PROJECT MANAGEMENT IN HIGH PRESSURE CLEANING SYSTEM MANUFACTURING

by

Mr. Prin Sonwai

A Final Report of the Three-Credits Course
CE 6998 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
in Computer and Engineering Management
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Project Title	Project Management in High Pressure Cleaning System Manufacturing
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Academic Year	March 2002

The Graduate School of Assumption University has approved this final report of the three-credit course, CE 6998 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

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ABSTRACT

The main purpose of this project is to develop the appropriate system for performing the manufacturing project for the manufacturer of lance cleaning system (high pressure water cleaning system), and to ensure that the manufacturing project will meet its objectives which contain performance, scope, cost, and time or schedule.

This project emphasizes on studying the process of planning and controlling by using the Microsoft Project program for generating all necessary information and charts. The way in developing the system of the manufacturing project is as follows:

This project has started at studying the existing system. The list of problems is created, and the procedure of the manufacturing project is formulated and documented to the mutual understanding of all parties involved. After getting all necessary information, the work breakdown structure of the project is created, and later on the task relationship table is created. The task relationship table shows the relationship among tasks, duration, resources, and precedence relation.

Next step, the planning can be done by putting all necessary information into the Microsoft Project program, the outcomes of this step are the project Gantt chart, the project activity schedule table, the scope of task table, and many valuable reports.

Finally, the existing progress measurement or evaluation is analyzed and the outcomes are the suitable progress evaluation formulas for each type of tasks. Later, the progress report tables for each type of tasks are developed to record and monitor the progress of the manufacturing project, and the project summary report which contains the status of manufacturing project is developed to be presented to all involved parties.

Effective implementation of the developed system starts from planning, monitoring, and controlling can help us meet the objectives of the manufacturing project.

ACKNOWLEDGEMENTS

In our lifetime, there are not many occasions to publicly thank other people for what they did to us. I would like to take this opportunity to express my gratitude to my project advisor and dean of Master of Science in Computer and Engineering Management, Dr. Chamnong Jungthirapanich, whose invaluable advice, patient assistance, and continuous encouragement motivated me to complete the project. I would like to express my appreciation to all my respected instructors, as well.

I wish to express my sincere appreciation to my friend. Even though I cannot list all their names on this page, please be assured that I will always remember their great friendship. Special appreciation is due to Ms. Chaleepan Loasom for her contribution.

Finally, I would like to express by deepest gratitude to my mom who always encourages and adds great love, understanding, and sparkling to my life.

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I. INTRODUCTION

In the world of rapid growing technologies and high competition, enterprises need to improve their performance and efficiency of doing business continuously. If they could not improve or adapt themselves, they would no longer survive, since they could not make their customers satisfied.

As many times noted, to make customers satisfied the enterprises need to produce the right things at the right time, for the right persons, at the right places, and with minimize cost. In order to cope with the above mentioned, a project management is one of the appropriate tools to improve the performance of the manufacturing enterprises.

In manufacturing projects, the company always encounters with the problem, which is it could not meet or deviate from its objectives.

Applying the project management in manufacturing projects appropriately, the company will minimize the deviations from its objectives or no longer miss its objectives, which are: to produce the right things at the right time, for the right persons, at the right places, and with minimize cost.

1.1 Background of the Company

The company is a fully owned subsidiary of the well-known company in Germany, which is a leading manufacturer of high pressure plunger pump and high pressure cleaning system for various industrials (pressure range from 50 bar to 2500 bar) that has been operating in this very high competitive situation. The company is responsible for the whole Asian market. The product line of the company can be separated into two main parts as follows:

(1) Producing high pressure pump units

(2) Producing high pressure cleaning systems which most of them have been designed and manufactured according to customer requirements.

What this **studying project** will emphasize is the second part, which is the manufacturing of high pressure cleaning system for reactors or tanks. Note that, in the production of most chemical or petrochemicals, reactors, vessel internal surfaces such as agitator blades must necessary be cleaned. A clean vessel leads to improve production efficiency, better product quality, and reduce residence times, which can be directly related to improve profitability. Also in this day and age, pollution control requires friendly environmental plant operations. The cleaning systems of the company, cleaning with water, offer these benefits. And the detail of the manufacturing's procedure will be discussed in later section.

1.2 Objectives of the Research

To ensure that the projects will meet their objectives, which comprise of four important factors as follows:

(1) Performance

(2) Scope

(3) Cost or Budget

(4) Time or Schedule

1.3 Scope of the Research

As mentioned above, a project management is seen as one of the interested tool, which can be used for improving the performance of performing the manufacturing projects of the company. There are two main processes within the project management, which this **study project** will focus as follows:

1.3.1 Planning

As it is observed, good project planning cause a lot of pain at the beginning, but the pain will diminish as the project progresses. With no planning or cursory planning, there is not much pain at the beginning, but it grows significantly as the project goes ahead.

In the beginning of the project, the work breakdown structure; WBS will be constructed and later on the relationship among tasks, duration, resources, and precedence relation will be created.

After getting the above information, the Microsoft Project program will be used for planning.

1.3.2 Control

If you are going to keep a project on schedule, budget, within scope, and meet quality requirements, you must have a way to measure where you are for each variable of interests.

The Microsoft Project program will be used for tracking the progress of project, during tracking the progress, few questions should be always asked:

(1) What is the actual status of the project?

(2) What caused of the deviation? (When there is one)

(3) What should be done about it?

Also some of earned values such as BCWS, BCWP, ACWP, Schedule Variance, and Cost Variance will be used in tracking the progress. Finally, the progress reports and project summary report will be updated on a weekly basis.

II. LITERATURE REVIEW

In this chapter, the readers will know some of important foundation of project management and how important they are for the project.

2.1 Introduction to Project Management (Lewis 1998)

A project may be defined as a one-time definable start and completion activity with a well defined set of desired end results as its objectives. Every project has some unique elements.

A project is generally deemed successful if it meets predetermined objectives set by the client (both customer or management), performs the job it has been intended to do, or solves and identifies problem within predetermined time, cost, and quality or performance constrains. To meet these objectives the project manager uses project management system to effectively plan and control the project.

Project management is a specialized management technique to plan and control projects to meet their objectives. These objectives will include cost, performance, time, and scope. The cost objective is normally called the project budget. Performance has to do with the quality of work that is done. Time is the schedule, and most projects in today's world are deadline-driven. Scope is the magnitude of work to be done. These are related as follows:

$$\mathbf{C = \mathit{f}(P,T,S)}$$

The expression reads: **Cost (C)** is a function of **Performance (P), Time (T)**, and **Scope (S)**. To understand this better, consider Figure 2.1.

Relationships of P, T, C, and S

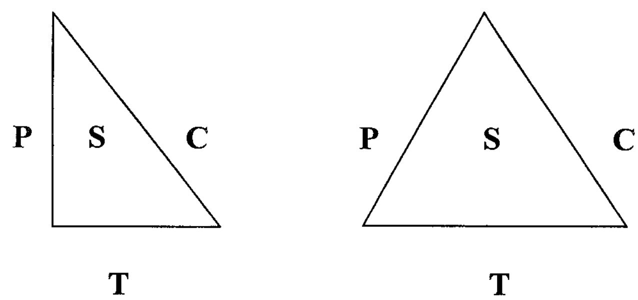

Figure 2.1. The Relationship between Cost, Performance, Time, and Scope.

Note that if we assign values to the sides of triangle, the area (Scope) of the project is defined. In other word we could say, "Here what you will get for this cost, over this time, and performance level. If you want more scope than is going to achieved with this combination, you have to change one of the sides, which is usually costly."

The above-mentioned relationship is the most important thing that a project manager should know, because he is always making tradeoff among them. A project manager should be prepared to show managements that they can pick three of the variables, but he (the project manager) gets to pick the remaining one.

The project management is a blend of art and science; the art of getting things done through and with people informally organized groups and the science of handling large amounts of data to plan and control so that the project duration, resource, and cost are balanced.

There are many project management techniques, which can be applied in difference situations such as network planning, Program Evaluation and Review Technique (PERT), and etc.

Network planning technique presents in diagrammatic from all activities, which must be carried out and their mutual time dependencies. Network diagram is simple and effective for communicating complex activity relationships. It also serve as a basis for the calculation of work schedules and provides a mechanism for controlling project time as the work progress. Network planning can be classified into two major groups namely Activity-on-Arrow and Activity-on-Node systems.

PERT is based on network planning technique also. But it uses probabilistic activity-time estimates to aid in determining the probability that a project could be completed by a given time. It has primarily been employed for research and development projects.

The purpose of this **studying project** is to study the underlying principles and techniques of project management, which are **plan** and **control** and also to identify areas where improvement can be made.

2.2 Work Breakdown Structure (Bruke 1997)

The success of the whole planning and control processes depends on the project planner being able to define the project's full scope of work quickly and accurately. The Work Breakdown Structure (WBS) provides a tool to address this.

The WBS may described as a hierarchical structure which is design to logically sub-divide all the work-elements of the project into a graphical presentation, this is similar in structure to an organization chart. The full scope of the work for the project is placed at top of the diagram, then sub-divided uniformly into smaller elements of work at each level of the breakdown. We also can define that the WBS breaks the projects down into smaller and smaller unit until we arrive at a level where decent estimate of time, resource, and cost can be done. At the lowest level of the WBS the element of work is called a **work package** or can be called **activity** or **task**.

Effectively use of the WBS will graphically outline the scope of the project and the responsibility for each work package. Designing the WBS required a delicate balance to address the different needs of the various disciplines and project location. There is not necessarily a right or wrong structure because what may be an excellence fit to one discipline may be an awkward burden for another. Figure 2.2 shows an example the WBS.

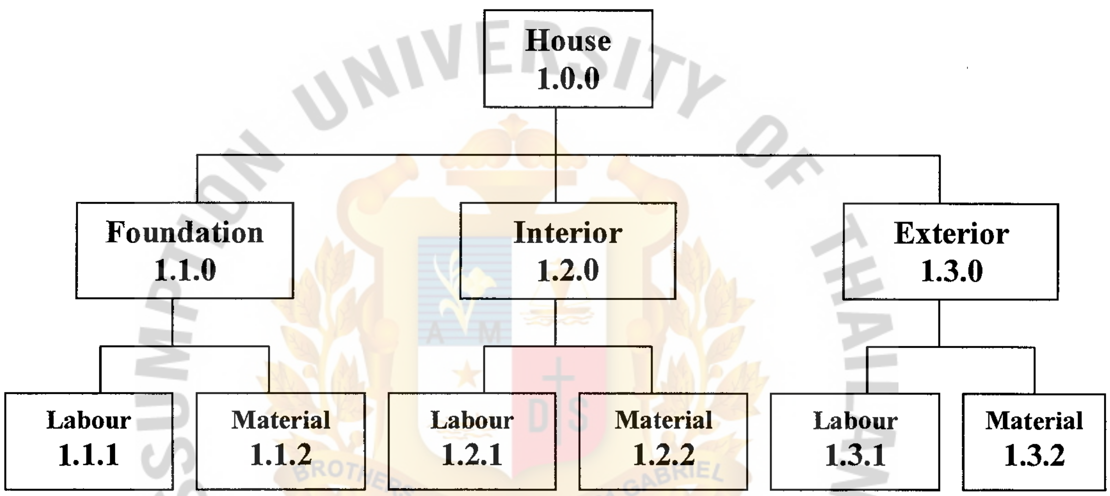

Figure 2.2. WBS Sub-Divided by Location.

In this **studying project**, we will construct the WBS of existing manufacturing project of the company and also the relationship among tasks, duration, resources, and precedence relation will be created.

2.3 Planning in Project Management

The term planning and scheduling are often used interchangeably. However, if a distinction is required, planning generally refers to the process of generating a time framework for the project, which becomes a schedule when dates are assigned to the activities.

The tool of choice for scheduling projects is critical path method (CPM). Arrows are used in the critical path diagram to show the order in which work is performed. The method also allows the determination of which path through the project is the longest one, and thereby we can tell the earliest finish for the entire job.

The critical path diagram is absolutely necessary in order to find the longest path in very large schedule, try to do this with a bar chart can be very misleading, because you might show things being done in parallel that simply can't be done that way. However, a CPM diagram is not easy to be interpreted. It should always be converted to a bar chart or Gantt chart. Also the schedule in this studying project will be generated by software, which is Microsoft Project, the concept of CPM still needed to be discussed later in next section.

Gantt charts are widely used in projects because they provide an effective presentation which is not only easy to understand and assimilate by a wide range of people, but also conveys the planning and scheduling accurate information.

One important point about scheduling software is that people seem to think that project management is primarily scheduling, and in line with that belief, that is if they have a good scheduling package, they will successful in managing projects. The software is just a tool, and without a proper understanding of project management methodology, all it will do is help document your failures. (Lewis 1998)

After getting all necessary information as mentioned in previous section, this **studying project** will create a schedule of the project by using the Microsoft Project.

2.4 The Critical Path Method (CPM) (Buay 2001, Devaux 1999)

Most project management literature puts the birth of modern project management as 1957 or 1958. These are the years in which CPM and PERT were developed in the construction and defense industries respectively. Today, the two terms are used more or less interchangeably, even though PERT actually means something slightly different.

In 1964, IBM project managers developed an enhancement or the traditional network logic diagram, called Precedence Diagram Method (PDM).

There are two difference diagramming techniques used for displaying CPM work flow: activity-on-node (AON) and activity-on-arrow (AOA). In AON diagramming, the activity is representing by a box or node, while the predecessor/successor relationship is represented by an arrow pointing from the predecessor to the successor. Figure 2.3 shows an AON diagram, with activity A as predecessor of both B and C, and both B and C being predecessor of D.

AON is by far the more intuitive and simpler method of diagramming CPM. With AOA, the arrow represents both the relationship and the activity, as an arrow running between the start of an activity and its finish. The arrow is therefore expected to serve two functions, and it cannot always serve both adequately. As a result, it is sometimes necessary to include "dummy" activity in an AOA diagram, that is, activities that do not really exist, and have zero duration, but which must be included in order to properly to model the relationships. Figure 2.4 display the same four-activity project as in Figure 2.3, but in order to show that both B and C are predecessors of D, we have to include a "dummy" activity to tie the finish of C as a predecessor to the start of D.

AOA is an obsolete method that is rapidly disappearing as fewer an fewer software packages support it.

In order to use CPM for scheduling, you need two items of information about each task: **duration** and **precedence**. This information should be supplied for each detail level activity of WBS. Once duration and precedence information have been entered for every detail-level activity, the foundation will have been laid for implementing CPM.

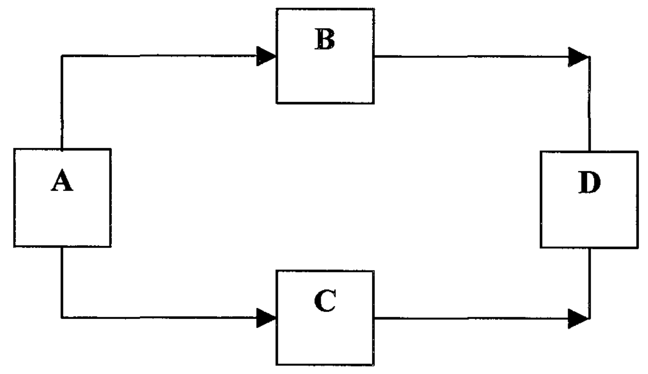

Figure 2.3. Example of an Activity-On-Node Diagram.

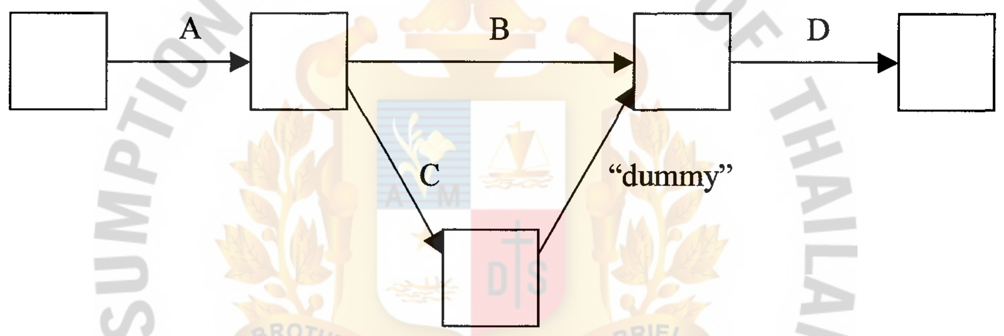

Figure 2.4. Example of an Activity-On-Arrow Diagram.

CPM is split down in to the following step:

2.4.1 Create a Work Breakdown Structure

The WBS has already been discussed in the previous section of this Chapter.

2.4.2 Creating a Network Diagram of the Project

This issue has already been discussed in the previous section of this Chapter and in the beginning of this section.

2.4.3 Computing Activity Times

The network diagram can be used to compute the activity on start and finish times, which are needed for scheduling activities in the project. There are four important activity times:

(1) Activity Earliest Start Time (EST) and Activity Earliest Finish Time (EFT)

As an activity cannot start until all of its immediate predecessors have been completed, its EST will be dependent upon its immediate predecessor' EFTs. Activity ESTs are computed by performing a Forward Pass on the network diagram as follows:

(a) Assign an EST of 0 to the start activity

(b) Moving forward through the network diagram, proceed to the next activity. The EST of the next activity is the latest of the EFTs of all its immediate predecessors. Note that an activity's EFT is obtained by adding its duration to EST.

(c) Continue until the ESTs of all activities are computed

There are different conventions in displaying Activity's ESTs, EFTs, and durations in the AON network diagram. In most project of planning software, you can customize how these are displayed. Figure 2.5 shows the example of one convention.

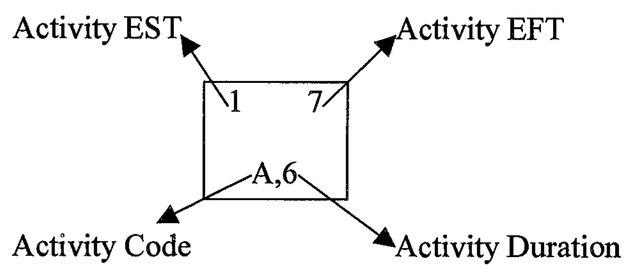

Figure 2.5. EST, EFT, Activity Code and Duration in an Activity On-Node Diagram.

(2) Activity Latest Start Time (LST) and Activity Latest Finish Time (LFT)

The LST and LFT of an activity are the latest possible times at which the activity can start and finish respectively without delaying the project. Activity LSTs are computed by performing a Backward Pass on the network diagram after the Forward Pass has been computed.

(a) Assign the LFT of the End activity to be equal to its EFT.

This is done as we want the project to be completed as early as possible. This would happen if the End activity's LFT is made equal to its EFT.

(b) Moving backward through the network diagram, proceed to the previous activity. The LFT of this activity is the earliest of the LSTs of all its successors. Note that and activity's LST is obtained by subtracting its duration from its LFT.

(c) Continue until the LFTs of all activities are computed

Activity LSTs and LFTs will be shown in the AON network diagram as in Figure 2.6.

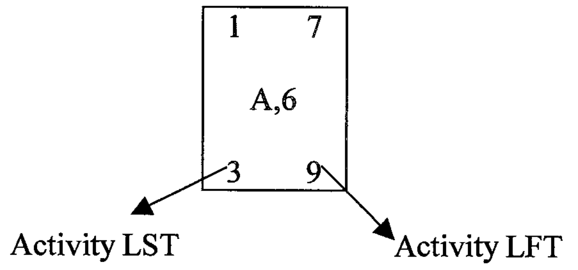

Figure 2.6. EST, EFT, Activity Code and Duration in an Activity-On-Node Diagram.

2.4.4 Computing Activity Total Float

Activity Total Float is the amount of time that an activity can be delayed without affecting the overall project duration. The formula of the Total Float shown following:

Activity Total Float = Activity LST – Activity EST

The Total Float is depicted in the AON network diagram as shown in Figure 2.7.

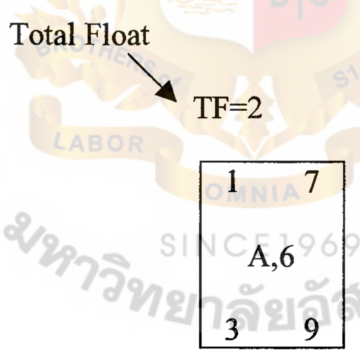

Figure 2.7. Depicting Total Float in an Activity-On-Node Diagram.

Total Float can have two components, namely Free Float and Interfering Float. It is possible for total float to contain a mix of free and interfering float, to contain entirely of free float or to contain entirely of interfering float.

Free Float is that part of total float whose usage will not affect the total float on sub-sequence activities.

Free Float = min. EST of Activity's successors – Activity EFT

Interfering Float is that part of total float whose usage will affect the total float on subsequence activities.

Interfering Float = Total Float – Free Float

If by some reasons we were forced to delay some activities in a project, we would first choose to delay activities with free float. Once we have run out of such activities, we would then delay activities with interfering float. But in delaying such activities, we would have to re-compute the total float of all subsequence activities as they may have disappeared.

Finally, choose to delay activities without any total float only as a last resort as doing so it would cause the project to be delayed.

2.4.5 Computing Project Duration and Critical Path

The **shortest possible project duration** is equal to the **EST** of the End activities. The **critical path** is the path comprising all activities with zero total float. Delays in any of the activities in the critical path will result delaying the entire project. We can thus identify the critical path by looking for all activities with zero total float. The **critical path** is also always the longest continuous path of activities a network diagram from beginning to the end of a project. The duration of the critical path is always equal to the shortest project duration. And it is useful to label the critical path by coloring and highlighting it.

2.4.6 Creating Activity Scheduling

The activity ESTs, EFTs, LSTs, LFTs, and floats can be computed directly on the network diagram as previously discussed. Once this is completed, it is possible to derive a schedule for all activities in the project. This is best presented in a **Activity Schedule Table**. This table is useful as the activities in a project may be assigned to a difference team member. It is easier for each team member to refer to the Activity Schedule Table to check his activity's times than to search for it in the network diagram. Table 2.1 shows the format of an Activity Schedule Table.

Table 2.1. Format of an Activity Schedule Table.

Act.	Dur	EST	EFT	LST	LFT	Total Float	Free Float
A							
B							
C							
etc.							

2.4.7 Creating Gantt Chart Schedule

A pictorial way of displaying the information in the activity schedule table is to create a Gantt Chart Schedule. The Gantt chart is a bar chart with time as the horizontal axis. Each activity is plotted as a bar on a separate line of the vertical axis. The bar starts at the **EST** of the activity. The length of the bar is the activity duration. **Total float** is shown as an arrow after the bar, with the length of the arrow equal to total float.

2.5 Resource Scheduling (Buay 2001)

The schedule produced by the CPM is based solely upon time alone (in terms of activity duration). It has not explicitly taken into account resource constraints. For example, an activity scheduled at a particular time may in addition require availability of 2 workers. The availability of these 2 workers must be checked and the schedule adjusted if necessary. This is known as resource scheduling.

Resource scheduling requires that a resource usage chart be plotted for each resource used in the project. Next a technique called resource leveling is applied. Both of these will be explained in the sections below:

2.5.1 Resource Usage Chart

A resource usage chart is plotted based upon the Gantt Chart (which is a pictorial schedule of all activities based upon their EST). The number of resource units used is plotted on the vertical axis while time is plotted on the horizontal axis. To plot the resource for a specific resource, we consider a particular point on the time axis. At this point in time, we check from the Gantt chart which activities are in progress. Then sum up the units of resource used by all these activities and plot this on the vertical axis at this point in time. Repeat for all other point in time.

2.5.2 Resource Leveling

In many projects, the available resources are limited. Resource scheduling would involve re-scheduling activities so that the usage of these resource never exceeds their limit. This would be facilitated if resource usage is made as even and level as possible. This would prevent the occurrences of peak resource usage which may overwhelm the resource pool. This technique is called resource leveling. It also balances overall resource requirements by reducing peak and through demands.

The procedure of resource leveling is carried out by plotting a resource usage chart. From the resource usage chart, period of resource overloading can be identified. Starting with the earliest period of resource overloading, look for activities using that particular resource in that particular period which have float. Such activities should be rescheduled to a later time. Note that the re-scheduling of activities without free float will in turn consume the float of subsequence activities. This subsequence activities must not be rescheduled without checking how much of their float has been consumed and continue until no more resource overloading occurs.

2.6 Control in Project Management (Buay 2001, Devaux 1999, Lewis 1998)

Needless to say planning is a pointless exercise unless the execution of the plans are tracked and controlled by obtaining accurate feedback on performance. If we are going to keep a project on schedule, budget, within scope, and meet quality requirements, we must have a way to measure where we are for each variable interest.

2.6.1 Important of Project Control

Once a project plan and schedule has been prepared using the critical path method, project implementation can begin. It is at this stage that the project control must be exercised.

Project control is important because unforeseen circumstances and imperfect planning can result in project progress deviating from the project plan. It is therefore important that the project be monitored and controlled so as to correct these deviations.

Project Control involves:

(1) Monitoring project progress. This involves regularly checking the status of the activities in the project. This can be done through status reports of the activities as well as by physically inspecting the activities.

(2) Assessing the impact of deviations of project progress from the original plan. Deviations (which may take the form of delayed or earlier activity starts and extended or reduced activity durations) must be updated in both the AON network diagram or the Gantt Chart. The impact of these deviations on the project duration and critical path must be assessed.

(3) Taking remedial action where the impact is unacceptable.

(4) Comparing variances between the project progress and project plan and determining the cause of these variances.

2.6.2 Impact of Deviations of Project Progress from Project Plan

As the project progresses, activities will be started and completed. Some activities may be started at time, which differ from the ESTs or LSTs of the original project plan. Furthermore, activity durations may turn out to be shorter or longer than the durations in the original project plan.

It is necessary to assess the impact of these deviations on the project duration, critical path, and remaining activity times.

This is done by updating the AON network diagram. As each activity is started, its EST and LST are changed to the actual start date. Its EST and LST are frozen in all future AON network diagram updates. Next, the forward and backward passes have to be recomputed to update the AON network diagram.

Similarly, as each activity is completed, its EFT and LFT should be change to the actual finish date. Its EFT and LFT are frozen in all future AON network diagram updates. Next, the forward and backward passes have to be recomputed to update the AON network diagram.

As the AON network diagram is updated, the project duration, critical path, and remaining activity times may change. The project manager should note this. Where the changes are not acceptable, then the appropriate action must be taken.

2.6.3 General Progress Report

A step above the system of reporting progress as OK or not OK is to report schedule performance only. This is done as shown in Figure 2.8.

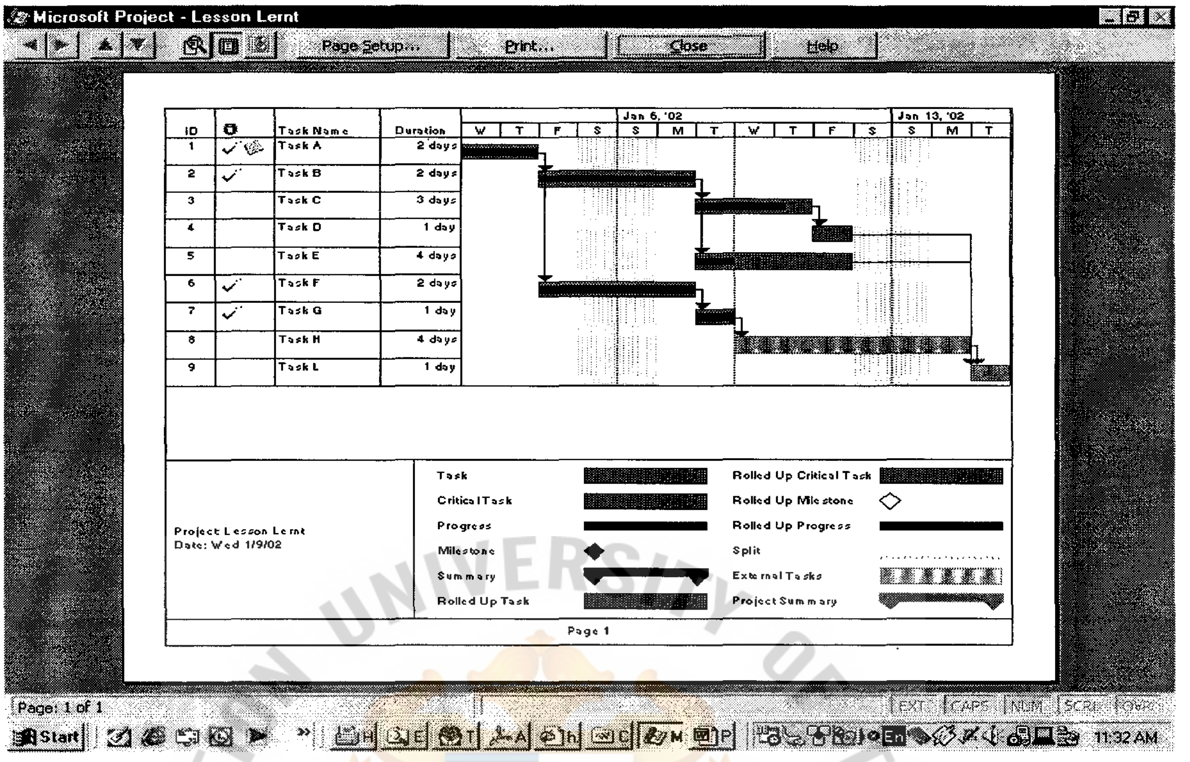

Figure 2.8. Schedule of Progress.

This report is from Microsoft Project, but most scheduling software reports progress in similar way. Note that the dotted line drawn at January 9 is where we are supposed to be as of today. The shaded areas represent weekends or holiday. Task H and L are on critical path. Progress is shown by the small bars, which run inside the task bars. From this report, we can see that the tasks have the status shown in Table 2.2.

Table 2.2. Tasks Status for Sample Schedule.

Task	Status
A, B, F, G	Completed
C	One day ahead
D, H, L	Not started
E	Right on target

The problem with this report is that the information is very limited. First of all, we know nothing about performance or scope. Assuming that the quality of work being done is correct, as well as scope of work. Furthermore we know nothing about what has been done to achieve the result. By this, it means that we don't know the cost whether it is expressed in monetary terms or simply working hours expended.

In any case, knowing that a person is on schedule, but that he worked twice as many hours to get there as he had planed, tells us that his work is not going well and that the project maybe in jeopardy. The sooner we know this, the sooner we can address the problem and make a decision about what should be done. Conversely, if we find that a person is only taking half of the time to get the job done, then we can begin to think about what this will ultimately mean to the project.

What we would like, rather than the simple reporting of schedule progress, is an accounting for what we got, how much effort was required, and how much effort was originally scheduled to be done. This is best accomplished by translating everything into monetary equivalent. For those who familiar with earned value analysis, the terms used to measure progress are BCWS (budgeted cost of work scheduled), BCWP (budgeted cost of work performed), and ACWP (actual cost of work performed). These numbers give us the capability to tell where we are with regards to both work efficiency and spending efficiency and enable us to make some predictions where the project is headed.

2.7 Earned Value (Bruke 1997)

The performance measuring mechanism should be periodically assessed progress and costs in comparable units against a baseline plan. It is essential for effective project control that performance is measured while there is still time to take corrective action.

The earned value approach to project control overcomes the problem of managers making decisions based on isolation information. Consider Figure 2.9, where cost and progress information are being reported separately. From the top graph the accountant would report that the project is under-spent, with planned expenditure 50% and actual expenditure 45%. Here the forecast looks good for the project to be completed under budget.

The planner on the other hand would not be so optimistic with planned progress 50% and actual progress 40% complete; the forecasting would predict a project time overrun, but now considers what happens when the two are integrated. The project is 45% spent but has only achieved 40% of the work. The analysis now indicated that not only is the project overspent but is also behind schedule. Thus giving a clear signal to the project manager that he needs to apply control and correct deviation. And the figure clearly shows a need to integrate the project's cost and time information. Based on progress information alone the project manager would have been mislead, believing that the project would meets its objective without the need for corrective control.

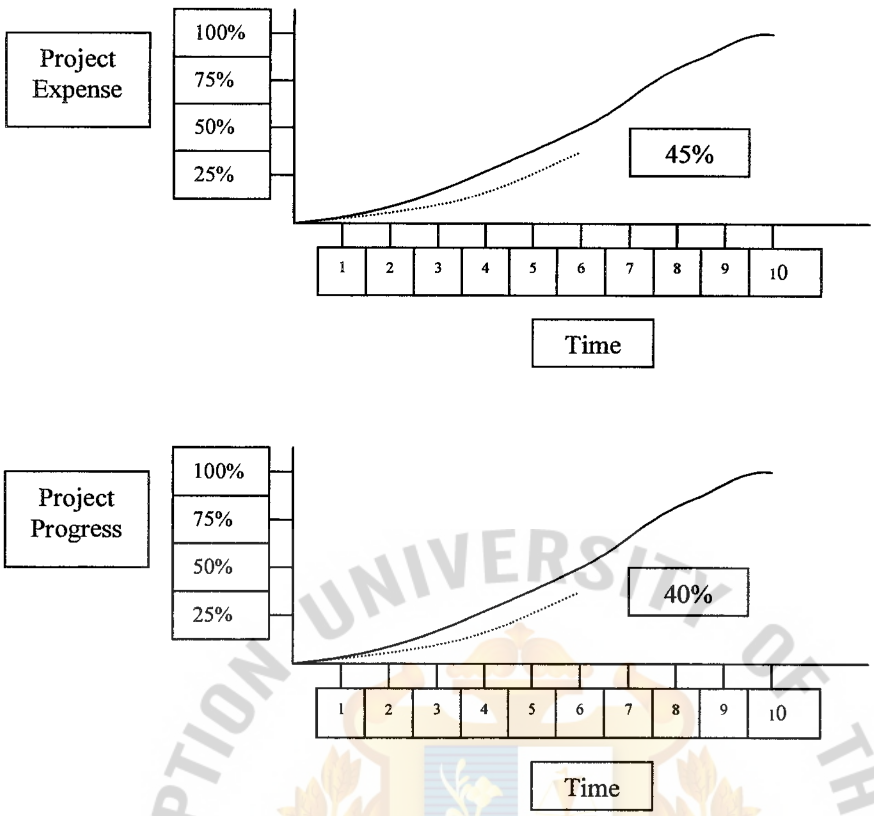

Figure 2.9. Lack of Cost and Progress Integration.

Terminology:

(1) Budget at Completion (BAC): This is the original cost estimate, budget or quotation, indicating the funds required to complete the work. At the project management level the BAC does not include the profit.

(2) Percentage Complete (PC): The PC is a measure of activities performance and progress to time now and is required for the earned value calculation. PC also can be calculated from remaining duration.

(3) Budgeted Cost of Work Scheduled (BCWS): The BCWS may be considered to the same as the accumulated expenditure S curve. This curve forms the basis of the baseline planned by providing a measure of planned work output

with respect to time. The BCWS is calculated and plotted from the following equation:

BCWS = (Baseline planned percentage complete) **x BAC**

(4) Budgeted Cost of Work Performed (BCWP): The BCWP is also called **earned value**, is a measure of achievement or value of work done. The BCWP is calculated and plotted from the following equation:

BCWS = PC (actual) **x BAC**

(5) Actual Cost of Work Performed (ACWP): This is the amount of payable for the work done to now. It is the real cost incurred executing the work to achieve the reported progress. Take care to ensure that both PC and ACWP are based on the same data.

(6) Estimate at Completion (EAC): EAC is a revised estimate of the cost to complete the activity, work package or project based on current productivity. The EAC is calculated by extrapolating the performance trend from time now to the end of the project. This value assumes that the productivity to-date will continue at the same rate to the end of the project. The EAC is calculated from the following equations:

$$\mathbf{EAC} = \frac{\mathbf{ACWP}}{\mathbf{BCWP}} \times \mathbf{BAC}$$

$$\mathbf{BCWP} = \mathbf{PC} \times \mathbf{BAC}$$

Therefore

$$\mathbf{EAC} = \frac{\mathbf{ACWP}}{\mathbf{PC}}$$

(7) Schedule Variance (SV): The SV calculation is a measure of the time deviation between the actual and planned progress. The interesting feature about this time variance is that it is measured in money units. The SV is calculated from the following equation:

$$SV \quad = BCWP - BCWS$$

The sign of the variance will indicate if the project is ahead or behind the planned progress.

Negative variance: The project is behind the planned progress.

Positive variance: The project is ahead the planned progress.

(8) Cost Variance (CV): The CV calculation is a measure of the deviation between the earned value and the actual cost of doing the work. The CV is calculated from the following equation:

$$CV \quad = BCWP - ACWP$$

The sign of the variance will indicate if the cost is over or under the estimate.

Negative variance: The cost is higher than the original estimate. (BAC)

Positive variance: The cost is lower than the original estimate. (BAC)

2.8 Computer Based Project Management System

Personal computers have not only changed the face of project management over the 1980s and 1990s but also have continued to do so into the next century with more and more crucial role. Today, a number of powerful but inexpensive project management software are readily available for the personal computer. The high speed digital computers have immense power for handling large and complex projects. It is capable of processing large volumes of data with not only short space of time but also with low risk of error. Currently, managing project is nearly impossible without the computer's help.

Project management software requires simple activity information. An the mean time, it is capable of applying reasonably sophisticated project management techniques (such as resource leveling, project management tracking, and updating) to project the reasonable size with multi-project capability and with reasonable set of reporting options. It allows project manager to make experiment with various condition through "what-if" simulation. Most new microcomputer based Project Management Information System (PMIS) are considerable more sophisticated; they use the microcomputer's graphics color and other features more extensively. However, it must be realized that although the use of project management software can help the project manager to plan and control the project, with a wide range of facilities but this is true only if the project manager understands and can apply the principle and techniques of project management. The project manager must be inventive and force the software to accomplish the desired results. Since the software cannot make on the job management decision and no piece of software can do all things, it only release the project manager from processing large amount of data manually and then allow him to has more time and accurate information to concentrate on and manage project effectively.

III. THE EXISTING SYSTEM

This studying project has studied the existing system as follows:

3.1 Overview of the Existing System

As already mentioned in the previous section that in the production of most chemical or petrochemicals, reactors, vessel internal surfaces such as agitator blades must necessary be cleaned. A clean vessel leads to improved production efficiency, better product quality, and reduce residence times, which can be directly related to improve profitability. In the era of globalization, there are many manufacturers producing the **High Pressure Cleaning System** which most of them use very high pressure water for cleaning the internal surfaces of any vessels and tanks. To be survived within this very high competition, the company needs to periodically consider where is its weakness, and try to eliminate or reduce all of them (weakness) and also find out the ways for continuous improvement.

The process of producing the high pressure cleaning systems of the company starts from designing, purchasing, manufacturing, assembly, function testing. By investigating the existing process of producing the high pressure cleaning systems of the company, for the similar manufacturing projects, most projects always encounter with the similar problems, which can be described as follows:

(1) There is no any formal planning for each project.

(2) There is no formal means to track or control the progress of each project

(3) Very often the manufacturing project is fufilled too late comparing to the original target.

(4) Sometime, scope of the projects is always not clear, so the additional scope always happens at each stage of the projects.

(5) Cost of some projects are much more higher than original estimated.

(6) Budget shortage may happen with some projects to buy the expensive-equipments. This problem can caused the late delivery.

3.2 Existing Procedure of Manufacturing Project

At the present time, as everybody already knows about the procedure of performing manufacturing project, but none of the procedure and flow chart are formally documented. To ensure that the procedure strictly implemented, the procedure should be documented. And to avoid any problems from happening, everybody who involves with the procedure should be explained or trained. The diagram of procedure of manufacturing projects is shown in Figure 3.1.

The first step is called the **Information Gathering** stage, which after our sales people gets the formal order from customers, the information/ specification can be passed through the designer via both kick off meeting or order confirmation document. After getting all necessary information/ specification, the designer will start conceptual design, this is called the **Initial Design** stage, and the outcome of this stage is the approval drawings.

Next stage the approval drawings will be sent to the authorized person for approval, this stage is called **Concept Approve**. And later the approved drawings will be sent to customer for approval. This stage is called the **Customer Approve**. At this stage, the customer may not approve or comment about the approval drawing, so, we cycle back into **Initial Design** stage. If the answer is yes, we can proceed to next stage, which is the **Detailed Design** or **Drawing Revised**. At this stage, the assemble drawings and other necessary drawings will be created by the designer. And later the part lists will be created according to the information from the previous stage, this stage is called **Make/ Edit Part List**.

Next stage we need to check whether we need to purchase the material or not, this stage is called the **Material Check**. If the answer is yes, we go to next stage for purchasing the materials from both domestic and international, which is called the **Material Purchasing** stage. If not, we will pass over this stage to the **Manufacturing** stage. At this stage, the machine works will be divided for both internal and contract out manufacturing.

Next stage, the initial quality check will be done by QC staff according to the drawings or specification, this stage is called the **Initial QC**. Parts and accessories that do not meet their specification will be cycled back to the **Manufacturing** stage or the **Detailed Design** or **Drawing Revised** stage, which depends on whether they need to revise the drawing or not. Those that meet their specification will be passed to next stage, which is called the **Assembly** stage. At this stage, all parts and accessories will be assembled into the complete system.

Next stage is called the **Final QC** or **Function Test**, the system will be functioning tested and final inspected. If the system does not meet its specification, it will cycle back to the **Material Check** stage or the **Detailed Design** or **Drawing Revised** stage, which depend on whether it needs to revise the drawing or not. If the system meets its specification will be passed for next stage, which is call the **Close out Project** stage.

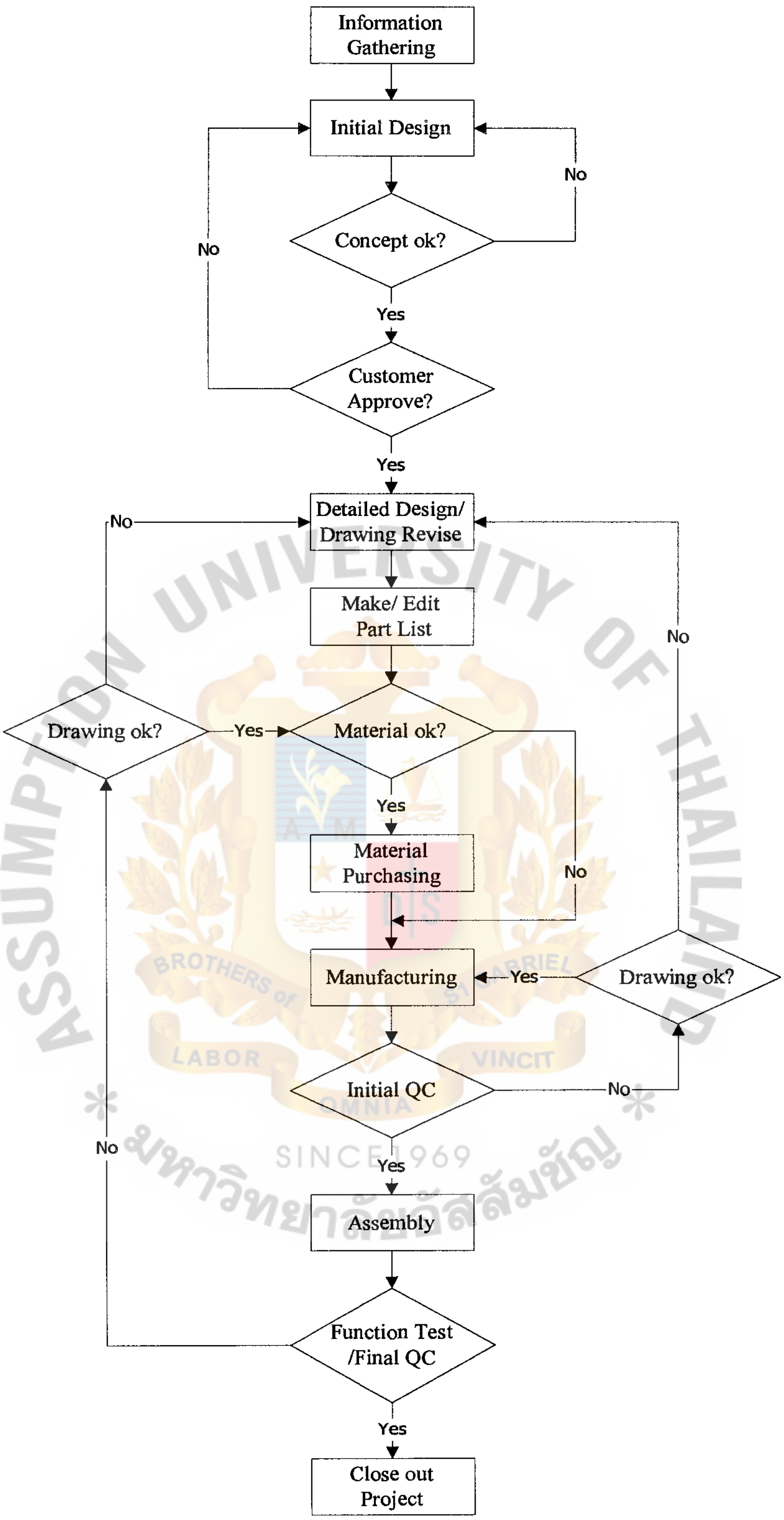

Figure 3.1. Diagram of the Procedure of Manufacturing Project.

3.3 Part List for Lance Cleaning System

There are many types of HP cleaning system that URACA has been manufacturing, and the most frequently manufactured is "**Lance Cleaning System**". These systems will be mounted with the customers' reactors or tanks for cleaning their internal surfaces.

This **studying project** will concentrate in studying on the existing lance cleaning system-manufacturing project, which is called **LG Yongxing Project**. The customer of this project is LG Yongxing Chemical Co.,Ltd., Ningbo, China.

The part lists are only created for individual project, and they are the outcomes of the sixth stage (**Make/ Edit Part List)** from the manufacturing project procedure. The part lists of this project are already created, and there are totally 8 part lists. The quantity shown in each part list is a number of parts or equipments required for manufacturing one system only. Figure 3.2 shows the example of part list of this project.

URACA

Far East

Engineering Ltd.

Project No.:UFE2001-02-013

Part List No.: UFE2001-02-013-4

URACA Part list

Page: 1/1

Revision: 1

Drawing: D305947

Dual Chains System; LGY

Item	Part No.	Description	Qty (st)	Drawing	Standard/Mat'l
1	0300105	Helical Warm Geared Motor Ex-Proof Motor with Brake& Thermister Model: SUA506A IECAD-BD80L4 21 RPM, 0.75 kW, 380V/50Hz/3pH Protection Class: EExDeIIBT4 Brake Voltage: 220V/ 50Hz/ 1PH	1		
2	2106038	Cap Screw M10x25	8		DIN 912/A2-70
3	2111006	Spring washer for M10	8		DIN 127/A2-70
4	D305661	Motor Support Plate 240x240x260	1	D305661	St 37 with Zn Plating
5	2103026	Hexagon Screw M10x35	8		DIN 933/A2-70
6	2111006	Spring Washer for M10	8		DIN 127/A2-70
7	2106038	Cap Screw M10x25	4		DIN 912/A2-70
8	2111006	Spring Washer for M10	4		DIN 127/A2-70
9	D305681	Bearing Support Plate 230x190x78	2	D305681	St 37 with Zn Plating
10	2103024	Hexagon Screw M10x25	8		DIN 933/A2-70

Printed Date: 4/17/02 **Example Part List**

Figure 3.2. Example Part List of LG Yongxing Project.

IV. THE PROPOSED IMPROVEMENTS

This studying project has some proposals for improvement as follows:

4.1 Development of Work Breakdown Structure for LG Yongxing Project

At the present, none of **Work Breakdown Structure** of the manufacturing project (lance cleaning system) is documented. However, only the part lists of the projects are used in performing manufacturing project. From the part lists of this project, the overall project can be classified into few main functions and need to be performed as shown in the WBS. And each main functions comprises of numbers of sub-functions. Not every item in the part lists is shown in the WBS, the identical/ similar parts or equipments will be grouped in the same sub-function. The detail of each sub-function will be discussed in following section of this chapter. The WBS of the **Lance Cleaning System** can be drawn as shown in Figure 4.1.

The first level represents the full scope of the **Lance Cleaning System** project. The project is sub-divided into six main functions as follows:

(1) Designing

(2) Material Purchasing

(3) Manufacturing

(4) Assembly and Test

(5) Function Test

(6) Packing

Some functions in turn are then further sub-divided in third and forth level. The lowest level of each particular function can be called **work packages** or **tasks**. In next section the relationship among tasks, duration, resources, and precedence relation of the example project will be created.

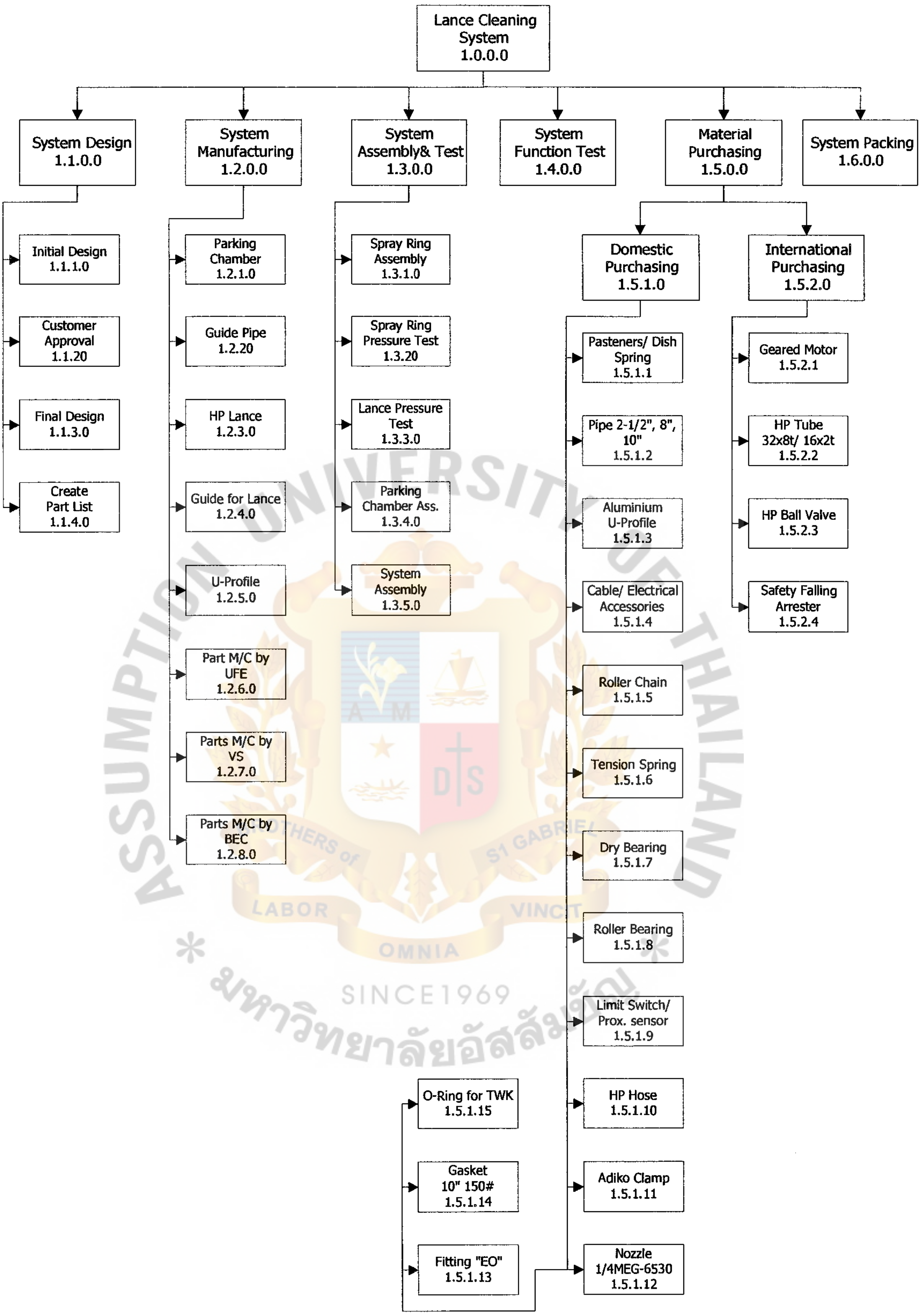

Figure 4.1. Work Breakdown Structure of Lance Cleaning System.

4.2 Development of Task Relation

This section will start using the information from the WBS of the previous section (section 4.1), they are the work packages or the tasks. From this information, we can create the relation among tasks, duration, resources, and precedence relation as shown in Table 4.1.

Note that the resources which are named by the position means there are more than one unit and those which are named by their name means there is only one unit. And the relation between the predecessor tasks and successor tasks which are shown in the table is FS type (Finish-to-Start). Later on the information from this section will be used in planning by Microsoft Project program.

Table 4.1. Task Relationship Table.

ID	Task Name	Duration	Predecessors	Resource Names
1	**LG Yongxing III**			
2	**Designing (Cleaning System)**			
3	Initial Design	4 days		Prin
4	Customer Approval	2 days	3	Prin
5	Final Design	3 days	4	Prin
6	Create Part List	2 days	5	Prin
7	**Material Purchasing**			
8	**Domestic Purchasing**			
9	Fastener& Disc Spring	5 days	6	Purchaser
10	Pipe 2-1/2", 8", 10"	3 days	6	Purchaser
11	U-Profile 100x50x5t	10 days		Purchaser
12	Cable Duct	1 day	6	Purchaser
13	Roller Chain	5 days	6	Purchaser
14	Spring	10 days	6	Purchaser
15	Dry Bearing	10 days	6	Purchaser
16	Roller Bearing	5 days	6	Purchaser
17	Limit Switch& Prox. Sensor	20 days	5	Purchaser
18	HP Hose	5 days	6	Purchaser
19	Adiko Clamp	5 days	6	Purchaser
20	Nozzle "1/4MEG-6530"	20 days	5	Purchaser
21	Fitting "EO"	3 days	6	Purchaser
22	Gasket 10" 150#	5 days	6	Purchaser
23	O-Ring for TWK	3 days	6	Purchaser
24	**International Purchasing**			
25	Geared Motor	45 days	4	Prin,Purchaser
26	HP Tube 32x8, 16x2	15 days	3	Purchaser
27	HP Ball Valve	20 days	4	Prin,Purchaser
28	Safety Falling Arrester	15 days	3	Purchaser
29	**Manufacturing**			
30	Parking Chamber Manufacturing	20 days	10	VS,Niyom
31	Guide Pipe Manufacturing	20 days	10	BEC,Niyom
32	Lance Manufacturing	20 days	26	VS,Niyom
33	Guide for Lance Manufacturing	20 days	10	VS,Niyom
34	U-Profile Manufacturing	7 days	6,11	Technician, Niyom
35	Part Machining by UFE	12 days	6	Technician, Niyom
36	Parts Maching by VS	20 days	6	VS,Niyom
37	Parts Maching by BEC	10 days	6	BEC,Niyom
38	**Assembly and Pressure Test**			
39	Spray Ring Assembly	2 days	21,26,30,36	Technician
40	Spray Ring Hydrostatic Test	1 day	39	Technician
41	Lance Hydrostatic Test	1 day	32	Technician
42	Parking Chamber Assembly	3 days	19,20,9,40	Technician
43	System Assembly	5 days	12,13,14,15,16,22,25,31,33,34,35,36,37,41,42,9	Technician, Niyom
44	**System Function Test& Final QC**	**1 day**	**43,17**	**Niyom,Samran,Technician**
45	**Packing**	**1 day**	**44,18,23,27,28**	**Packing Company**

4.3 Project Planning by Microsoft Project

Since there are no any formal plans of the manufacturing projects have been created, some projects may have only minutes of meeting, which things are needed to be done are only written in general prescribed form. In this section, this **studying project** will start using **Microsoft Project** program to help in planning/ scheduling, the tasks information from the previous section (Table 4.1) will be put in the Microsoft Project Program including task, duration, predecessor, and resource. During put in the data, there are also few additional factors needed to be assigned such as task priority, lag time, and unit of resource. The main outcome of this process will be the **Gantt Chart** for the project which is shown in Figure 4.2.

From the Gantt Chart, there are six main functions as already discussed needed to be done, and the total number of work packages or tasks (the lowest level from each function) are 38. The "**Task ID**", "**Task Name**", and "**Duration**" of each task is shown in the left section of the figure. The resources and their units are shown at the right side of each task. The bars represent the start date, finish date, and duration of each task, and also the critical paths/ tasks are shown.

From Figure 4.2, the following tasks are in critical paths:

(1) Initial Design

(2) Customer Approve

(3) Final Design

(4) Create Part List

(5) Limit Switch & Prox. Sensor Purchasing

(6) Nozzle "1/4MEG-6530" Purchasing

(7) Geared Motor Purchasing

(8) HP Tube 32x8t, 16x2t Purchasing

(9) Guide for Lance Manufacturing

(10) System Assembly

(11) System Function Test and Final QC

(12) Packing

The project has been planned to start on 3rd December 2001 and finish on 22 February 2002. The total duration is 58 days. And the Activity Schedule Table is also one of the outcomes from this process, is shown in Table 4.2. This table is useful as the activities in the project have been assigned to a difference team member. It is easier for each team member to refer to the Activity Schedule Table to check his activity's times than to search for it in the Gantt Chart. The resource leveling is also applied by the Microsoft program automatically according to the given unit of resource and priority of each activity. The example of resource usage chart for particular resource is shown in Figure 4.3.

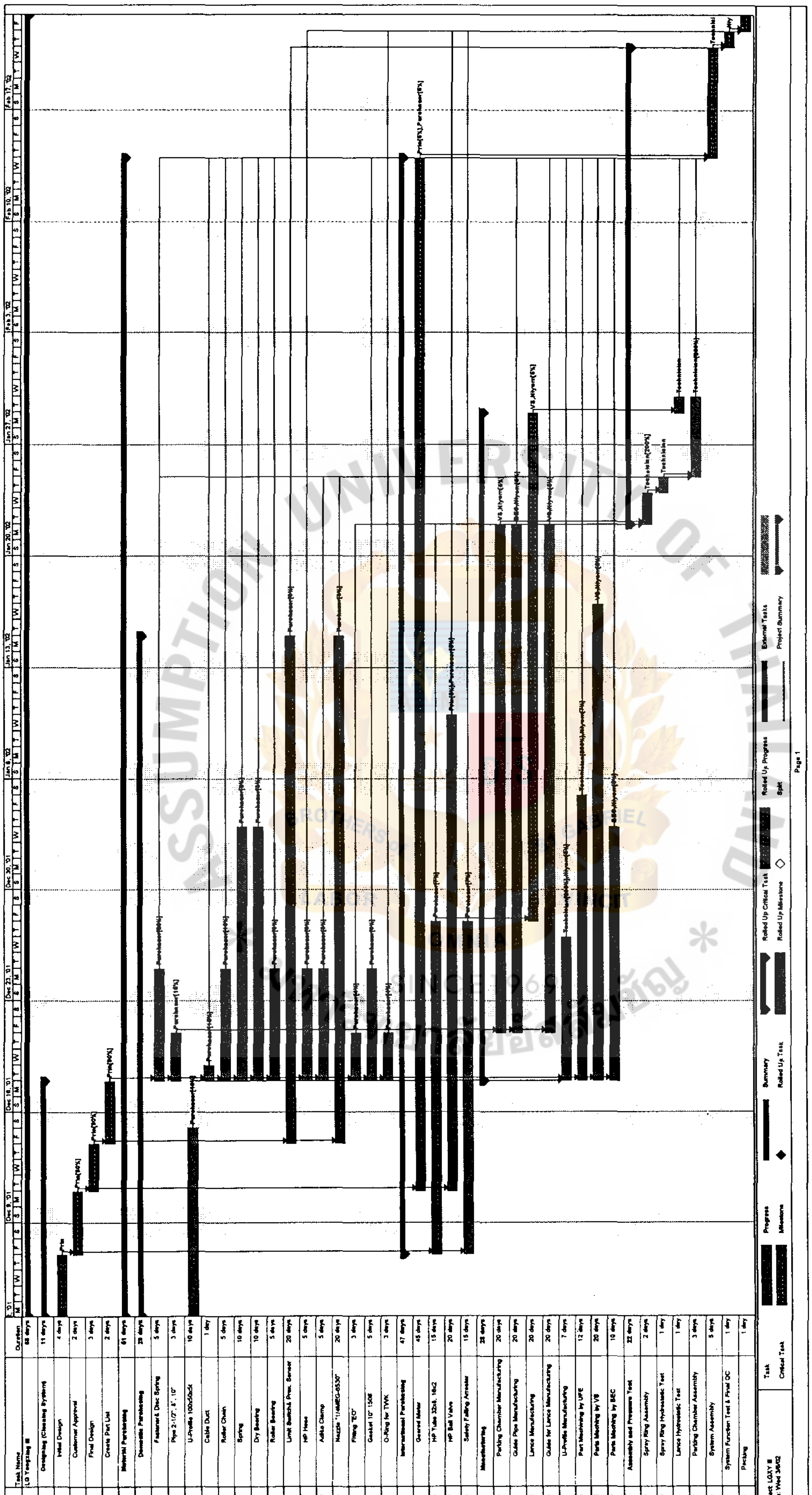

Figure 4.2. Gantt Chart of LG Yongxing Project.

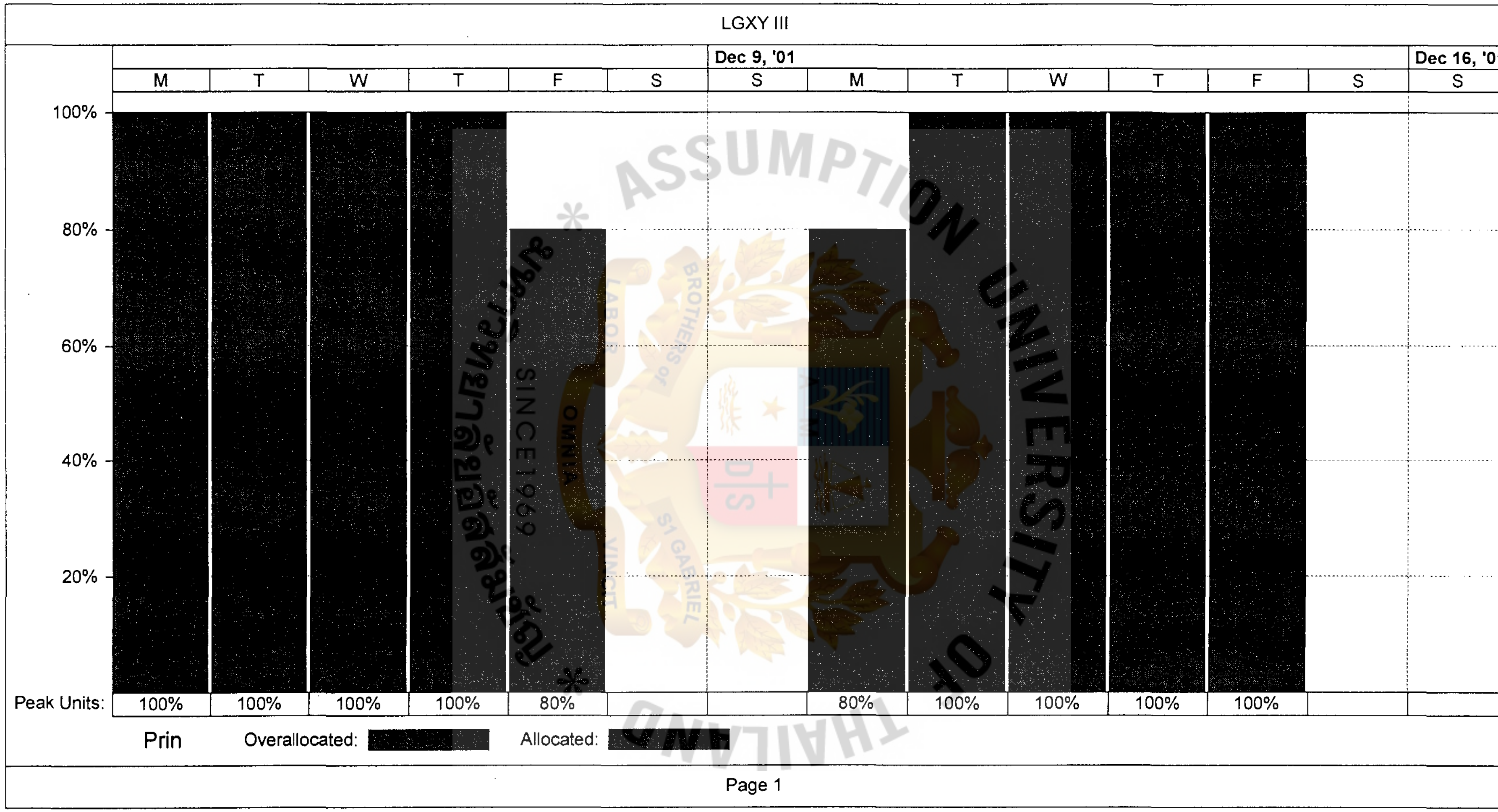

Figure 4.3. Example of Resource Usage Chart of LG Yongxing Project.

Table 4.2. The Project Activity Schedule Table.

Project Activity Schedule Table

Project No.: UFE2001-02-013

Updated Date: 12/3/01

Project Description: LG Yongxing III

ID	Name	Duration	Early Start	Late Start	Early Finish	Late Finish	Total Float	Free Float	Predecessor	Successor	Resource Names
1	**LG Yongxing III**	**58 days**	**12/3/01**	**12/3/01**	**2/22/02**	**2/22/02**	**0 days**	**0 days**			
2	**Designing (Cleaning System)**	**11 days**	**12/3/01**	**12/3/01**	**12/17/01**	**12/17/01**	**0 days**	**0 days**			
3	Initial Design	4 days	12/3/01	12/3/01	12/6/01	12/6/01	0 days	0 days		4,26,28	Prin
4	Customer Approval	2 days	12/7/01	12/7/01	12/10/01	12/10/01	0 days	0 days	3	5,25,27	Prin
5	Final Design	3 days	12/11/01	12/11/01	12/13/01	12/13/01	0 days	0 days	4	6,17,20	Prin
6	Create Part List	2 days	12/14/01	12/14/01	12/17/01	12/17/01	0 days	0 days	5	9,10,12,13,14,15,16,18,19,21,22,23,34,35,36,37	Prin
7	**Material Purchasing**	**51 days**	**12/3/01**	**12/7/01**	**2/13/02**	**2/13/02**	**0 days**	**0 days**			
8	**Domestic Purchasing**	**29 days**	**12/3/01**	**12/14/01**	**1/14/02**	**1/14/02**	**0 days**	**0 days**			
9	Fastener& Disc Spring	5 days	12/18/01	1/8/02	12/24/01	1/14/02	13 days	13 days	6	42,43	Purchaser
10	Pipe 2-1/2", 8", 10"	3 days	12/18/01	12/25/01	12/20/01	12/27/01	5 days	0 days	6	30,31,33	Purchaser
11	U-Profile 100x50x5t	10 days	12/3/01	12/28/01	12/14/01	1/14/02	19 days	1 day		34	Purchaser
12	Cable Duct	1 day	12/18/01	1/14/02	12/18/01	1/14/02	17 days	17 days	6	43	Purchaser
13	Roller Chain	5 days	12/18/01	1/8/02	12/24/01	1/14/02	13 days	13 days	6	43	Purchaser
14	Spring	10 days	12/18/01	12/28/01	1/2/02	1/14/02	8 days	8 days	6	43	Purchaser
15	Dry Bearing	10 days	12/18/01	12/28/01	1/2/02	1/14/02	8 days	8 days	6	43	Purchaser
16	Roller Bearing	5 days	12/18/01	1/8/02	12/24/01	1/14/02	13 days	13 days	6	43	Purchaser
17	Limit Switch& Prox. Sensor	20 days	12/14/01	12/14/01	1/14/02	1/14/02	0 days	0 days	5	44	Purchaser
18	HP Hose	5 days	12/18/01	1/8/02	12/24/01	1/14/02	13 days	13 days	6	45	Purchaser
19	Adiko Clamp	5 days	12/18/01	1/8/02	12/24/01	1/14/02	13 days	13 days	6	42	Purchaser

Table 4.2: The Project Activity Schedule Table. (Continued)

Project Activity Schedule Table

Project No.: UFE2001-02-013 Updated Date: 12/3/01

Project Description: LG Yongxing III

ID	Name	Duration	Early Start	Late Start	Early Finish	Late Finish	Total Float	Free Float	Predecessor	Successor	Resource Names
20	Nozzle "1/4MEG-6530"	20 days	12/14/01	12/14/01	1/14/02	1/14/02	0 days	0 days	5	42	Purchaser
21	Fitting "EO"	3 days	12/18/01	1/10/02	12/20/01	1/14/02	15 days	15 days	6	39	Purchaser
22	Gasket 10" 150#	5 days	12/18/01	1/8/02	12/24/01	1/14/02	13 days	13 days	6	43	Purchaser
23	O-Ring for TWK	3 days	12/18/01	1/10/02	12/20/01	1/14/02	15 days	15 days	6	45	Purchaser
24	**International Purchasing**	**47 days**	**12/7/01**	**12/7/01**	**2/13/02**	**2/13/02**	**0 days**	**0 days**			
25	Geared Motor	45 days	12/11/01	12/11/01	2/13/02	2/13/02	0 days	0 days	4	43	Prin,Purchaser
26	HP Tube 32x8, 16x2	15 days	12/7/01	12/7/01	12/27/01	12/27/01	0 days	0 days	3	32,39	Purchaser
27	HP Ball Valve	20 days	12/11/01	1/17/02	1/9/02	2/13/02	25 days	25 days	4	45	Prin,Purchaser
28	Safety Falling Arrester	15 days	12/7/01	1/24/02	12/27/01	2/13/02	32 days	32 days	3	45	Purchaser
29	**Manufacturing**	**28 days**	**12/18/01**	**12/28/01**	**1/28/02**	**1/28/02**	**0 days**	**0 days**			
30	Parking Chamber Manufacturing	20 days	12/21/01	12/28/01	1/21/02	1/28/02	5 days	0 days	10	39	VS,Niyom
31	Guide Pipe Manufacturing	20 days	12/21/01	12/28/01	1/21/02	1/28/02	5 days	5 days	10	43	BEC,Niyom
32	Lance Manufacturing	20 days	12/28/01	12/28/01	1/28/02	1/28/02	0 days	0 days	26	41	VS,Niyom
33	Guide for Lance Manufacturing	20 days	12/21/01	12/28/01	1/21/02	1/28/02	5 days	5 days	10	43	VS,Niyom
34	U-Profile Manufacturing	7 days	12/18/01	1/18/02	12/26/01	1/28/02	21 days	21 days	6,11	43	Technician, Niyom
35	Part Machining by UFE	12 days	12/18/01	1/11/02	1/4/02	1/28/02	16 days	16 days	6	43	Technician, Niyom
36	Parts Maching by VS	20 days	12/18/01	12/28/01	1/16/02	1/28/02	8 days	3 days	6	39,43	VS,Niyom
37	Parts Maching by BEC	10 days	12/18/01	1/15/02	1/2/02	1/28/02	18 days	18 days	6	43	BEC,Niyom
38	**Assembly and Pressure Test**	**22 days**	**1/22/02**	**2/6/02**	**2/20/02**	**2/20/02**	**0 days**	**0 days**			
39	Spray Ring Assembly	2 days	1/22/02	2/6/02	1/23/02	2/7/02	11 days	0 days	21,26,30,36	40	Technician

Table 4.2. The Project Activity Schedule Table. (Continued)

Project Activity Schedule Table

Project No.: UFE2001-02-013 Updated Date: 12/3/01

Project Description: LG Yongxing III

ID	Name	Duration	Early Start	Late Start	Early Finish	Late Finish	Total Float	Free Float	Predecessor	Successor	Resource Names
40	Spray Ring Hydrostatic Test	1 day	1/24/02	2/8/02	1/24/02	2/8/02	11 days	0 days	39	42	Technician
41	Lance Hydrostatic Test	1 day	1/29/02	2/13/02	1/29/02	2/13/02	11 days	11 days	32	43	Technician
42	Parking Chamber Assembly	3 days	1/25/02	2/11/02	1/29/02	2/13/02	11 days	11 days	19,20,9,40	43	Technician
43	System Assembly	5 days	2/14/02	2/14/02	2/20/02	2/20/02	0 days	0 days	12,13,14,15,16,22,25,31,33,34,35,36,37,41,42,9	44	Technician, Niyom
44	**System Function Test& Final QC**	**1 day**	**2/21/02**	**2/21/02**	**2/21/02**	**2/21/02**	**0 days**	**0 days**	**43,17**	**45**	**Niyom,Samran,Technician**
45	**Packing**	**1 day**	**2/22/02**	**2/22/02**	**2/22/02**	**2/22/02**	**0 days**	**0 days**	**44,18,23,27,28**		**Packing Company**

4.4 Development of Task Scope

Refer to the WBS, the Tasks Relationship Table, and the schedule from the previous section, the lowest level of each function is called work package or task. At the end of this section, the scope of some tasks those have grouped a numbers of identical/ similar parts or equipments from part lists together will be developed by the form of table which called "**Scope of Task Table**", such as Roller Bearing (Task ID: 16) and Part Machining by UFE (Task ID: 35). Some tasks that can be easily understood do not need to have the Scope of Task Table such as Initial Design (Task ID: 3), Create Part List (Task ID: 6). Tables 4.3 and 4.4 show the example of how to identify the scope of Task.

Table 4.3. The Example of Scope of Task Table.

Scope of Task Table					
Task ID:		16	Project ID:	UFE2001-02-013	
Task Name:		Roller Bearing	Project Name:	LG Yongxing Project	
Start Date:		18-Dec-01	Finish Date:	24-Dec-01	
Incharge Person:		Purchaser			
Scope of Task:		To purchase the Bearing as shown following			
Item	Drawing/ Part No	Description	Material	Quantity	Remarks
1		Y-Bearing Flange Unit SKF/ FYTB35 TF		12	
2		Y-Bearing Flange Unit SKF/ FYTB35 TF		12	
3		Ball Bearing SKF/ 6005-2Z		12	

Table 4.4. The Example of Scope of Task Table.

Scope of Task Table					
Task ID:		35	Project ID:	UFE2001-02-013	
Task Name:		Part Machining by UFE	Project Name:	LG Yongxing Project	
Start Date:		18-Dec-01	Finish Date:	4-Jan-02	
Incharge Person:		Niyom, Technician			
Scope of Task:		To manufacturer the following items.			
Item	Drawing/ Part No	Description	Material	Quantity	Remarks
1	E305945	Welding Connector 1-1/2" / M36x2	AISI 316Ti	18	
2	E305953	Switch Support 50x47.5x70	AISI 304	6	
3		Washer 45/30.2 x 2 t	Copper	24	
4	E305081	Shim 38x32x2	AISI 304	48	
5	C305955	Aluminium U Profile_Right 100x50x5x6965/ 6165	Aluminium	12	
6	E213105	Ring 60/25.3x10	Brass	12	
7	E213106	Ring 60/25.3x25	Brass	12	
8	E305127	Washer 60/40x3.5	AISI 304	24	
9	E213107	Ring 60/21x15	AISI 304	12	
10	E305708	Safety Lug 74/M20x37	AISI 304	6	
11	E305706	Lifting Lug 74x74x73.8	AISI 304	6	
12	E305707	Bush 37/28x30	Brass	6	
13	D305958	U-Profile 100x50x5tx950	Aluminium	12	

4.5 Development of Monitoring and Control System

As soon a project is launched, monitoring and control become the dominant function. Project control is important because unforeseen circumstances and imperfect planning can result in project progress deviating from the project plan. It is therefore important that the project must be monitored and controlled so as to correct these deviations. Without effective control, the project manager has merely little influence on the project.

The development of monitoring and control system for the Lance Cleaning System manufacturing project is aimed to establish the appropriate system, which can provide necessary information to control the project to be as close as possible to the project plan.

For achieving the above mention, the following steps will be implemented.

4.5.1 Progress Report Analysis

Currently, in every manufacturing project, there is no formal way to monitor the progress of the project. Most of progresses have been tracked or monitored by the way of verbal communication. However, at the manufacturing stage, there is only the progress report for monitoring the progress of manufacturing parts. This progress report has been updated by QC people on a weekly basis. The following is the current way of measure the progress of manufacturing parts:

Factors of measure the progress are divided into five progress factors and each progress factor has it own percentage of progress as shown in Table 4.5.

Table 4.5. Existing Progress Measurement Factor.

Item	Progress Factor	Percentage Complete
1	Material Available	0% or 10%
2	Lay out	0% or 5%
3	Machine/ Welding	0% or 60%
4	QC Check	0% or 15%
5	Final Surface/ Cleaning	0% or 10%
	Total Progress	0%, 10%, 15%, 75%,90%, or 100%

Each progress factor is measured step by step respectively starting from the first factor, which is **Material Available** until the last factor, which is **Final Surface/ Cleaning**. For each progress factor, in case that the quantity of the particular part is being measured the progress is higher than one, all pieces/ sets of the same parts need to be finished before each progress factor is evaluated as finish.

For example, if there are 4 pieces of Support Plate are being measured the progress, and the material is available, the progress will be evaluated 10% progress. If in the lay out step just finishes for 2 pieces and another 2 pieces are in progress, the progress will still be evaluated 10% (10% + 0%) progress. If the lay out step is finished, and the machine/ welding step is in progress, the progress will be evaluated 15% progress (10% + 5%). Finally, the progress of each particular part will be averaged (equal weight) as a total progress of the manufacturing stage. Table 4.6 shows how to evaluate the progress of the manufacturing stage.

Table 4.6. The Current Progress Evaluation.

Pos.	Drawing No.	Description	Qty	Mat. Available		Layout		MC/ Welding		QC Check		Final Surface		% Progress
				Qty	10%	Qty	5%	Qty	60%	Qty	15%	Qty	10%	
1	E305100	Support Plate	4	2	0%	0	0%	0	0%	0	0%	0	0%	0%
2	E305101	Flat Bar	8	8	10%	4	0%	0	0%	0	0%	0	0%	10%
3	D305102	Lance	2	2	10%	2	5%	2	60%	0	0%	0	0%	75%
4	C305103	Reel	2	2	10%	2	5%	2	60%	2	15%	0	0%	90%
5	E305104	Ring	12	12	10%	12	5%	12	60%	12	15%	12	10%	100%
Total Progress (Equal Weight Average)														55%

From above table, since there are five items (parts) in the above manufacturing task, and assume that the duration for manufacturing the first four positions is one day each, and for the last position is 6 days. By investigating, even if, the last position which consumes 6 days for manufacturing is almost finished, the result of the **total progress** is still only 55%. This may cause from each position is assigned the weight equally, no matter how long with its duration.

This **studying project** has proposed the appropriate way for evaluating the progress of each task on a weekly basis, and later on this information will be used for updating the progress in Microsoft Project program. So, later the progress evaluation for each task will be made in the same standard. The methods for evaluating the progress can be classified as follow:

(1) Manufacturing Progress Evaluation

This **studying project** has proposed to calculate the progress by assign the weight to each particular item before calculation the total progress. The weight will vary according to the duration of each item. This means that the more duration of each item consumes, the more influence it effects to the total progress.

From the above proposed, the detail of how to evaluate/ calculate the progress is shown in Table 4.7.

Table 4.7. The Propose Progress Evaluation for Manufacturing Task.

Item	Drawing No.	Description	Qty	Mat. Available		Layout		MC/ Welding		QC Check		Final Surface		% Progress	Weight	Weight Progress
				Qty	10%	Qty	5%	Qty	60%	Qty	15%	Qty	10%			
1	E305100	Support Plate	4	2	0%	0	0%	0	0%	0	0%	0	0%	0%	0.1	0%
2	E305101	Flat Bar	8	8	10%	4	0%	0	0%	0	0%	0	0%	10%	0.1	1%
3	D305102	Lance	2	2	10%	2	5%	2	60%	0	0%	0	0%	75%	0.1	8%
4	C305103	Reel	2	2	10%	2	5%	2	60%	2	15%	0	0%	90%	0.1	9%
5	E305104	Ring	12	12	10%	12	5%	12	60%	12	15%	12	10%	100%	0.6	60%
Total Progress (Unequal Weight Summary)																78%

From Table 4.7, by following the proposed evaluation system, the total progress is changed from 55% progress to 78% progress. This means that pos. no.4 (Drawing No.: E305104), which consumes 6 days of duration, has higher influence to the total progress comparing to the first four items.

(2) Initial Design Progress Evaluation

The Initial Design Task can be classified into few steps, which are Information Gathering, Concept Creation, and Approval Drawing Creation. From experience, in the Approval Drawing Creation step has consumed higher duration comparing with another two steps, this also means that the Approval Drawing Creation step has higher influence on the progress. Table 4.8 shows the recommended weight for evaluating the progress of each step.

Table 4.8. The Progress Evaluation for the Initial Design.

Item	Steps	Weight
1	Information Gatehring	0.1
2	Concept Design	0.2
3	Approval Drawing Creation	0.7
	Total Progress (Accumulate)	0%, 10%, 30%,up to 100%

Note that, the progress of the first two steps (Information Gathering and Concept Design) can be evaluated only 0% or 100% progress, but the progress for the last step (Approval Drawing Creation) can be evaluated starting from 0% up to 100% progress. And these progresses will be weighted by the recommend weight. So the total progress can be ranked from 0%, 10%, 30%, and up to 100% progress.

(3) Customer Approval Progress Evaluation

The Customer Approval Task can be classified into few steps, which are Send Approval Drawing to Customer, Concept Discussion, and Get Approval Drawing from Customer. By using the same principle with the previous section, the weight for evaluating the progress of each step is shown in Table 4.9. All steps can be evaluated 0% or 100% progress. And these progresses will be weighted by the recommended weight, so, the total progress can be ranked from 0%, 20%, 50%, and 100%

Table 4.9. The Progress Evaluation for the Customer Approval.

Item	Steps	Weight
1	Send App. Dwg. to Customer	0.2
2	Concept Discussion	0.3
3	Get App. Dwg. from Customer	0.5
	Total Progress (Accumulate)	0%, 20%, 50%, or 100%

(4) Final Design Progress Evaluation

The method of evaluating the progress of the Final Design is similar to the way, which is used for evaluating the progress of the manufacturing task shown in section (1). The difference is that, the Final Design Task has only one progress factor. Table 4.10 shows part lists to be designed for LG Yongxing Project and how to evaluate the total progress of the Final Design Task.

Table 4.10. The Progress Evaluation for the Final Design.

Item	Part List	Drawing	% progress (0%, 50%or 100%)	Weight	Weight Progress
1	Main Part List	A305941	100%	0.3	30%
2	Parking Chamber for 10" 150# Flange 97 EHY 19621-R1	C305189	100%	0.1	10%
3	Spray Ring Installation UFE2001-02-013-2	E211095	0%	0.05	0%
4	Guide Installation UFE2001-02-013-3	D305946	100%	0.2	20%
5	Motor Installation UFE2001-02-013-4	D305947	50%	0.2	10%
6	Chain Tensioner UFE2001-02-013-5	C305948	0%	0.05	0%
7	Chain Safety Device UFE2001-02-013-6	A305943	100%	0.05	5%
8	Guide for Pipe 2-1/2" UFE2000-02-021-6	D305692	0%	0.05	0%
Total Progress (Unequal Weight Summary)					75%

(5) Create Part List Progress Evaluation

The progress evaluation for the Create Part List Task is similar to the way, which is used for evaluating the progress of the Final Design Task shown in section (4). Since, to create the part lists, there is not much time consumption difference among all part lists. So, in the Create Part List Task all part lists are weighted equally. Table 4.11 shows part lists to be created for LG Yongxing Project and how to evaluate the total progress of the Create Part List Task.

Table 4.11. The Progress Evaluation for the Create Part List.

Item	Part List	Drawing	% progress (0%, 50%or 100%)	Weight	Weight Progress
1	Main Part List	A305941	100%	1/8	13%
2	Parking Chamber for 10" 150# Flange 97 EHY 19621-R1	C305189	50%	1/8	6%
3	Spray Ring Installation UFE2001-02-013-2	E211095	0%	1/8	0%
4	Guide Installation UFE2001-02-013-3	D305946	100%	1/8	13%
5	Motor Installation UFE2001-02-013-4	D305947	50%	1/8	6%
6	Chain Tensioner UFE2001-02-013-5	C305948	0%	1/8	0%
7	Chain Safety Device UFE2001-02-013-6	A305943	100%	1/8	13%
8	Guide for Pipe 2-1/2" UFE2000-02-021-6	D305692	100%	1/8	13%
Total Progress (Equal Weight Summary)					63%

(6) Material Purchasing Progress Evaluation

The Material Purchasing Task can be classified into few steps, which are Issue Enquiry, Get Quotation, Issue PO, Get Order Confirmation, Get Delivery Note, and Get Material. By using the same principle with section (3), each step is evaluated step by step from first step to last step and each step has different priority. The weight for evaluating the progress of each step is shown in Table 4.12.

Table 4.12. The Progress Evaluation for the Material Purchasing Task.

Item	Steps	Percentage Complete
1	Issue Enquiry	0.05
2	Get Quotation	0.05
3	Issue PO	0.2
4	Get Order Confirmation	0.1
5	Get Delivery Note/ Information	0.4
6	Get Material	0.2
Total Progress (Accumulate)		0%, 5%,10%, 30%, 40%, 80%,or 100%

(7) Assembly, Function Test, and Packing Progress Evaluation

The Assembly and Function Test stage can be divided into five tasks, and each task consumes not many of durations. It is also similar to the last two tasks, which are System Function Test & Final QC and Packing. So, the progress can only be evaluated as not-finish or finish (0% or 100% progress).

4.5.2 Development of Progress Report Table

Almost this type of projects; Lance Cleaning System have been taken about few months for manufacturing. It is not necessary to monitor the progress everyday, since most activities take few days or maybe few weeks until finish. And also this **studying project** recommend to evaluate the progress on a weekly basis. To evaluate the progress of each particular task effectively, the proposed "Progress Report Application" on the previous section (4.5.1) will be used as a guideline for designing the appropriate tables for monitoring the progress of each type of task. These tables are called "Progress Report Table", and all of them are designed to be commonly used for each type of task of the project such as Designing, Purchasing, Manufacturing, and etc. Table 4.13, 4.14, and 4.15 show the example of the recommended Progress Report Table for design task, purchasing task, and manufacturing task respectively.

Table 4.13. The Example of Progress Report Table for Design Task.

Progress Report Table (Design Task)					
Task ID:		3	Project ID:	UFE2001-02-013	
Task Name:		Initial Design	Project Name:	LG Yongxing Project	
Start Date:		3-Dec-01	Finish Date:	6-Dec-01	
Actual Start:			Actual Finish:		
Updated Date:			Updated by:		
Incharge Person:		Prin			
Scope of Task:		To preliminary design the Approval Drawings for Lance Cleaning System.			
Item	Drawing/ Part No	Description	% Progress 0% or 100%	Weight	Weight Progress
1		Information Gathering		0.10	
2		Concept Design		0.20	
3		Approval Drawings Creation (Progress evaluated from 0% up to 100%)		0.70	
Total Progress (Un-Equal Weight Summary)					

Table 4.14. The Example of Progress Report Table for Purchasing Task.

Progress Report Table (Purchasing Task)					
Task ID:		25	Project ID:	UFE2001-02-013	
Task Name:		Geared Motor	Project Name:	LG Yongxing Project	
Start Date:		11-Dec-01	Finish Date:	13-Dec-01	
Actual Start:			Actual Finish:		
Updated Date:			Updated by:		
Incharge Person:		Purchaser			
Scope of Task:		To purchase material according its scope.			
Item	Drawing/ Part No	Description	% Progress 0% or 100%	Weight	Weight Progress
1		Issue Enquiry		0.05	
2		Get Quotation		0.05	
3		Issue PO		0.20	
4		Get Order Confirmation		0.10	
5		Get Delivery Note/ Information		0.40	
6		Get Material		0.20	
Total Progress (Un-Equal Weight Summary)					

Table 4.15. The Example of Progress Report Table for Manufacturing Task.

Progress Report Table (Manufacturing Task)

Task ID:	30	Project ID:	UFE2001-02-013
Task Name:	Parking Chamber Manufacturing	Project Name:	LG Yongxing Project
Start Date:	26-Dec-01	Finish Date:	24-Jan-02
Actual Start:		Actual Finish:	
Updated Date:		Updated by:	
Incharge Person:	Niyom, VS		
Scope of Task:	To manufacture Parking Chamber and Accessories as follows:		

Item	Drawing/ Part No	Description	Material	Qty	Mat. Available		Layout		MC/ Welding		QC Check		Final Surface		% Progress	Weight	Weight Progress
					Qty	10%	Qty	5%	Qty	60%	Qty	15%	Qty	10%			
1	C305064	Chamber od406x700	AISI 304	6												0.65	
2	C305190	Cover 495x308x34	AISI 304	6												0.25	
3	E210860	Flat Bar 50x20x35	AISI 304	24												0.05	
4	E208889	Flat Bar 20x10x50	AISI 304	24												0.05	
Total Progress (Un-Equal Weight Summary)																	

4.5.3 Monitoring Project Progress and Control

As the project is performed, every attempt should be made to stick to the plan. The most important guiding aspect of the plan is the Gantt Chart and the project activity schedule table which are already shown in section 4.3. As the project progresses, the progress report tables of each task must be weekly recorded by the persons who are responsible for those tasks. After getting all necessary information, the progress report tables and the Gantt Chart in the Microsoft Project program will be updated accordingly. Finally, project summary report will be filled out and prepared for presentation to every party concerned with the project. The recommended project summary report contains of the summary information about the project such as duration, start date, finish date, work hours, cost, task status, earned value, percent complete and also includes the conclusion part at the end of the report. The updated Gantt chart and updated Project Activity Schedule Table should be attached with the project summary report.

At this stage, all possible deviations can be captured by comparing the information from the progress report tables and from the Gantt chart to the original plan (baseline plan). All deviations must be assessed by the persons who responsible for the project. If deviations cannot be accepted, all necessary ways to avoid deviations will be implemented such as adding the resource or working overtime to finish tasks with still remain the limited duration. The plan/ schedule will be revised accordingly. This revised plan will be used instead of the original plan for project monitoring and control. Table 9.16 shows the example of the recommended project summary report.

Table 4.16. The Project Summary Report.

Project Summary Report			
Project No.:			
Project Name:			
Date Reported:			
Week Reported:			
Reported by:			

Project Information Summary			
Description	Baseline Plan	Scheduled Plan	Up to Date
Duration (day):			
Start Date			
Finish Date			
Work Hour (hrs)			
Cost (Baht)			

Task Status Summary	
Task Status	Tasks
Tasks not yet completed	
Tasks in progress	
Tasks completed	
Total Tasks	

Earned Value Summary	
Earned Value	Baht
BCWS	
BCWP	
ACWP	
SV = BCWP-BCWS	
CV = BCWP-ACWP	

Percent Complete Summary	
Description	Percent Complete
By Duration	
By Work Hour	

Conclusion

V. SYSTEM EVALUATION

The information from the LG Yongxing project is used as a guideline for developing the system for performing the manufacturing project, which can be used for the similar type of project in the future. It will guide the way for working with the manufacturing project starting from planning, monitoring, and control to meet the objectives of the manufacturing project, which are performance, scope, cost or budget, and time or schedule.

Currently, the way to work with the duration of the project is just to get the answer from the management or maybe from the meeting room. After getting the answer, the involved persons try to finish their tasks within the given timeframe or as soon as possible.

The results of this studying project have directly benefited the lance cleaning system manufacturing. The project can be planned, monitored and controlled systematically. Scope, cost or budget, and time or schedule for each tasks and the whole project can be precisely estimated, monitored and controlled.

The developed system is evaluated by basing the expected benefits, which should be gained from each application of the developed system.

With formulating and documenting the procedure of performing the manufacturing project, this can make all involved persons having the same understanding about how to perform the manufacturing project and also can increase the overall **project performance** as well. The project performance is one of the objectives of this studying project.

With formulating the work breakdown structure, the project scope is broken down into the lowest levels of each particular function, which are work packages or tasks. After getting the tasks from the work breakdown structure, the relationship among tasks, duration, resources, and precedence relation are created in tabular form, which is call task relationship table. Effective use of the work breakdown structure, task relationship table, and scope of task tables will graphically outline the scope of the project and also the scope of each task. Therefore the **project scope and cost** can be defined quickly and accurately, both of scope and cost are also the objectives of this studying project.

The information from the work breakdown structure and task relationship table is used for planning by putting this information into the Microsoft Project program and the outcomes of this process are the Gantt chart, the project activity schedule table and many of valuable reports of the Microsoft Project program. Later, the scope of task tables are developed which the important information about of task is shown such as scope of task's description, quantity, start date, finish date, and resources. The project can be started implementation with the above mention information. With good planning, therefore, the **project time** can be precisely estimated and controlled, as the time or schedule is also one of the objectives of this studying project.

During implementation, to ensure that the monitoring and control process will effectively work, the progress evaluation concepts for each type of task are developed in section 4.5.1. This information is used as a guideline for developing the progress report tables for each type of task such as the Progress Report Table (Design Task), the Progress Report Table (Purchasing Task), and Progress Report Table (Manufacturing Task) are shown in Tables 4.13, 4.14, and 4.15 respectively. These tables will be used for monitoring and recording the progress for each task. The persons who are responsible for the tasks have to record the progress in the progress report table and send to the person who is responsible for updating the plan, schedule and the project summary report.

In section 4.6, the project summary report is developed as shown in Table 4.16. This report, Gantt Chart, and project activity schedule table will be updated by using the information from the Microsoft Project program and will be presented to everyone who involves with the project. These reports consist of the necessary information for assessing the status of the manufacturing project.

Finally, the cycle of planning-monitoring-control is a continuous process. If this process is appropriately and continuously implemented as per the developed system, this studying project can be expected to meet all of its objectives.

VI. CONCLUSIONS AND RECOMMENDATIONS

This chapter concludes the project planning and control system, which has been developed for the lance cleaning system manufacturing. Then the system is evaluated based on the expected objectives which should be gained from all applications which have been developed from the traditional system. The recommendations for further improvements of the system are also proposed.

6.1 Conclusions

The main proposes of this project are to develop the appropriate system for performing the manufacturing project (lance cleaning system project), and to ensure that the manufacturing project will meet its objectives which comprise of performance, scope, cost or budget, and time or schedule.

The developed system in this project is based on the project management fundamental, many tools have been studied and applied within this studying project. This studying project emphasizes on studying the process of planning and controlling by using the Microsoft Project program for generating all necessary information and charts. The way for developing the system for performing the manufacturing project is as follow:

This studying project has started at investigating the existing system of performing the manufacturing project (lance cleaning system) and the problems that the company always encounters are listed. From the list of problems, what this studying project has concluded is that the company always lacks of the systematic planning and control system. This information later on is used for formulating of which parts of project management should be taken into consideration and applied.

Step 2, the procedure of performing the manufacturing project is formulated and documented in the form that all involved parties can easily understand. This procedure has to be presented or explained to all involved parties for the same understanding. Following this procedure effectively can increase the overall performance of performing the manufacturing project.

Step 3, all necessary information has been gathered as much as possible from both project kick off meeting or the order confirmation. The project scope is broken down in to work packages or tasks by using the work breakdown structure. Later the task relation table can be created. This table shows the relationship among tasks, duration, resources, and predecessor relation.

Step 4, the planning can be done by putting all necessary information into the Microsoft Project program, the outcomes of this step are the project Gantt chart, the project activity schedule table, and many of valuable reports such as the resource chart. The resource leveling also automatically applied in the Microsoft Project program for allocating the units of the resources appropriately.

Step 5, the scope of task tables of each task are developed to ensure that the scope of the manufacturing project is not overlooked. This scope also will be used for evaluating the progress of each task in later step. Up to now the manufacturing can be started the implementation.

Step 4, to ensure that the monitoring system will work effectively, the progress evaluation systems are studied, and the appropriate progress report tables for each particular function are developed. This table will be used for evaluating and recording the progress of each task on a weekly basis by the person who is responsible for the task. This progress report will be sent to person who will update in the Microsoft Project program, prepare the project summary report for presenting to management and all involved parties.

Final step, the deviations will be assessed, if deviations cannot be accepted, all necessary ways to avoid deviations will be implemented such as adding the resource or working overtime to finish tasks while still remain the limited duration. This means that the project Gantt chart, the project activity schedule, and other reports will be revised accordingly.

The cycle of planning-monitoring-control is a continuous process, if this process is appropriately and continuously implemented, the objectives of the manufacturing project and also this studying project can be achieved.

6.2 Recommendations

Planning is the most important process in performing the manufacturing project, it is the first process in every project. Had good plan been designed, there would have been easy to the next process and problems would have been decreased and been able to control.

Before stating to plan the project, all necessary information must be gathered. Since there are many times of encounter with the same problems such as scope is not clear, delivery time is not specified, and cost is not given, the company should find out the way for communicating, so that the right information can be given to the right persons within the right time.

Monitoring is also one of the most important processes in performing the manufacturing project, so, the appropriate way for evaluating the progress of the project must be addressed.

Controlling is also one of the most important processes in manufacturing project, the project status should be periodically reviewed by all involved persons and especially by the management. The project meeting should be periodically held for presenting the status of the manufacturing project and ensuring all problems are not overlooks. And all deviations must be assessed, and the suitable ways must be addressed within the right time.

The planning-monitoring-controlling is a continuous process. To ensure that this process will be used effectively, therefore the procedure for performing the manufacturing project must be always implemented and improved continuously.

There were lots of problems in the manufacturing projects. Main objective of this studying project is to provide the necessary and significant way for achieving the objectives of the manufacturing project. And this studying project might be a useful reference for any manufacturing projects in the future.

This studying project developed the system for performing the manufacturing project (lance cleaning system-made to order manufacturing) without implementation with the existing manufacturing project, and this system can be adapted for using with any types of projects. Therefore, it is recommended to further develop or improve the similar systems for implementing with any kinds of the manufacturing project.

BIBLIOGRAPHY

English References

1. Buay, Seah Seow and Ong Chin Tiong. Project Management: How to Plan, Control and Manage Project. Singapore: Prentice Hall, 2001.

2. Burke, Rory. Project Management: Planning and Control. Chichester: John Wiley & Sons, 1997.

3. Devaux, Stephen A. Total Project Control: A Manager's Guide to Integrated Project Planning, Measuring, and Tracking. NY: John Wiley & Sons, 1999.

4. Lewis, James P. Mastering Project Management: Applying Advanced Concepts of Systems Thinking Control and Evaluation Resource Allocation. NY: McGraw Hill, 1998.

Thai Reference

1. พวงแก้ว แสงตระกูล และ จีรบูรณ์ นิจสุชัด. บริหารงานสู่ความสำเร็จด้วย Microsoft Project 98. กรุงเทพฯ: บริษัท ซัคเซส มีเดีย จำกัด, 2541.