2.x_3. \ldots\ldots\ x_n)^{1/n} \qquad (11)$$

With:

MG = *Geometric Mean*

$x_1, x_2, \ldots, x_n$ = judgment of decision maker 1,2, 3, ... , n

5.6 Closing the Session of Decision Making Process of a Decision Model from GDSS-OP

Closing the session of a decision making process will show that the process of collecting the opinions of each decision maker is considered done. If a model is stated done, then decision makers can no longer changes or updates their judgements in the decision model. But, decision maker can still view the results of the obtained group decision making. The closing process of a decision model can only be done either by user of type 1 or the owner of the model.

6. Conclusion

GDSS-PO is mean to enhance the flow of information among individual in the company, and also to enhance the group decision making process, which happens in the company. The GDSS-PO is designed to support the group decision making that could occur in various level of management in project-oriented company. Hierarchical decision model in GDSS-OP requires indenpendency between criteria. Int this case, there is no accomodation yet for the calculation process of dependent criteria.

The development of GDSS-PO is just like another engineering process, which has to be done continously – after some improvements and developments, there will be another needs and lacks that are still not accomodated. The proposed software prototype is still limited to no more than four hierarchy levels. Besides, the kind of information involved in the software prototype is still limited.

References:

Alter, Steven. *Transforming DSS Jargon into Principles for DSS Success.* Prentice Hall, Inc. New Jersey. 1994.

Archibald, R.D. *Managing High Technology Program and Project.* John Wiley & Sons Inc. 1976.

Bennet, J. "*User Oriented-Graphics, Systems for Decision Support In Unstructured Tasks,"in User-Oriented Design of interactive Graphics Systems,* ed. S. Treu. 3-11. New York : Association for Computing Machinery, 1977.

Cleland, I. David, Gareis Roland. *Global Project Management Handbook.* Mc-Graw Hill International. 1994.

Cleland, I. David And King W.R. *System Analysis and Project Management.* Mc Graw-Hill Book Company, 1984.

DeSanctics, Gerardine And Gallupe, Brent. *Group Decision Support Systems : A New Frontier.* Database, Winter 1985.

Gannon, M.J. *Organizational Behaviour : A Managerial and Organizational Perspective.* Boston : Little, Brown, 1979.

Gerrity, T.P. *"Design of Man-Machine Decision Systems : An Application to Portfolio Management," Sloan Management Review*, Winter 1971,59.

Gray, Paul. *Decision Support and Executive Information System*. Prentice Hall International.

Huber, G.P. "*Issues in The Design of Group Decision Support Systems," MIS Quarterly, 1984.*

Ito, Takayuki And Shintani, Toramatsu. *Persuasion among Agents : An Approach to Implementing Group Decision Support System based on Multi Agent Negotiation.* Nagoya Institute of Technology.

Kerzner, H. *Project Management For Executives,* Van Nostrand Reinhold Company, 1982.

Mann. H.Stuart And Triantaphyllou.*Using The Analytic Hierarchy Process For Decision Making In Engineering Applications :Some Challenges.*International Journal of Industrial Engineering Applications and Practice. Vol 2, no.1 pp.35-44,1995.

Saaty,T.L.*Multicriteria Decision Making. The Analytic Hierarchy Process. Planning, Priority Setting, Resource Allocation.* Eta Services Ltd., Beccles, Suffolk. 1988.

Saaty,T.L. Pengambilan Keputusan Bagi Para Pemimpin. Proses Hierarki Analitik Untuk Pengambilan Keputusan dalam Situasi yang Kompleks. PT.Pustaka Binaman Pressindo. 1993.

Saaty,T.L.*Decision Making in Economic,Political,Social And Technological Environments with the Analytic Hierarchy Process*. RWS Publication.Ellsworth Avenue.1996.

Saaty,T.L. *Decision Making With Dependence and Feedback.The Analytic Network Process.* RWS Publication.Ellsworth Avenue.1996.

Saaty,T.L. *The Seven Pillars of The Analytic Hierarchy Process.*

Saaty,T.L. *Fundamental of The Analytic Hierarchy Process.* ISAHP.1999,Kobe, Japan.

Simon, Herbert. *The New Science of Management Decision.* New York : Harper & Row, 1960.

Soeharto. *Manajemen Proyek Dari Konseptual Sampai Operasional*. Erlangga.Jakarta.1988.

Sprague, H.Ralph And Watson, J.Hugh. *Decision Support System. Putting Theory into Practice.* Prentice Hall Inc.1993