Chapter III

Theoretical Considerations

The theories used for developing the Decision Support System in Maintenance Planning can be categorized into two fields: the maintenance and the decision support system. In the maintenance field, the maintenance system, the maintenance planning and scheduling, the maintenance costs, and the optimal maintenance models are discussed. For the decision support system field, the architecture and components of the decision support system are presented.

3-1 Overview of the Maintenance System

Maintenance is defined as a set of activities to maintain or restore the equipment in order to achieve the maximum availability and performance. The performance of the equipment needs to be maintained in the condition that can produce the required output in both quality and quantity. To maximize the availability and performance of the equipment requires the integration of people, policies, management, time, skills, technologies, and facilities. These factors are the input of the maintenance system. The maintenance system will integrate and change these inputs through planning, controlling, and organizing processes into the output results. The outputs of the maintenance system are the availability and performance of the equipment, the productivity, the quality of products. and the profits.

In order to create the effective maintenance system, the activities in planning, organizing and controlling of maintenance are required. According to Duffuaa et al (1998), the planning activities in the maintenance system are the selecting of maintenance policy for the production plant, the forecasting of equipment load and planning of its capacity, the creating of maintenance organization, and the maintenance task scheduling. The activities in organizing the maintenance system involve with designing the maintenance jobs and setting the work standards. The controlling activities in the maintenance system concern with the control of the maintenance work, the inventory, the quality, and the costs. The typical maintenance system model presented by Duffuaa et al (1998) are shown in figure 3.1.

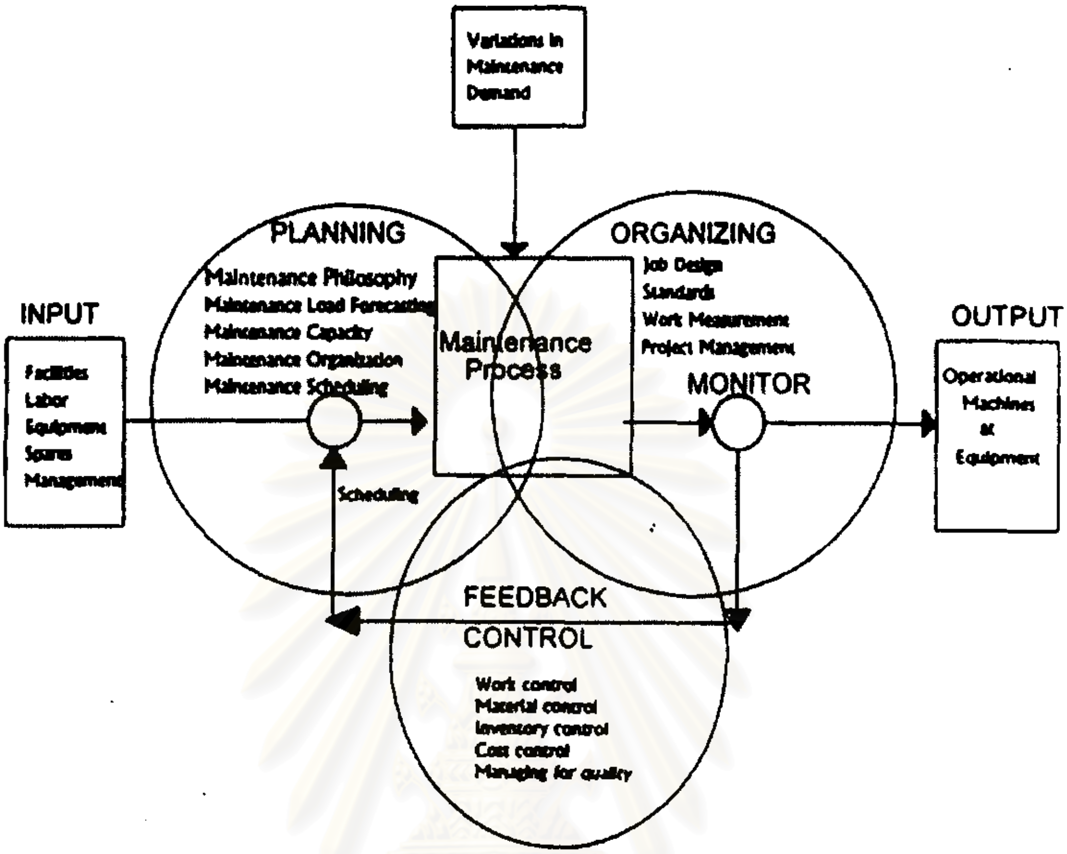

Figure 3.1 Maintenance System Model (Duffuaa et al, 1998).

3-2 Maintenance Planning and Scheduling

The effectiveness in maximizing the availability and performance of the equipment and utilizing the resources can be achieved through the maintenance planning and scheduling. Planning is the activity in determining the elements to perform a task before starting work. For the maintenance planning, workforces. work hours, materials, and tools required in performing maintenance work are the important elements. These elements have to be considered for their availability, quantities, conditions, etc, in order to assure that the job can be performed effectively and met the objectives. Scheduling concerns with the specific time to perform the tasks. It involves in monitoring, controlling, and reporting of the works. The objectives of the maintenance planning and scheduling are to maximize the availability and performance of the equipment, to minimize the maintenance costs, and to maximize the utilization of maintenance resources. In order to achieve these objectives, the effective maintenance planning procedure proposed by Duffuaa et al (1998) is presented as follows:

(1) Identifying the content of maintenance task.

(2) Determining the sequence, the method and the procedure in performing a maintenance job.

(3) Identifying the workforces required for the job.

(4) Planning and ordering for the parts, the materials, and the equipment used in a maintenance job.

(5) Assigning a job to the workers who have the appropriate skills.

(6) Reviewing the safety procedures.

(7) Setting the priorities for the maintenance tasks.

(8) Estimating for the maintenance costs.

(9) Completing the work orders.

(10) Reviewing and controlling the backlog.

(11) Predicting the future maintenance load.

After setting the maintenance plan, the jobs are scheduled by considering the availability of resources to perform the jobs and the sequences of the jobs at the certain time. The priority of the maintenance task, the availability of resources of the job, and the production schedule are used to determine for setting the maintenance schedule. The estimation of the situations and the flexibility of the schedule need to be considered. The steps for scheduling the maintenance works recommended Duffuaa et al (1998) are presented as follows:

(1) Sorting the backlog work orders.

(2) Arranging the maintenance work orders by priority.

(3) Organizing a list of the completed jobs and backlogs.

(4) Determining the work hours and availability of resources for the job.

(5) Scheduling the maintenance works.

(6) Setting the daily maintenance schedule.

(7) Assigning the maintenance tasks to workers.

3-3 Maintenance Costs

The costs of maintenance can be used to reflect the maintenance performance. The high costs of maintenance indicate the inefficient and ineffective of maintenance system. The increase of maintenance costs can effect to the profits of the company. As a result, the maintenance costs need to be controlled and minimized. The maintenance costs are consisted of direct and indirect costs. The direct costs of maintenance are labor cost and material or equipment cost used in performing maintenance tasks. The direct costs are varied depending on number of maintenance activities in production plant.

According to Pintelon and Gelders (1992), the indirect costs of maintenance are caused from the effect of maintenance to the equipment, production and products. The maintenance indirect costs are usually higher than the maintenance direct costs. They are very difficult to estimate. The examples of the maintenance indirect costs from the equipment loss are the accelerated wear of the equipment, the inefficiency of the equipment in energy consumption due to the lack of maintenance, and the cost in storing and handling the high level of spare parts and equipment in inventory. In the production, the losses affected by maintenance are from the product defects, rework, production downtime, reschedule, overtime, and miss contact due to late delivery products to customer. The indirect costs of maintenance related to the products concern with the quality and reliability of the products, the opportunity loss due to downtime, and the warranty claims from the customers.

3-4 Maintenance Optimization Models

According to the two optimum preventive maintenance policies presented by Barlow and Hunter (1960), the optimization maintenance models are developed. From these two policies, Duffuaa et al (1998) have developed the optimization models to find the expected maintenance costs per unit time and the interval time for performing each maintenance task. The parameters used in models are presented as follows:

$UEC(t_p)$	=	Expected cost per unit time
$EC(t_p)$	=	Expected cost per cycle
C_p	=	Preventive maintenance cost
C_f	=	Breakdown maintenance cost
$f(t)$	=	Time-to-failure probability density function

$F(t)$	=	Time to failure distribution
$r(t)$	=	Failure rate function
$N(t_p)$	=	Number of failures in the interval $(0,t_p)$
$H(t_p)$	=	Expected number of failures in the interval $(0,t_p)$
$R(t)$	=	Reliability function
$M(tp)$	=	Expected value of the truncated distribution with a p.d.f. $f(t)$ truncated at t_p

The policy I for optimizing preventive maintenance is defined as the following. Preventive maintenance is performed after t_p hours of the continuing operation without failure or when failure occurs before t_p. The t_p can be finite or infinite. If t_p is infinite, preventive maintenance is not scheduled. If failure happen before t_p and preventive maintenance is performed, reschedule preventive maintenance. Assume that the system is as good as new after performing preventive maintenance. From this policy, the interval time (t_p) of preventive maintenance can be identified by the optimization maintenance model. This interval time will minimize the total expected costs per unit time of maintenance. The optimization maintenance model for the policy I is defined as:

$$UEC(t_p) = \frac{\text{Total expected cost per cycle or } EC(t_p)}{\text{Expected cycle length}}$$

where $EC(t_p) = C_p \times R(t_p) + C_f[1 - R(t_p)]$

Expected cycle length $= t_p R(t_p) + M(t_p)[1 - R(t_p)]$

$R(t_p)$ and $M(t_p)$ are defined as:

$$R(t_p) = 1 - \int f(t)dt$$

$$= 1 - F(t)$$

$$M(t_p) = \frac{\int t\, f(t)dt}{1 - R(t_p)}$$

Thus,

$$UEC(t_p) = \frac{C_p \times R(t_p) + C_f[1 - R(t_p)]}{t_p R(t_p) + M(t_p)[1 - R(t_p)]}$$

The policy II is defined as the following. Preventive maintenance is performed after t_p hours of operation only. If the failure occurs before t_p hours, the minimal repair will be performed. It assumes that the minimal repair does not effect to the failure rate of the equipment. Thus, the preventive maintenance schedule does not change. The optimization model to determine the optimal interval time in the policy II is defined as:

$$UEC(t_p) = \frac{\text{Total expected cost per cycle or } EC(t_p)}{\text{Expected cycle length}}$$

where $EC(t_p) = C_p + C_f\, H(t_p)$

Expected cycle length $= t_p$

$H(t_p)$ is defined as:

$$H(t_p) = \int r(t)dt$$

where r(t) or failure rate function is

$$r(t) = \frac{f(t)}{1 - F(t)}$$

Thus,

$$UEC(t_p) = \frac{C_p + C_f\, H(t_p)}{t_p}$$

3-5 Overview of the Decision Support System

The Decision Support System is the computer-based system used to support the managerial decision making by analyzing and transforming the data into the alternatives of decision. The main characteristics of the DSS are the ability to solve unstructured problems, the flexibility to change with the different criteria and environment, the application of models and techniques to analyze data, and the ease of use. These characteristics make the DSS different from the other computer-based systems. The architecture of the DSS composes of three major components: the dialog, the data, and the model. The dialog or user interface component is used for interacting with the users. It is consisted of the knowledge base, the action language, and the presentation language. These sub-components are used for questioning and reporting to support the user decision. The data component is used to store the data and information for analyzing and reporting to the users. The model component is used for processing and analyzing the data and information. According to Turban (1988), the relationships of the dialog, the data, and the model in the DSS architecture are presented in figure 3.2.

3-6 Decision Support System Components

According to the DSS architecture in figure 3.2, three major components of the DSS are presented as follows:

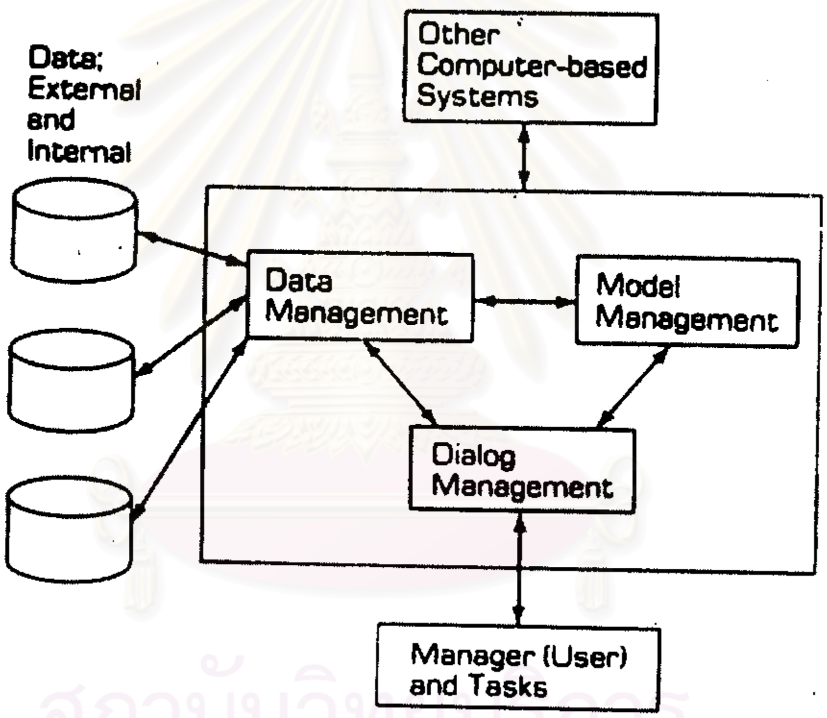

Figure 3.2 DSS Architecture (Turban, 1988).

3-6-1 Dialog Component

The dialog component is the part that allows the users to interact with the system. According to Watson and Sprague (1993), the dialog component helps to inform the users how to use the system. It provides the orders for the users to direct the system for the action. It is also used to present or report the result of the system to the users. The dialog component can be divided into three parts: the knowledge base, the action language, and the presentation language.

Knowledge base contains information from the knowledge of the decision-maker for making a decision. It also provides the information that the users need to know in order to use the system effectively. The knowledge base is the important part of the system for providing the ability to deal with the problems.

Action language provides the ability for the users to communicate and control the system. It is the form of input required by the system for receiving the requests or commands from users. It can be in various formats such as the menu, the command language, the question and answer, the input/output structured, and etc. The action language can be used through many types of medias, such as keyboard, mouse, voice activation, and optical reader.

Presentation language is used to present the output of the system to the users. It provides the results to support all steps in the decision making process. These results are not only from the final analysis but also from the intermediate phases of decision making. The presentation language is presented through various formats and medias. It can be presented in text, graph, bar, or numerical data. It is provided to the users through the monitor screen, printed report, plotters, audio output, and etc.

3-6-2 Data Component

The data component in the DSS is used to store, to organize and to manage data and information. In the data component, two important parts are described. These parts are the database and the database management system.

Database is the set of data that is interrelated. The data in database are organized in the designed format to response with the different needs of users. The database can be designed and used in various applications. It is created by linking and organizing the different interrelated data files together into the integrated unit. It can be structured in various forms. The hierarchical database organizes the data files into tree structures with low flexibility in accessing the data. The network database structure is more flexible and complex. It allows the relationships between the different types of data. The relational database structure is the most flexible and popular type. It connects the same type of data from the different table files together.

Database management system is used to manage and control the activities in storing and retrieving data from the database. It provides the standard procedures in capturing and extracting data from the database. This allows various applications to be capable to access the required data in the database. According to Turban (1988), the database management system is capable in updating the data in the data files. It can interrelate the data from the different sources. The database management system can provide the security in access the data and track the usage of data.

3-6-3 Model Component

The model component provides the capability of the DSS in the analysis of the data and information. The types of models in the model component are various depending on the purpose of data analysis. The models are used to calculate the statistical values of data. They can help to optimize the data to identify the best alternative for a decision making. Two important parts in the model component are the model base and the model base management.

Model Base is composed of the different types of models grouped together. These models are used for data analysis in the DSS. In the model base, the models can be classified into four major types: the strategic, the tactical, the operational, and the model-building blocks and subroutines model. The strategic models help the management to identify the objectives and strategies of the company. Tactical models are used to allocate and control organization resources. They are used for the functional and mid-range planning in the organization. The operational models are used in the operational level in the organization to support the short-range decision, such as the weekly scheduling. The model-building blocks and subroutines consist of the statistical and operation research model tools, such as the linear programming and simulation. These models are used for analysis of the data to determine the required values for the users.

Model Base management has the function in creating and managing the models. It provides the abilities for the users to access, update, or modify the models in the model base. It is used to link the models with the database in order to access the required data when running the models. It allows the users to manipulate the models for the problem solving and data analysis.