Plant Maintenance Information System in BTS Project

By

Mr. Kunnawut Yodmalai

A Final Report of the Three - Credit Course
CS 6998 System Development Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
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Project Title	Plant Maintenance Information System
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The Graduate School of Assumption University has approved this final report of three-credit course, **CS 6998** System Development Project, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer Information Systems.

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ABSTRACT

This project presents the object-oriented analysis and design of plant maintenance information system for BTS (Bangkok Transit System) project. The scope of the project covers plant maintenance system which includes corrective maintenance and preventive maintenance.

Since BTS project is a green field project, the study of the project begins with the requirement analysis and business processes design of the new system by using Unified Modeling Language (UML) as the standard notations and using the method from IBM's Object Oriented Technology Center OOTC) as the method for developing information system. The system is developed based on the client-server application, GUI technology.

All the phases of the development of this information system is done in object oriented techniques which are flexible to change, have well-defined architecture and provide the opportunity to create and implement reusable components that will probably be used in the other software development projects.

ACKNOWLEDGEMENTS

The writer would like to thank Asst.Prof.Dr. Vichit Avatchanakorn for all of his comments and suggestions. The writer would also like to thank all project committee members of the Graduate of Computer Information Systems at Assumption University for their advice and all of his colleague at Siemens System Limited who designed and revised the business processes of this project.

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I. INTRODUCTION

1.1 Background of the Project

The Unified Modeling Language (UML) is a standard notation for modeling object oriented based information systems. It has the formal support from the Object Management Group (OMG) and its various member companies, which are well known in OO software business.

It's important to realize that the UML is only a standard notation. Essentially it defines a number of diagrams that you can draw to describe a system, and what this diagram means. It does not describe the processes you use to build software. Such process description or method would include a list of tasks that need to be done, what order they should be done in, the deliverables produced, the kinds of skill required for each task, etc. The traditional formal methodology consists of both notation and method.

The idea is that by standardizing on the notation, software developers can better communicate with each other within the team, providing all the deliverables in a method use the UML. However, different groups are free to use whichever method they want to use to actually go about building the software. Several methods have been proposed that use the UML. Rational has published its Objectory method, HP has the Fusion method. This project is based on the technique from IBM's Object-Oriented Technology Center (OOTC) as it is printed in the book "Developing Object-Oriented Software-An Experience – Based Approach".

The BTS project is the project for mass transportation in Bangkok, also called Thanayong Elevated train. According to the Maintenance Agreement between Bangkok Mass Transit System Corporation Limited and Siemens System Limited (Maintenance Contractor, MC), the MC has to make sure of the contractual availability of the E&M

system (Electrical and Mechanical Engineering). In order to support the MC's organization and to fulfil the contractual demands, the MC will install a Computerized Maintenance Management System (CMMS). This project is the example of some part of CMMS regarding plant maintenance functions with which object oriented analysis and design are used as the frame work to develop such part of CMMS.

1.2 Objectives of the Project

The objectives of this project are as follows:

(1) To understand the businesses and functions of corrective and preventive maintenance in plant maintenance domain.

(2) To use the object oriented technique for requirement analysis in plant maintenance information system.

(3) To use the object oriented technique for designing plant maintenance information system.

(4) To use the standard notation (UML notation) for analysis and design object oriented information system.

(5) To apply and use object oriented analysis and design CASE tool.

1.3 Scope of the Project

This project covers plant maintenance part of BTS project, which is directly concerned with preventive maintenance and corrective maintenance. Preventive maintenance includes the following topics:

(1) Maintenance task list

(2) Maintenance strategy

(3) Maintenance item

(4) Maintenance order.

Corrective maintenance includes the following topics:

(1) Maintenance notification

(2) Maintenance work center

(3) Maintenance order.

The method of analysis and design will be based on IBM OOTC Approach and use Rational Rose from Rational Software as CASE tool for creating UML notation. There are four deliverables in UML diagrams created by using Rational Rose 98:

(1) Use Cases Diagram

(2) Class Diagram

(3) Sequence Diagram

(4) State Transition Diagram.

This project consists of the analysis and design phase in the software development project. However, the programmer can make use of this project's deliverables as the reference tools to create and develop new business functions module in plant maintenance information system, especially in object oriented software development approach.

II. THE EXISTING SYSTEM

2.1 Background of the Organization

Since BTS project is a "green field" project, there is no "As-is" organization structure. It is the job of business process designer to design the organization structure of BTS project with the help of domain experts from Siemens System Limited. The result of the organization structure of BTS project is based on the organization structure of maintenance project done by Siemens System Limited around the world as shown in Figure 2.1. In Figure 2.1, there are five departments under Siemens system Limited

(1) Maintenance department

Is responsible for all of the maintenance jobs according to the agreement between Siemens System Limited and BTSC. Since the plant maintenance information system focuses on the maintenance function, the organization structure of maintenance department is described in detail in Figure 2.2 and in Section 2.2 "Maintenance Department Structure".

(2) Financial department

Is responsible for payroll system, account receivable, accounting payable, etc.

(3) Commercial department

Is responsible for reviewing and checking all of the jobs done by all of the sections in maintenance department according to the contract made between Siemens System Limited and BTSC company.

(4) Administration department

Is responsible for providing public information, personal recruitment, etc.

(5) Procurement department

Is responsible for spare part management, purchasing spare part, service contract, etc.

2.2 Maintenance Department Organization Structure

As described in Section 2.1, plant maintenance information system project focuses on the maintenance function. This section describes the maintenance department organization in detail. The maintenance department organization structure is shown in Figure 2.2.

Maintenance department consists of five departments:

(1) Permanent way & facilities section (see details on job description on 3.1.2 maintenance work center)

(2) Electronic section (see details on job description on 3.1.2 maintenance work center)

(3) Rolling stock section (see details on job description on 3.1.2 maintenance work center)

(4) Administration section (see details on job description on 3.1.2 maintenance work center)

(5) Maintenance center (see details on job description on 3.1.2 maintenance work center)

2.3 Existing Business Function

Since BTS project is a "green field" project, there is no "As-is" business process. Even though there are many maintenance projects done by Siemens System Limeted, business processes vary project by project. So, it is the job of business process designer to design business processes for BTS project with the help from domain experts from Siemens System Limited. However, the new business processes must conform to the

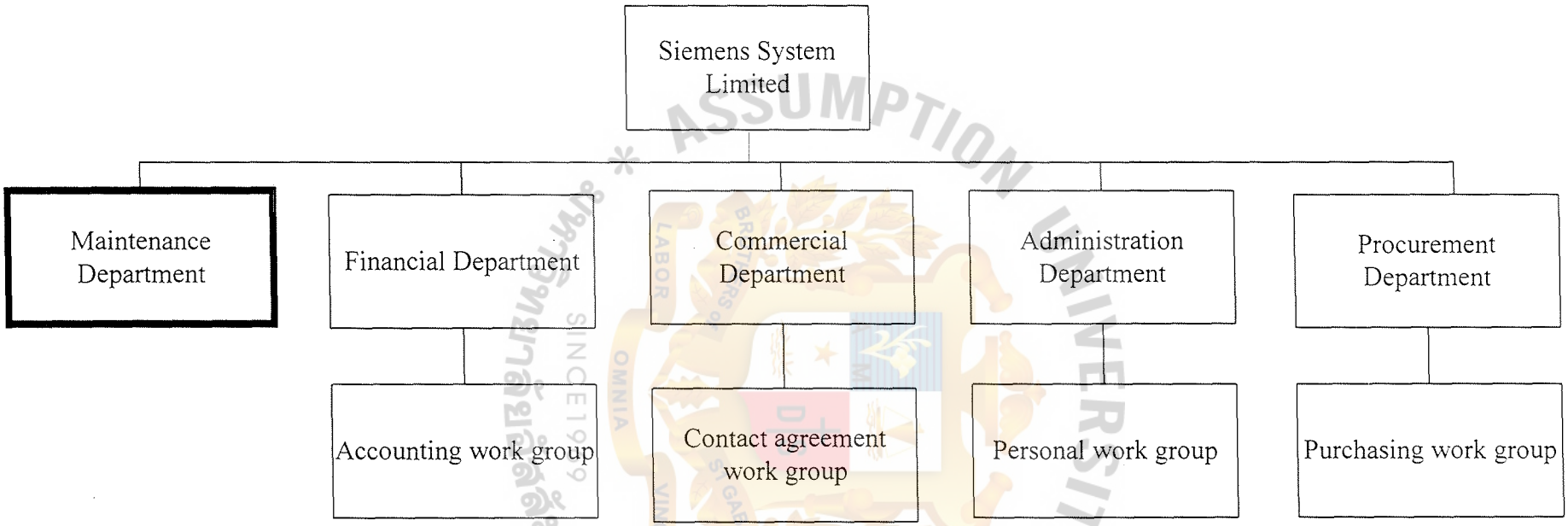

Figure 2.1. Organization Structure of BTS Project.

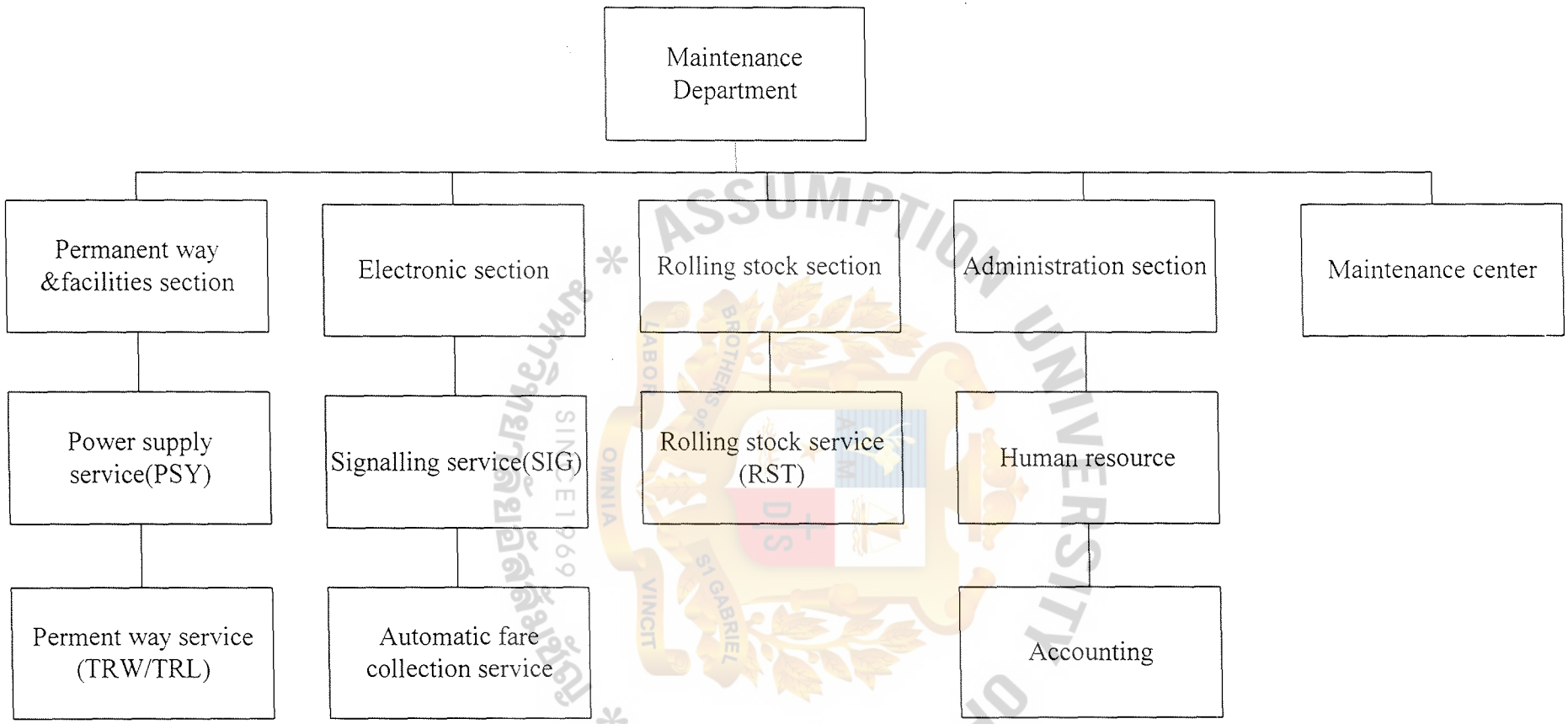

Figure 2.2. Organization Structure of Maintenance Department.

maintenance philosophy of Siemens System Limited worldwide and the contract agreement with BTSC company. The result of both outlines above are summarized into the "Objectives of Plant Maintenance Functions and Processes" in Section 2.4

2.4 Objectives of Plant Maintenance Functions and Processes

The main objective of the maintenance processes is to ensure the train operation according to the operating philosophy from Siemens System Limited. In general, safety of passengers is the first priority of this philosophy. In addition, the train service will be planned and adjusted to match actual demand. This philosophy in turn defines principles of maintenance system which include:

(1) Flexibility of maintenance operations and staffing arrangements. Planing and adjusting to match operation demand.

(2) High availability rate, fault tolerance level and safety requirement.

(3) Priority to provide maintenance service during normal and abnormal condition with minimum disruption to the passenger service.

(4) Cost effective maintenance operation.

To achieve these principles, the plant maintenance information system should provide the planner with all-necessary functions and reports. The planning and monitoring functions should give the real time information as well as history records to the planner. The planner can analyse the cause of failure; overall availability rate of each system and maintenance costs. Figure 2.3 shows the operation driven maintenance system that is used by Siemens worldwide, it starts from the operation requirement transforms into maintenance philosophy and apply to maintenance strategy and maintenance plan to fulfill the obligation of the maintenance agreement for each project.

The new function and the business processes of BTS project also conform to the Siemens System Limited 's maintenance philosophy which can be described below:

(1) Maintenance planning includes preventive maintenance, maintenance task list, etc. See more details in Section 3.1.3 Maintenance task list and 3.1.4 Maintenance planning.

(2) Capacity planning includes capacity of resources, for example workers and tools, etc. See more details in Section 3.1.5 Capacity planning.

(3) Maintenance processing includes corrective maintenance processing, notification processing. See more details in Section 3.1.7 Maintenance processing.

The result of business processes design and the details in business function is in part III "the proposed system" beginning at Section 3.1.3.

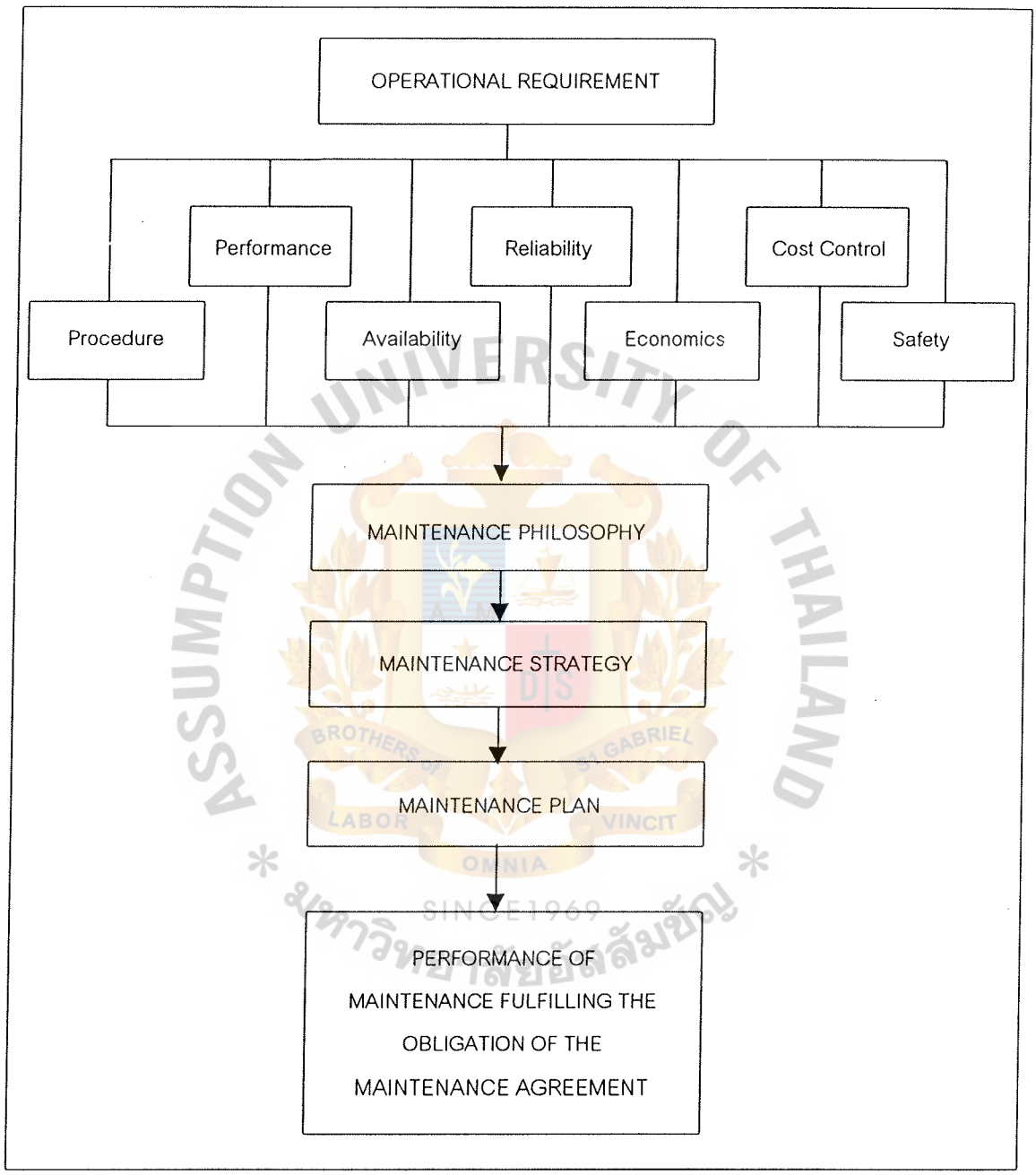

Figure 2.3. The Operation Driven Maintenance System.

III. THE PROPOSED SYSTEM

During the requirement analysis phase, the business processes and functions are investigated and designed by business process designer and domain expert from Siemens System Limited. The results are shown in section 3.1 Functional and Business Process Requirements.

3.1 Functional and Business Process Designed

3.1.1 Maintenance Structure

Maintenance department is responsible for maintaining all equipments and functions mentioned in the maintenance agreement. It is important for the department to make a structure of all maintenance equipment. Structuring will:

(1) Reduce the time required to manage the objects

(2) Simplify maintenance processing

(3) Reduce data entry time in maintenance processing

(4) Ensure the evaluation of maintenance data will be specific, thorough and quick

The department is responsible to maintain seven functions as follows:

Rolling Stock

Comprises of all trains, train equipment and train components

SIG System (Signaling system)

All the following SIG equipment and accessories are subject to maintenance under the agreement:

(1) CTC (Central Traffic Control) equipment at the Operations Control Centre (OCC)

(2) Signaling interlocking installations at the OCC and station equipment rooms

(3) Cables for transmission of signaling information

(4) Trackside signaling equipment (e.g. track circuits, signals and position indicators, point machines etc.)

(5) Signaling equipment in the Depot (e.g. track circuits, point machines signals and indicators)

(6) Trainborne and trackside Automatic Train Protection (ATP) and Automatic Train Operation (ATO)

SCADA System (Supervisory control architecture data acquisition system)

TEL System (Telecommunication system)

The TEL system equipment and installations as listed below are subject to maintenance under the maintenance agreement.

(1) OTN System (Open transport network system)

(2) Telephone System

(3) Radio System

(4) Public Address (PA) System

(5) Clock System

AFC System (Automatic fare collection system)

(1) AFC Central Computer System

(2) Station Computer System

(3) Ticket Issuing Machines

(4) Automatic Gates

(5) Analyser / Dispensers

Power Supply system (PSY)

Covers all PSY equipment and installations for Bulk Substation's, Station, Substation and Traction Substation.

TRW (Track work) and TRL (3rd Rail) System

Cover all functions, locations and installations of the TRW system (e.g. normal track, pocket track and point's) and 3rd rail (e.g. conductor rail and stinger system).

The Building Engineering Services (BES)

Maintenance tasks comprise of the contracted obligations and items like fire detection, fire alarm, fire fighting, escalators, elevators, low voltage, lighting of the administration building, depot, stations, ventilation, air conditioning, emergency power supply (diesel generator) and fresh water supply pump's.

Workshop Equipment

All workshop area and equipment in the depot (e.g. cranes, lifting plant, and heavy machines including service vehicle) are subject to maintenance under the agreement.

3.1.2 Maintenance Work Centre

Work centres in the maintenance department are the organisational units where the work steps are carried out. The work centres define where and by whom the operations are to be carried out. According to the organisation structure from Siemens, maintenance department has 16 organisational units (6 sections and 10 service units) However, there are 5 sections and 7 service units that actually perform maintenance and maintenance administration tasks. The maintenance sections and maintenance service units are:

Rolling Stock Section:

Jobs of assistant manager of rolling stock are carried out within this unit. The main responsibility is co-ordination and supervision of activities that are allocated to Rolling Stock Service which is responsible for scheduling, executing, and monitoring

maintenance jobs for rolling stock The supervisor in this unit has to manage and supervise staffs employed within its unit

Maintenance Centre Section:

The technical evaluation, notification and classification are carried out in this work unit. These tasks include malfunction and notification analyses, distribution of notifications to responsible work units and evaluation of reports received from operation. The maintenance centre is also responsible for the clarification of all interfaces between operation and maintenance.

Electronic Section

This unit carries out co-ordination and supervision of activities for the services allocated to Signaling Service, Automatic Fare Collection Service and Communication Service.

(1) Signaling Service (SIG)

Maintenance jobs related to SIG installations including software are managed in this work unit.

(2) Automatic Fare Collection Service (AFC)

This unit is responsible for the technical correction of the AFC system.

Communication Service (SCADA & TEL)

Maintenance jobs related to the TEL and SCADA system including software are managed in this work unit.

Permanent Way & Facility Section

This unit carries out co-ordination and supervision of activities for the services allocated to BES, Permanent Way Service, and Power Supply Service.

(1) Building Engineering Service (BES)

This unit is responsible for the technically correct condition of the system's mechanical and electrical installations in the buildings (For example, escalators, elevator, ventilation and air conditioning system).

(3) Permanent Way Service (TRW/TRL)

This unit is responsible for the technically correct condition of the TRW and TRL system.

(4) Power Supply Service (PSY)

This unit is responsible for the technical correction of PSY system.

Administration Section

Human resource Responsible for the recruitment of the staffs in order to support the maintenance department 's operation.

3.1.3 Maintenance Task List

Maintenance task lists describe a sequence of individual maintenance tasks that must be repeatedly performed within the maintenance department. Preventive maintenance orders should have a pre-defined task list. Equipment suppliers should provide task list information to the maintenance department. This information contains:

(1) Work steps

(2) Tools required

(3) Material required

(4) Duration of work

(5) Capacity and level of skill required

(6) Documentation required

For all equipment and material, the maintenance department can correct or modify task lists provided by the suppliers as appropriate. The suppliers should supervise all

changes. For corrective maintenance, some tasks list can be pre-defined. The maintenance department is responsible for maintaining those corrective maintenance task lists.

3.1.4 Maintenance Planing

Preventive Maintenance Planing

The maintenance department is responsible for planning maintenance tasks to ensure the availability of the BTS project. The availability rate should comply with the maintenance agreement between Siemens System Limited and Bangkok Mass Transit Corporation Limited. Cost of preventive and corrective maintenance is taken in to account for preventive maintenance planning.

The equipment suppliers should provide all maintenance plans. The maintenance department will adjust or change the plan according to failure history and changing of capacities. Figure 3.1 displays the maintenance planning cycle, it starts from defining maintenance strategy and creating the maintenance planning, which includes the instruction from suppliers or the maintenance manual from Siemens, and scheduling the maintenance plan to generate maintenance order.

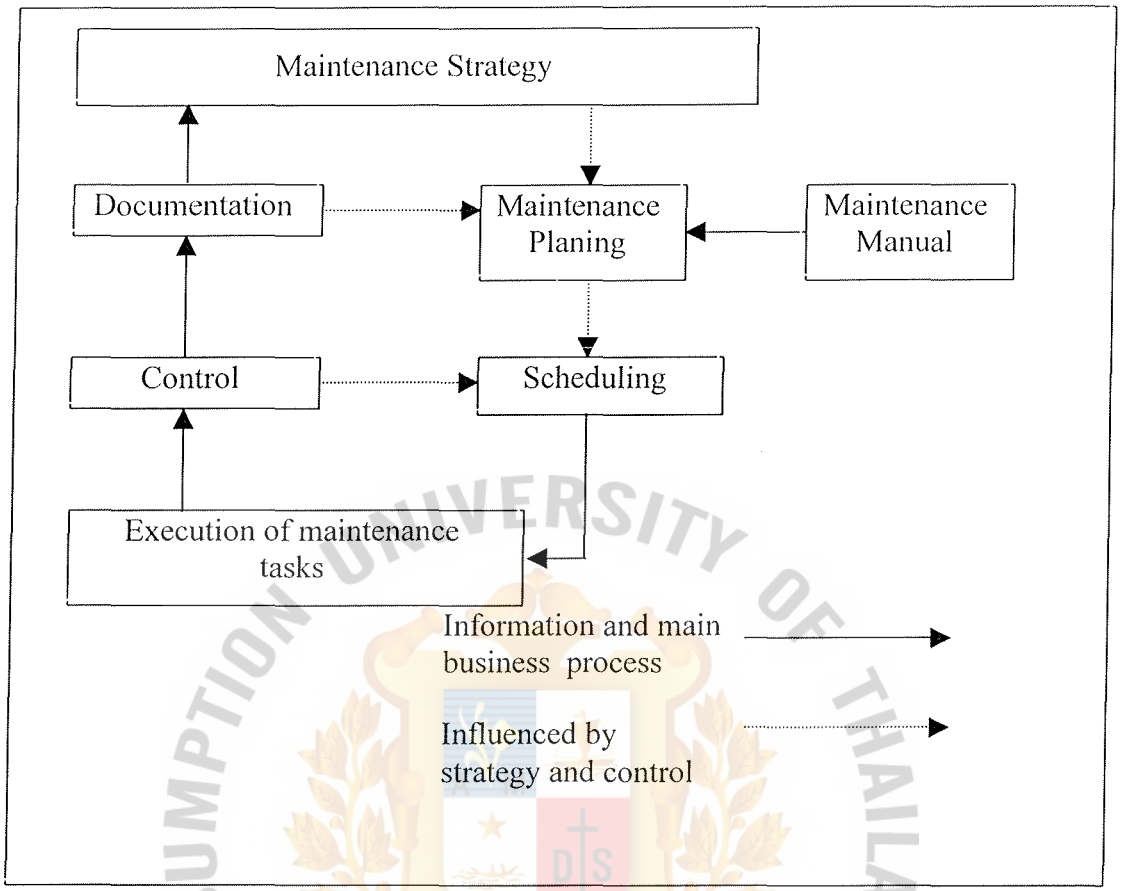

Figure 3.1. Maintenance Planning Cycle.

3.1.5 Capacity Planning

Manpower capacity is planned separately within each organization work unit. The supervisor (planner) in the work unit has to prioritize maintenance orders, estimate work load and schedule maintenance orders. If the capacity of the workforce is not sufficient to carry out the tasks, the planner should decide whether to increase staff or postpone the orders. The tools such as wheel lathes are also planned based on capacities.

3.1.6 Spare Parts Planning

The storekeeper manages stock level of hand tools (e.g. screw driver) and spare parts to ensure the continuity of maintenance operations. The keeper adjusts reorder

3.1.6 Spare Parts Planning

The storekeeper manages stock level of hand tools (e.g. screw driver) and spare parts to ensure the continuity of maintenance operations. The keeper adjusts reorder point and safety stock level of spare parts to match demand from maintenance tasks. The keeper also predicts the needed quantity of some spare parts and tools based on previous consumption and usage. The details of spare part management are beyond the scope of this project.

3.1.7 Maintenance Processing

Normally, there are two types of maintenance processing:

(1) Corrective maintenance which is the type of maintenance that has the objective to restore the function of maintenance object. It starts with the following processes:

   (a) Create maintenance notification to inform the malfunction of the equipment

   (b) Create maintenance order in order to perform and keep records of maintenance job

   (c) Confirm maintenance work order in order to confirm that the job is finished.

(2) Preventive maintenance which is the type of maintenance that tries to reduce the malfunction and the down time of equipment or machine. The most important data in preventive maintenance is maintenance plan which is used to generate maintenance order for doing the preventive maintenance. Normally, there are some information that have to be predefined in advance and are used in conjunction with maintenance plan, such information are

maintenance task list, maintenance item, etc. Preventive maintenance starts with the following processes:

(a) Create maintenance plan.

(b) Assign maintenance task list and maintenance item into maintenance plan.

(c) Schedule maintenance plan to generate maintenance order.

(d) Perform preventive maintenance job.

Furthermore, there are three subtypes of corrective maintenance described as follows:

(1) Corrective maintenance in emergency case, which means the type of malfunction that has to be responded and fixed immediately.

(2) Corrective maintenance in normal case, which means the type of malfunction that has no need to be responded and fixed immediately.

(3) Refurbishing, which means the process of fixing the malfunction equipment and restoring it to keep the equipment in the normal condition.

The four categories of maintenance processing in the maintenance department are described in Table 3.1.

Table 3.1. Maintenance Processing Category.

Maintenance processes	Notification	Warranty checking	Maintenance order creation
Preventive maintenance	Not required	No	Order is created according to maintenance plan.
Refurbishing	Optional	Yes	When needed
Corrective maintenance (normal case)	Required	Yes	After a malfunction is detected.
Corrective maintenance (emergency case)	Required	Yes	After maintenance task is finished

The processes of maintenance processing expand across the two work groups in the BTS project. Figure3.3 displays responsible area and business process in maintenance processing processes between Bangkok Mass Transit Corporation Limited and Simens System Limited maintenance department. It shows that all of the maintenance functions are done by Siemens except some parts of maintenance notification process are done by BTS party.

3.2 Information System Modeling and Deliverables

After the business processes and functions are investigated and reviewed, the information system and the deliverables of the proposed system are created based on the UML notation and IBM's OOTC method as described below:

3.2.1 Usecase and Usecase Diagrams

During the requirement analysis phase, the usecase which shows the high level of business process requirement in BTS project is derived and created which are shown in Appendix B, page 34. The overview function of each use case is shown in Appendix F, page 74. The usecase diagram which shows all usecases in BTS project and the actors who interact with each usecase is shown in Appendix B, page 34. The detail of each actor is shown in Appendix F, page 74.

3.2.2 Analysis Scenarios

For eac'ı use case in the usecase diagram, there are the possible scenarios that can be happened under certain assumptions and conditions for example, there are two scenarios in corrective maintenance which includes the emergency case and normal case. These scenarios for all of the usecases are shown in Appendix A, page 29.

3.2.3 Class Diagram

After the usecase diagram and the possible scenarios are defined, the business process designer derives the possible business entity to model the object from the business requirement which is normally in the narrative form to the business model that is in the form of the relationship between each business entity. This process results in the class diagram which is shown in Appendix D, page 40.

3.2.4 Diagram Specification

The specification of each class in the class diagram, for example the attributes of the class, the operation specification, and information that are necessary for developer are shown in Appendix F, page 43.

3.2.5 Sequence Diagram

The business function within each use case consists of many business processes which in turn consists of business entities or classes that have the interaction among themselves, for example the interaction of objects in the corrective maintenance processing in the normal case scenario consists of notification object, maintenance order object and so on. The interaction of each object in each scenario in each use case is shown in the sequence diagram Appendix C, page 35.

3.2.6 State Transition Diagram

From business processes and function of maintenance processing, there are many events that trigger the maintenance notification and order. Since such trigger can change the status of the object (notification, order) and each status of the object act as the guard to allow or not allow the new trigger events or the business to happen with the such object, for example when the creation of the notification events success, the status of the new notification object is "CREATED", if such notification is responded by supervisor. The status of the notification will change to "RELEASE" and if the worker has already fixed the malfunction, the status of the notification will change to "CLOSE". The

diagram that shows the changing status, the precondition and post condition of maintenance order and maintenance notification object are shown in the state transition diagram, Appendix E, page 41.

3.2.7 Database Design

The class diagram from Appendix C is mapped into persistent database table shown in Appendix G, page 78.

3.2.8 Data Input Screen and Report

There are the examples of the data input screens and the reports from BTS project based on the business requirement. The example data input screen and reports include:

(1) Defect code input screen

(2) Work center input screen and list of equipment output report

(3) Equipment input screen and list of equipment output report

(4) Maintenance plan input screen and list of maintenance plan output report

(5) Notification input screen and list of notification output report

(6) Strategy input screen and list of strategy output report

(7) Task list input screen and list of task list output report

(8) Work order input screen and list of work order output report

(9) Notification summary report input/output screen

(10) Order summary report input/output screen

(11) Maintenance plan report input/output screen

These input screens are shown in Appendix II, page 81.

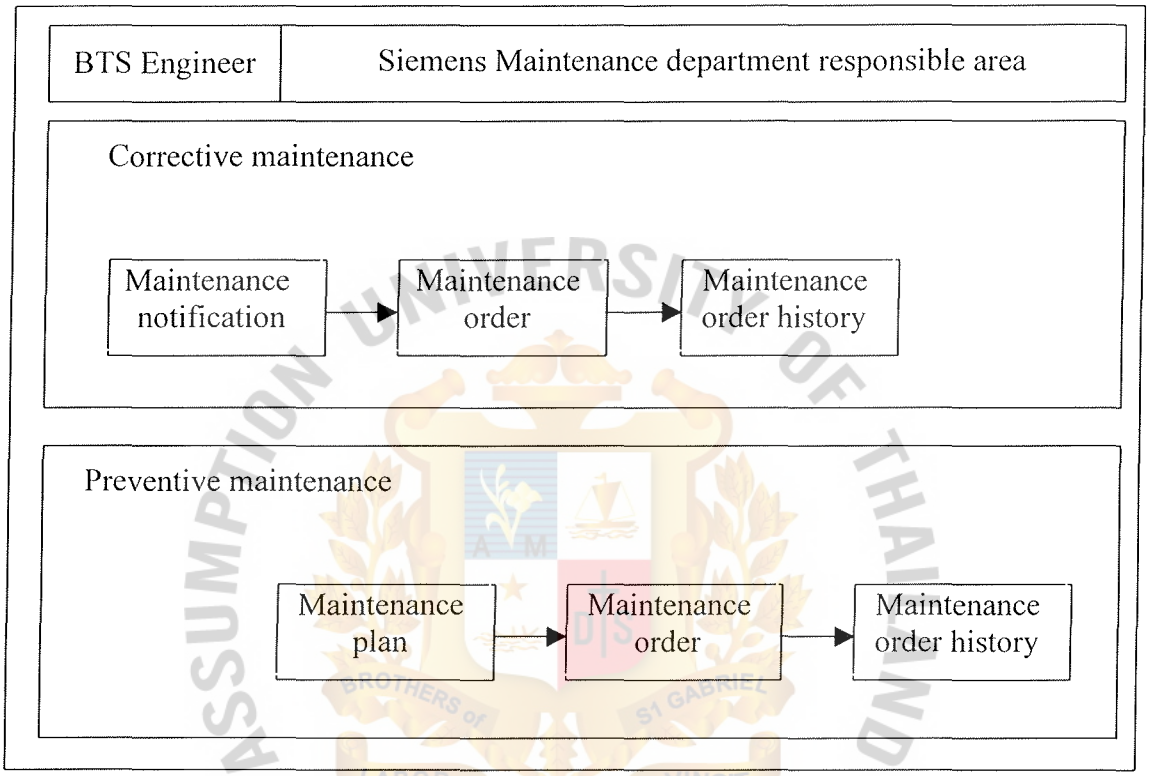

Figure 3.2. The Responsibility between BTS and Siemens Maintenance Department.

IV. SYSTEM REQUIREMENT

4.1 Hardware and Software Requirements

The hardware and software requirements for the proposed system are as follows. System configuration of BTS project is designed on the basis of Client/Server architecture and use TCP/IP as the network protocol, the hardware configuration is shown in Figure 4.1. The system will have one sever as application server and database server. However, there is plan to separate application server and database server in the future if there is the problem of system performance. At first, there will be two presentation clients located at the maintenance center room where maintenance supervisor from each department will work with the system.

4.1.1 Hardware Requirement

	QTY	BAHT
1. Server : Dell Poweredge 4200 server	1	390,000
- CPU Pentium III 300 MHz		
- Memory 1 GB		
- Hard Drive 4GB Ultra Wide SCSI		
2. Workstations	2	80,000
- CPU Pentium Pro 200 MHz		
- Memory 32MB		
- 3.5 inches floppy disk drive		
- 14 inches SVGA Color Monitor		
- Enhance 101-Key Keyboard		
- PS2 Mouse		
3. Printers		
- Laser Printer HP5	1	30,000

	QTY	BAHT
4. UPS	1	80,000
5. Hub 3Com 24 ports	1	20,000
4.1.2 Software Requirement		
1. MS Windows NT 4.0	1	80,000
2. MS SQL Server 7.0	1	75,000
3. MS Windows Thai Edition	1	35,000
4. Symantec Visual Café 2.5A	1	50,000
5. Microsoft Office Professional Thai Edition	1	35,000

4.2 Security and Control

Security is the very important issue in developing the information system. In BTS project there are only two clients that install the front end program, however there are at least ten supervisors from different maintenance department using such client. There are high possibilities that supervisor from different maintenance department change information of other department. It's not practical to limit the access of supervisor to only his own department data because sometimes some data has to be shared. In BTS project, the concept of authorization of business transaction plays the important role in security issue. Below are the proposed of authorization in the business transaction point of view

(1) Log-in password for access presentation client (Windows password)

(2) Log-in password for accesses BTS application. (Application level password)

Authorization of activities that are performed as the objects are set to four levels

(1) Display objects

(2) Change objects

(3) Create objects

(4) Delete objects

Supervisor of each department can perform all of the activities for related objects only at his data in own department. For the data in objects that belong to the other department, he can only display the information (no change, create, delete), for example, supervisor of AFC can do everything in the objects that contains AFC data and can only display the information in RST, SCADA, etc. The maintenance manager has the full authorization of activities in every maintenance department.

The security is not implemented only in the application level but also in the database, operating system and the other factors. Normally, all of the high-end database program provides the security checking and data integrity check. It's the job of database administrator together with system analyst and programmer to make use of the functionality that are provided in each database program during the design phase of application. In the operating system point of view, it is the job of system administrator to define the level of access when the users log on to the system for example restrict the domain, the directory, etc. The most important is the clear policies and procedures about the backup and recovery of the server and if this is the missing-critical application, it should have the other server run in parallel with daily operation server to guarantee the high rate in system availability. The other factors of security is, for example, use the UPS to prevent the loss and the unstable electric power that will result in the damage of hardware.

4.3 Cost/Benefit Analysis

The cost of new proposed computerized information system can be divided into 3 main categories, these are:

(1) Investment Cost

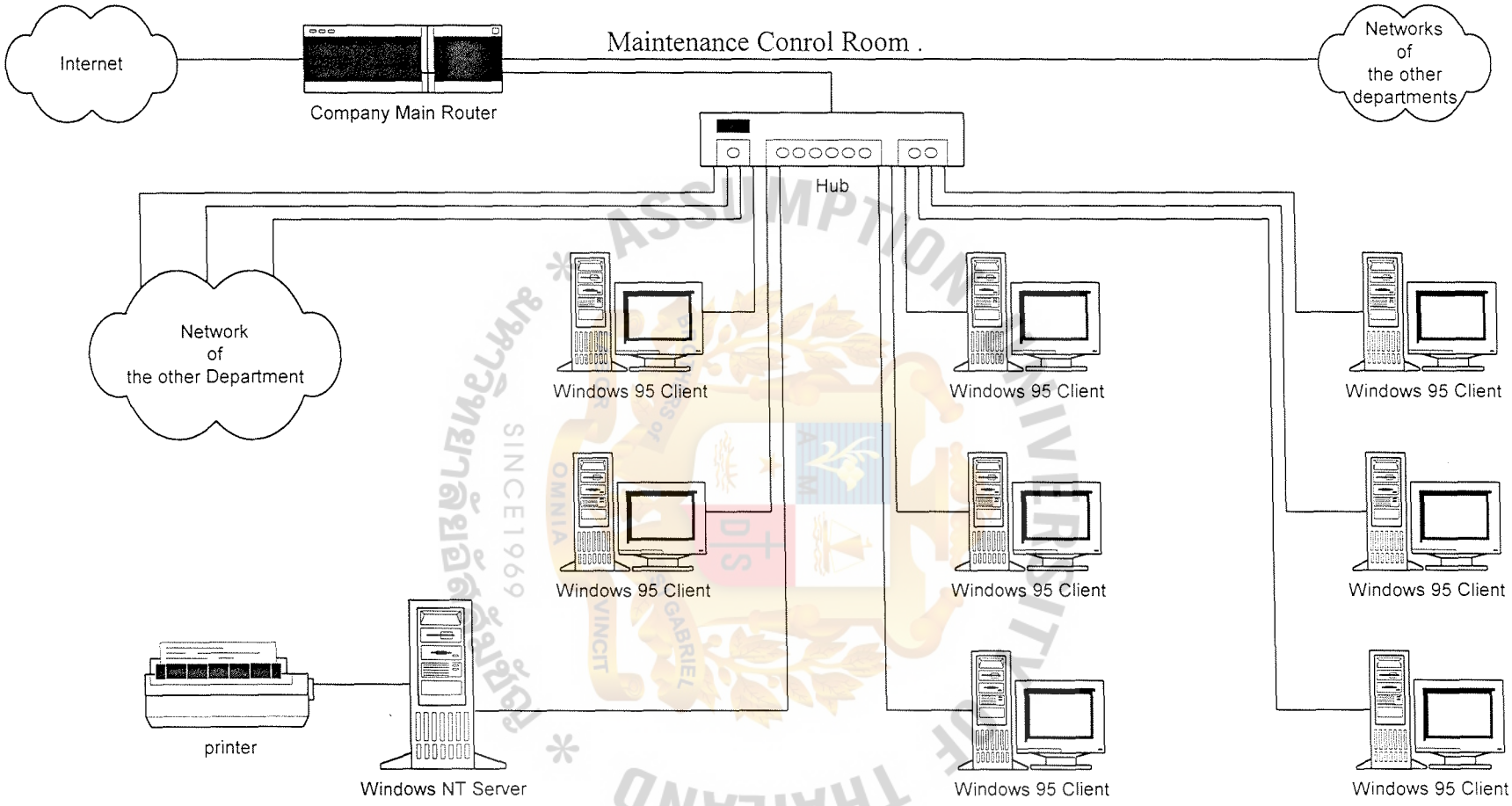

Figure 4.1. The Hardware Configuration in the Maintenance Conrol Room of BTS Project.

Since BTS project is a green field project, there is no existing computerized system. The investment cost for the proposed system is the cost of hardware and software requirement from topic 4.1.

The investment cost is a fixed cost, which occurs only one time at the implementation phrase of the new proposed system.

(2) Development Cost

The new proposed system requires programmers from independent software vendor to develop and implement. The cost for development of the proposed system is one time cost for two programmers. The lead time of development and implementation is three months.

(3) Operation Cost

The operation cost comes from the salary of staffs who perform routine operation. The assumption has been made that if the computerized system is used in BTS project, the number of staffs required to perform the routine operation will be reduced to two people compared with 5 people in the non-computerized environment. While, the cost of the stationary and miscellaneous in the computerized system are still the same as in the non-computerized system.

The cost comparison between the computerized system and the non-computerized are displayed in Tables 4.1.

Table 4.1. Cost Comparison between the Computerized System and the Non-computerized System for BTS Project.

Cost Items	Years				
	1	2	3	4	5
Non-computerized System :					
Staff (5 Staffs) (increase 5% per year)	780,000	819,000	859,950	902,948	948,095
Office Supplies Cost (increase 5% per year)	50,000	52,500	55,125	57,881	60,775
Office Equipment Cost	10,000	10,000	10,000	10,000	10,000
Utility Cost (increase 5% per year)	60,000	63,000	66,150	69,458	72,930
Total Cost (Baht)	900,000	944,500	991,225	1,040,287	1,091,800
Cumulative Cost (Baht)	900,000	1,844,500	2,835,725	3,876,012	4,967,812
Computerized System :					
Hardware Cost (5 years depreciation)	120,000	120,000	120,000	120,000	120,000
Software Cost (5 years depreciation)	55,000	55,000	55,000	55,000	55,000
Installation Cost (network and hardware)	95,000				
Development Cost (5 years depreciation)	60,000	60,000	60,000	60,000	60,000
Office Equipment Cost	12,000	12,000	12,000	12,000	12,000
Staff (3 Staffs) (increase 5% per year)	468,000	491,400	515,970	541,769	568,857
Maintenance Cost (increase 10% per year)	10,000	11,000	12,100	13,310	14,641
Office Supplies Cost (increase 5% per year)	70,000	73,500	77,175	81,034	85,085
Training Cost	30,000	30,000	20,000	20,000	20,000
Utility Cost (increase 5% per year)	80,000	84,000	88,200	92,610	97,075
Total Cost (Baht)	915,000	916,900	950,445	985,723	1,022,658
Cumulative Cost (Baht)	915,000	1,851,900	2,812,345	3,808,068	4,840,726

The data of Cumulative Cost from the computerized system and the non-computerized system in Tables 4.1 are plotted as shown in Figure 4.2 The breakeven point between implementing the computerized system and the non-computerized system in BTS project is around 2.75 years. It is clear that for the first 24 months the cost of the computerized system is high. This is because of the investment cost and the development cost of the new system. However, after the breakeven point the graph of computerized system increases in the lower rate than the non-computerized system because the operation cost of the computerized system is lower than that of the non-computerized system. If the computerized system is used, BTS project needs only 3 staffs to operate the routine job as compared with 5 staffs in non-computerized system. This results in the lower operating cost. Moreover, the accuracy and velocity of the routine operation can be guaranteed in the computerized system.

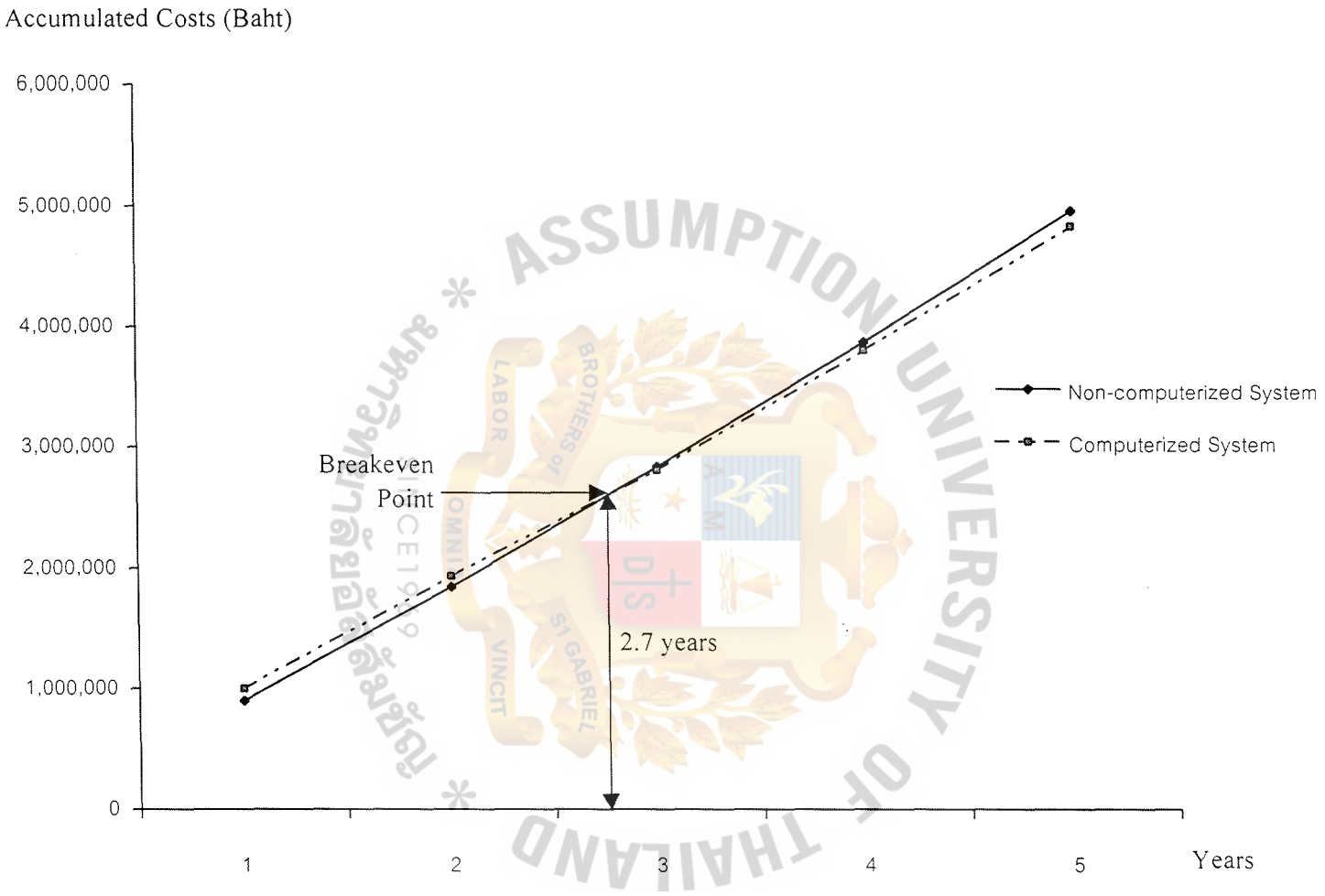

Figure 4.2. The Comparison of Cost between the Computerized and the Non- computerized System.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The plant maintenance information system for BTS project is developed by using object-oriented method which is the new paradigm in software engineering since the 1990's. The method that is used to develop this project is from IBM's OOTC. All of the deliverables in this project are in the form of UML notations which will be the standard notation in object-oriented analysis and design in the near future. All deliverables from every phase of IBM's OOTC method are kept in the repository of the Rational Rose 98 tools. One of the philosophy in object-oriented method is "reusable", so all of the deliverables from the previous project can be reused in the new software development project. There is also no exception for BTS project, all the deliverables; particularly from analysis and design phase; can be a good reference for the programmer (who are probably involved in this project later) to develop source code for this project no matter which object oriented programming language and platform are used.

5.2 Degree of Achievement of the Proposed System Compared with the Existing System

Table 5.1 shows the time spent on each process for one transaction of the Proposed System compared with the Existing System. It shows that each process of the Proposed System spends less time than each process of the Existing System which has to pass many manual work steps. This can be explained that the Proposed System is more efficient and effective than the Existing system.

Table 5.1. Degree of Achievement between the Proposed System and the Existing System.

Process	Existing System	Proposed System
Schedule Maintenance Plan Process	1 hrs.	10 mins
Maintain Notification Process	5 mins	5 mins
Maintain Work Order Process	20 mins	10 mins
Maintain Maintenance Task List Process	15 mins	8 mins
Maintain Maintenance Plan Process	20 mins	10 mins
Generate Report Process	1 hrs.	10 mins
Total	3 hrs.	53 mins

5.3 Recommendations

The development of BTS project to the new module of functionality should be in the object-oriented analysis and design concept and use the UML as the standard notation in order to keep the project to be traceable and reusable for the other developer to work with this project in the future.

(1) Developers should add the new functionality like material management and financial controlling in order to cover all of the business processes in plant maintenance information system.

(2) In the case developers add or delete some class or method in the application source code, it is recommended for developer to do the reverse engineer with all of the deliverables that will be impacted from such changes, so that the application source code and the model of the system always synchronize

(3) Building the complex software system requires the blue print which consists of business process requirement and system architecture. The developer should build the blue print which is independent from the specific

programming language and hardware platform. The blue print can be created by using visual modeling language for example UML, etc.

(4) Building the complex software system does not only require the visual modeling language but also requires the methodology for developing the software for example IBM OOTC technique or the other iterative software development method. Using the methodology when developing information system can reduce the risk of the project and guarantee the deliverables from phases to phases.

APPENDIX A

ANALYSIS SCENARIOS

ANALYSIS SCENARIOS

Use case 1: Maintain work order

Scenario 1.1: Maintain work order for corrective maintenance (normal processes)

Assumptions:

There are enough resources and capacities to perform work order.

Description of processes

1.1.1 The supervisor creates maintenance work order from notification that exists in the system (one order for one notification).

1.1.2 The supervisor schedules date and time of work order to be processed.

1.1.3 The supervisor assigns task list (the sequence of work) into work order and can also probably add more operations into work order.

1.1.4 The supervisor assigns materials and spare parts that are needed to process work order

1.1.5 The supervisor checks for the availability of capacities and resources for processing work order. If there are not enough of either capacities or resources, see scenario 1.2.

1.1.6 The supervisor releases work order for technicians to process maintenance job.

1.1.7 Technician processes maintenance job.

1.1.8 The supervisor does the confirmation of the work order processed by technician.

1.1.9 The supervisor closes work order and notification (that is linked to the work order).

Scenario 1.2: Maintain work order for corrective maintenance (not enough capacities or resources).

Assumptions:

Capacities and/or resources are not sufficient to process the work order.

Description of processes

1.2.1 Do the same processes as described in scenario 1.1 until it reaches the process 1.1.5, If there are not enough capacities and/or resources, the supervisor has to reschedule the work order to the date that the capacities and resources are enough to process work order. Consequently, the supervisor puts work order in process and does the same process described in 1.1.7 through 1.1.9.

Use case 2: Maintain notification

Scenario 2.1: Maintain notification (notification for corrective maintenance).

Assumption:

Maintain notification when there is a malfunction occurring in the equipment.

Description of processes

2.1.1 ECC (Engineer control center) is informed from the operation workers that there is malfunction occurring in the equipment of BTS project, he or she creates malfunction notification.

2.1.2 The supervisor performs use case "Maintain work order"

Scenario 2.2: Maintain notification (other notification that is not relevant to malfunction notification)

Assumption:

Maintain notification that is not relevant to malfunction notification.

Description of processes

2.2.1 The supervisor creates the new type of notification (not relevant to malfunction notification).

2.2.2 The supervisor puts the notification in the process.

2.2.3 The supervisor closes the notification.

Use case 3: Maintain maintenance plan

Scenario 3.1: Maintain maintenance plan for preventive maintenance.

Assumptions:

There have been maintenance strategies already in the system.

Description of processes

3.1.1 The supervisor creates maintenance plan and assigns the maintenance strategy (see details in "maintain maintenance strategy use case") into the maintenance plan.

3.1.2 The supervisor assigns the maintenance item (see details in " maintain maintenance item use case") into maintenance plan.

Use case 4: Maintain maintenance task list

Scenario 4.1: Maintain maintenance task list

Assumptions:

The work centers that the supervisor needs in the task lists have already been created in the system.

Description of processes

4.1.1 The supervisor creates maintenance task list and assigns maintenance strategy into maintenance task list.

4.1.2 The supervisor assigns work center in each operation of task list

4.1.3 In each operation, the supervisor assigns the duration time needed to perform such operation.

4.1.4 In each operation, the supervisor assigns the material (if needed) to perform such operation.

4.1.5 The supervisor assigns the package in each operation.

Use case 5: Schedule maintenance plan

Scenario 5.1: Skip work orders after execute scheduled maintenance plan.

Assumptions:

The supervisor does not want to process work order that is created by the system.

Descriptions of processes

5.1.1 The supervisor assigns the date of the starting cycle of the maintenance plan.

5.1.2 When the system generates the date of the next work order, the supervisor makes the decision that such work order should not be further processed and he skips such work order.

Scenario 5.2: Call work order after the execution of scheduled maintenance plan.

Assumptions:

The supervisor wants to continue to perform work order (use case 1) that is created by the system.

Descriptions of processes

5.2.1 The supervisor assigns the date of the starting cycle of the maintenance plan.

5.2.2 When the system generates the date of the next work order, the supervisor makes the decision that such work order should be further processed and he calls such work order and perform use case 1 (maintain work order).

Use case 6: Maintain work center

Scenario 6.1: Maintain work center

Assumptions:

Descriptions of process

6.1.1 The supervisor creates work center and assigns the name of such work center.

6.1.2 The supervisor assigns the group of responsibility people to work center.

6.1.3 The supervisor assigns the available capacities for work center in the period of time.

Use case 7: Maintain maintenance strategy

Scenario 7.1: Create maintenance strategy

Assumptions:

Descriptions of process

7.1.1 The supervisor assigns the type of strategy into maintenance strategy.

7.1.2 The supervisor assigns the package in maintenance strategy.

Use case 8: Maintain maintenance item

Scenario 8.1: Create maintenance item

Assumptions:

The maintenance task lists have already been created in the system

Descriptions of processes

8.1.1 The supervisor assigns maintenance strategy into maintenance item.

8.1.2 The supervisor assigns equipment into maintenance item.

8.1.3 The supervisor assigns maintenance task list into maintenance item.

ACTORS

(a) BTSC (Bangkok Mass Transit System Corporation Limited) actors are the group of persons who look into and analyze the report generated by the system together with Siemens actors.

(b) Siemens actors are the group of persons who see and analyze the report generated by the system together with BTSC actor.

(c) The maintenance supervisor for each maintenance department (from organization chart). It is the primary actor in this system and performs most of the functions (use cases) in this system.

(d) ECC (Engineer control center) is the engineer controller who is responsible for receiving the phone call from the operation workers in the BTS project about the malfunction of the equipment.

APPENDIX B

USECASE DIAGRAM

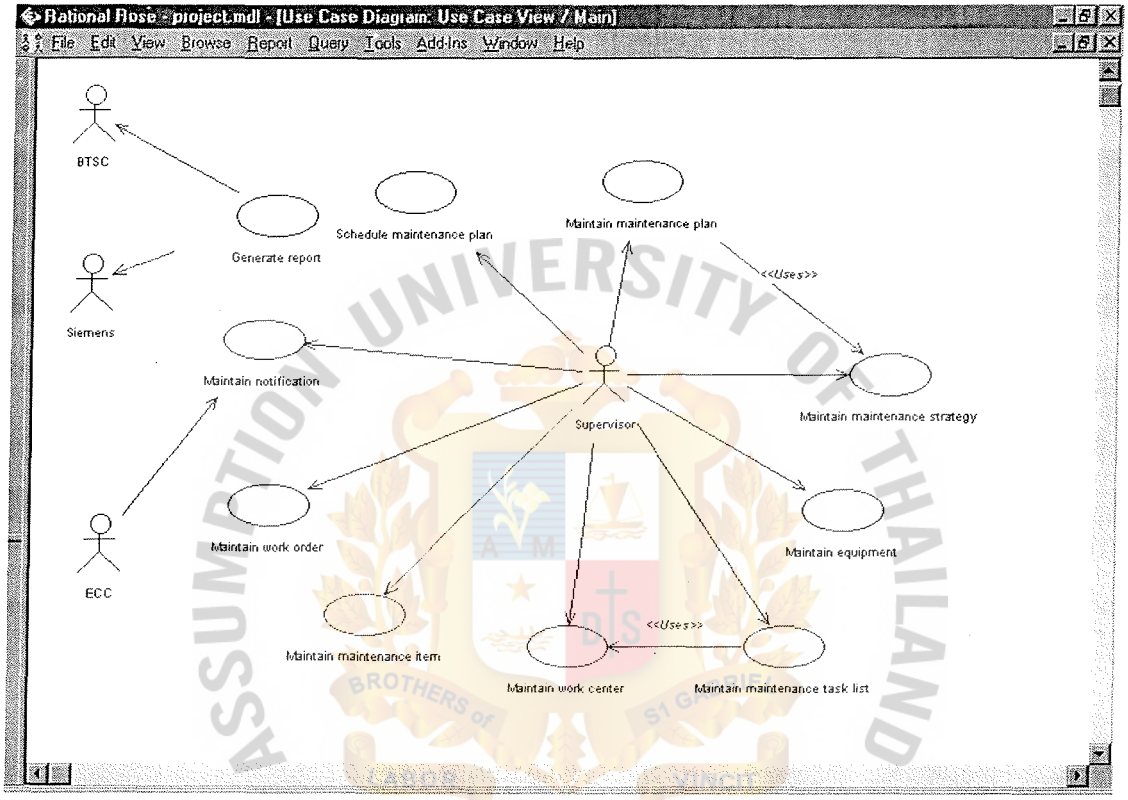

Figure B.1. Use Case Diagram.

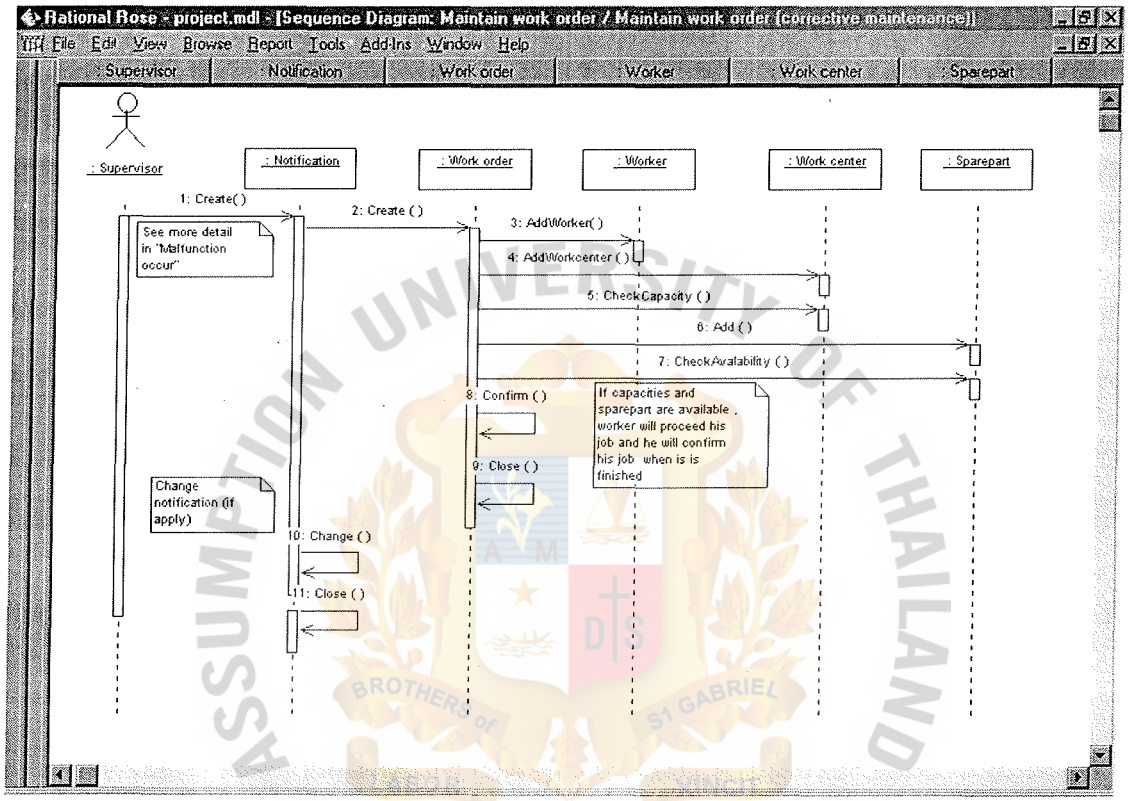

Figure C.1. Maintain Work Order (Corrective Maintenance) Sequence Diagram.

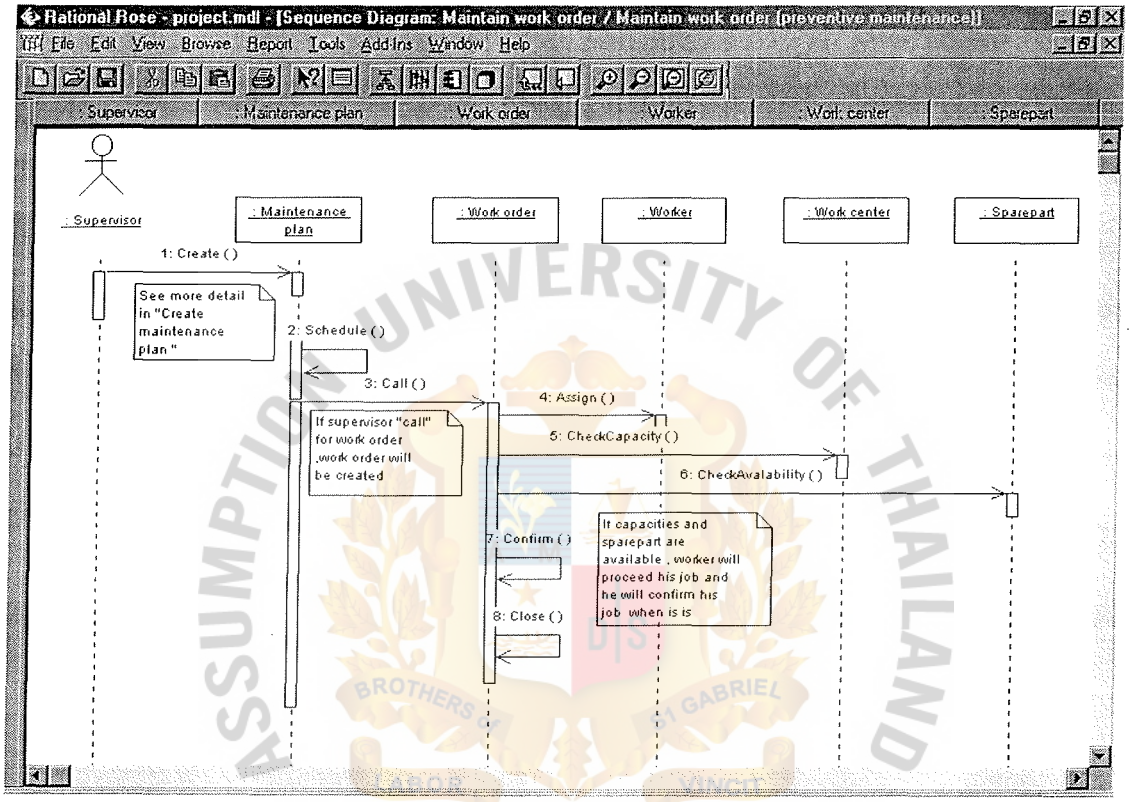

Figure C.2. Maintain Work Order (Preventive Maintenance) Sequence Diagram.

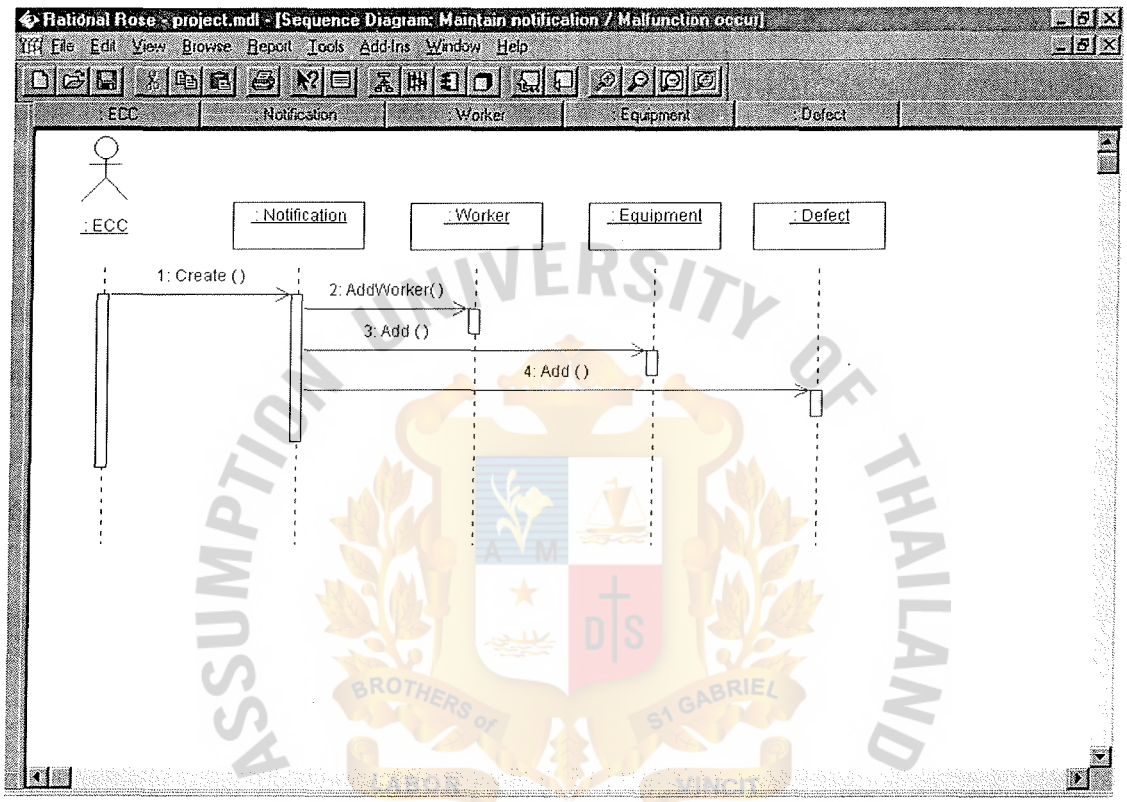

Figure C.3. Maintain Notification (Malfunction) Sequence Diagram.

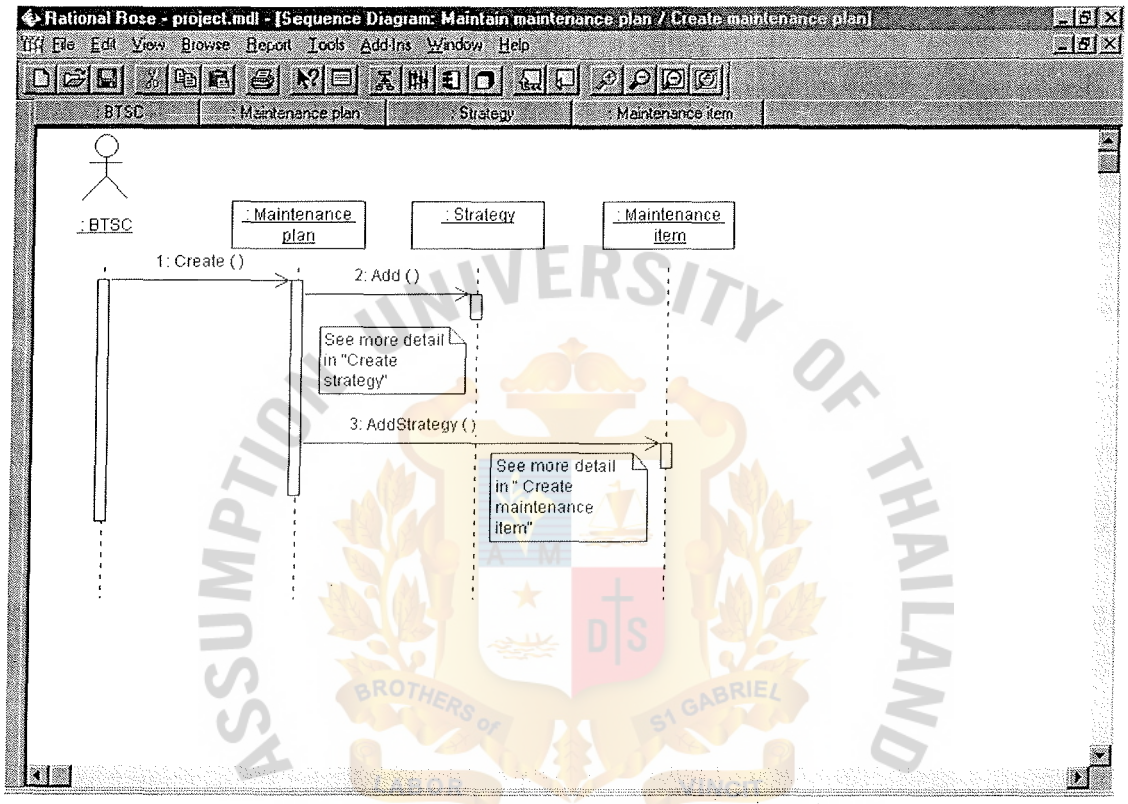

Figure C.4. Maintain Maintenance Plan Sequence Diagram.

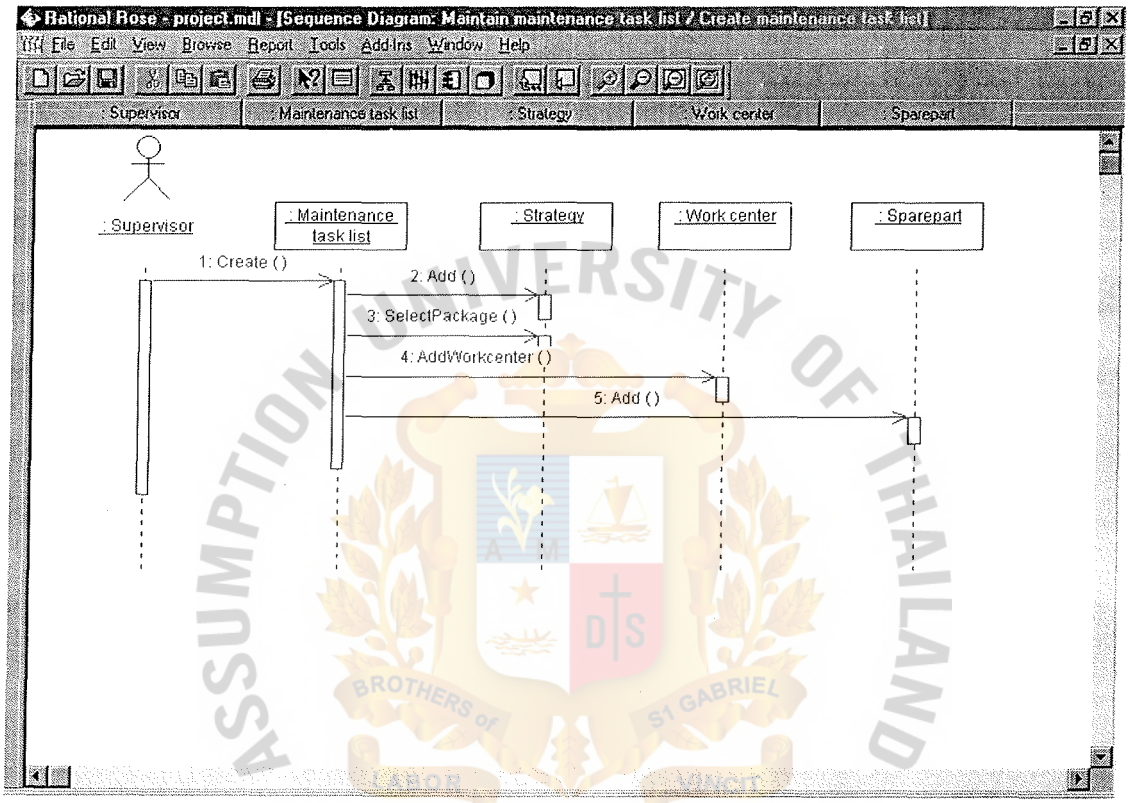

Figure C.5. Maintain Maintenance Task List Sequence Diagram.

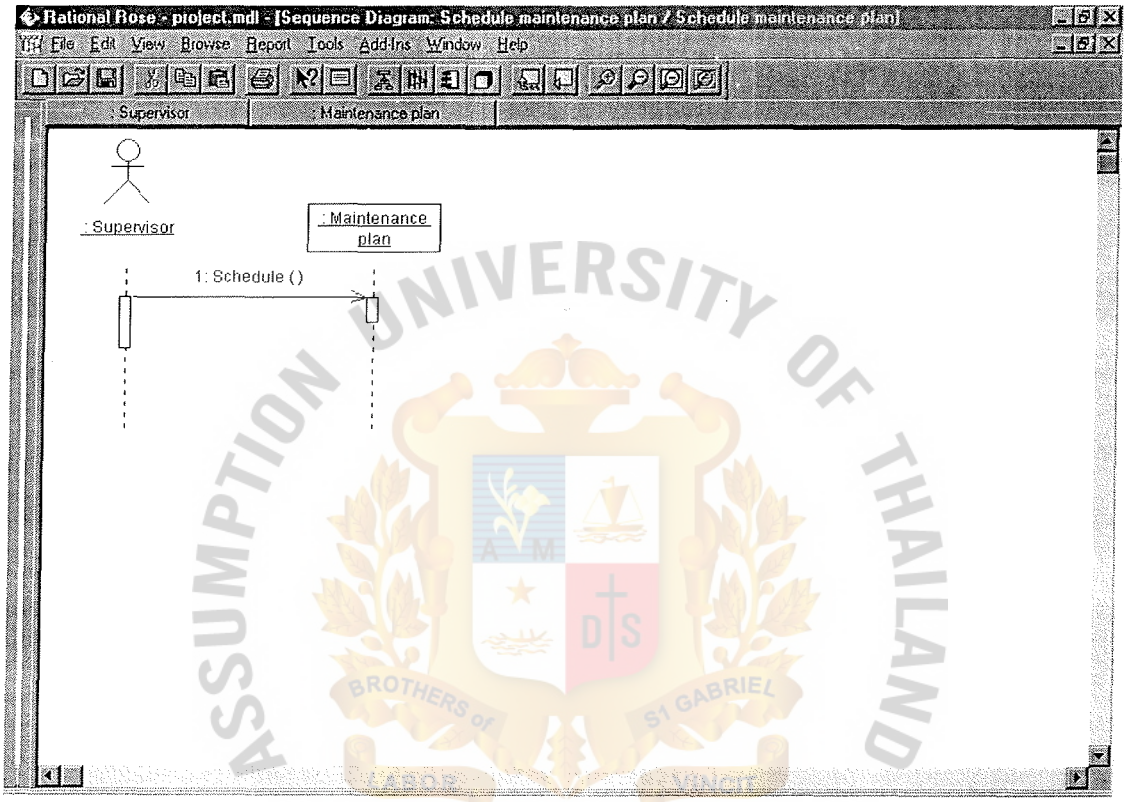

Figure C.6. Schedule Maintenance Plan Sequence Diagram.

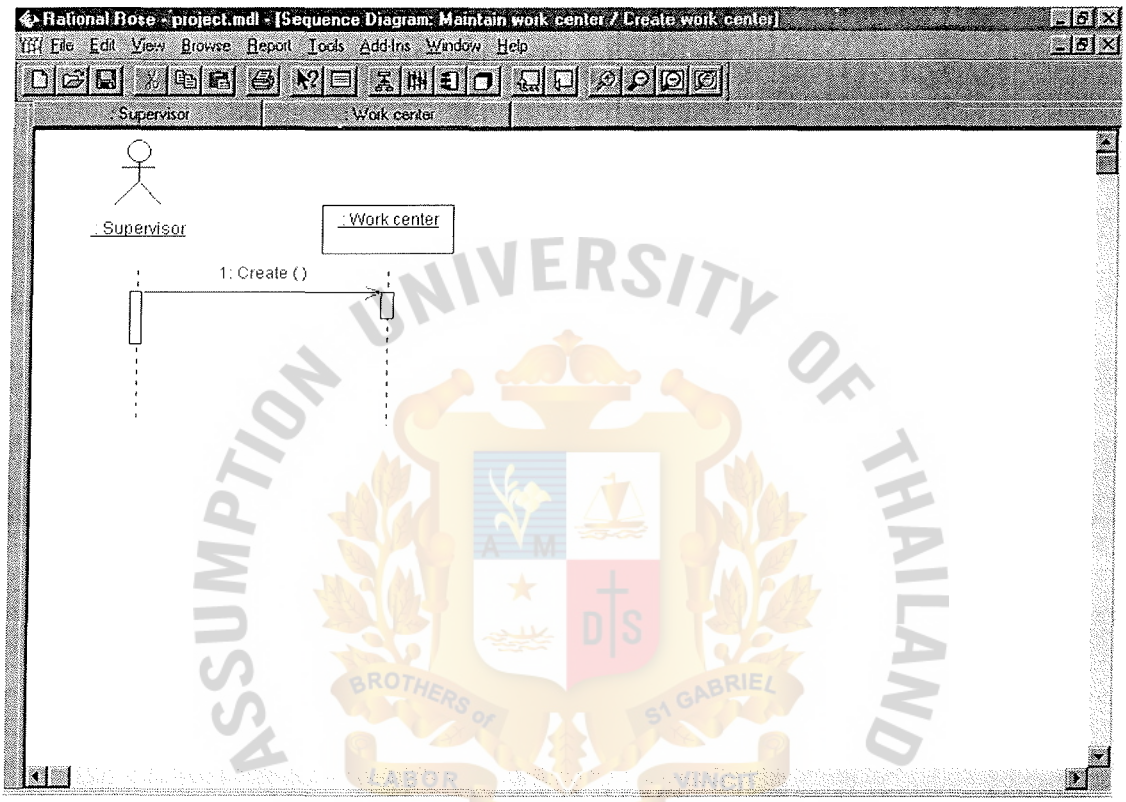

Figure C.7. Maintain Work Center Sequence Diagram.

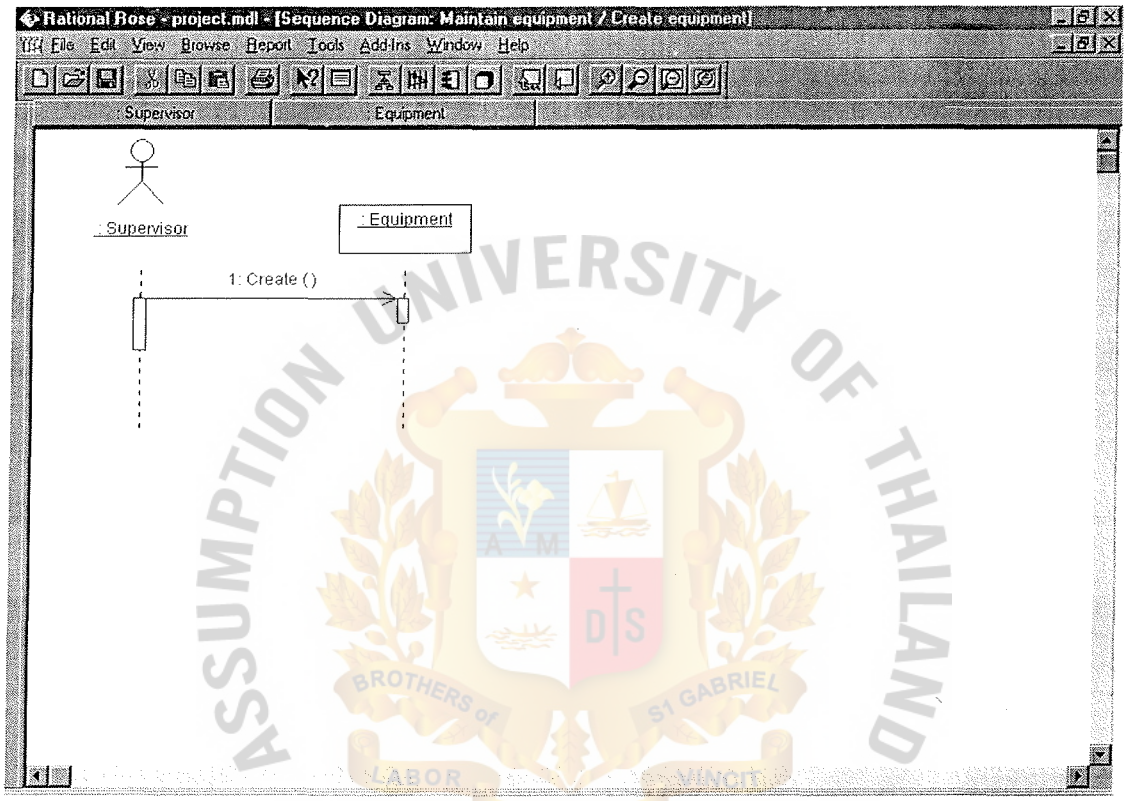

Figure C.8. Maintain Equipment Sequence Diagram.

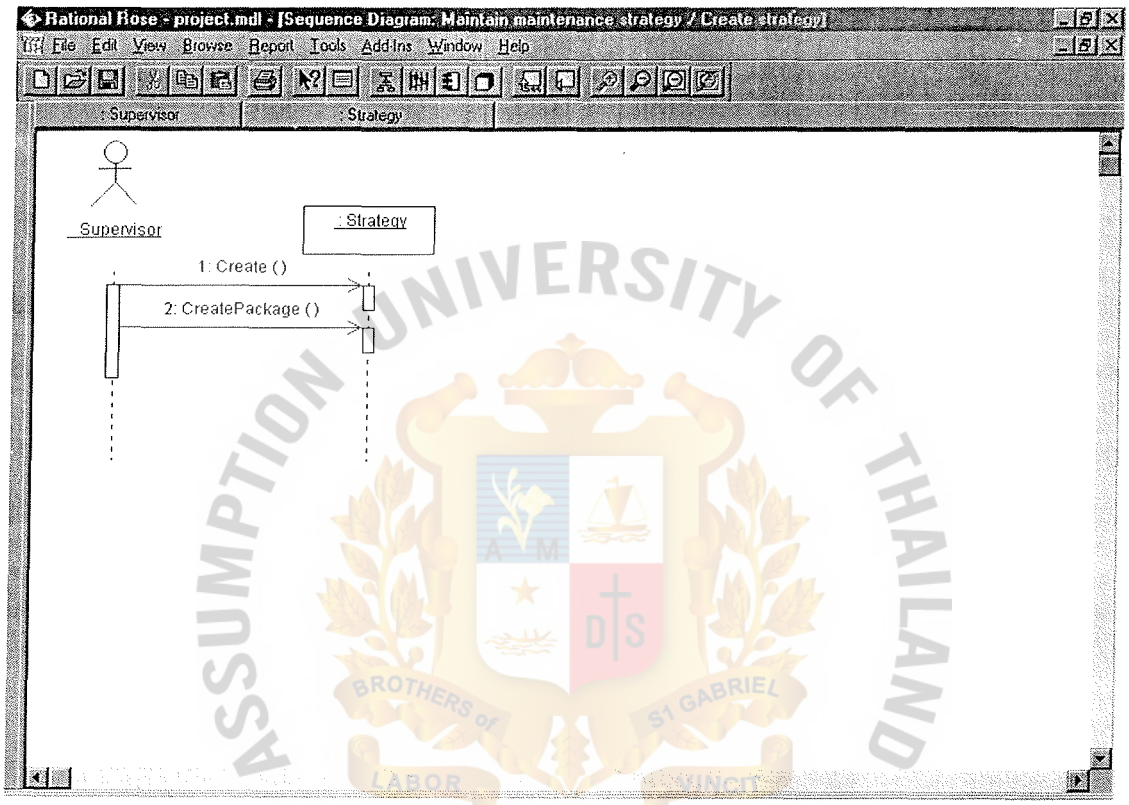

Figure C.9. Maintain Maintenance Strategy Sequence Diagram.

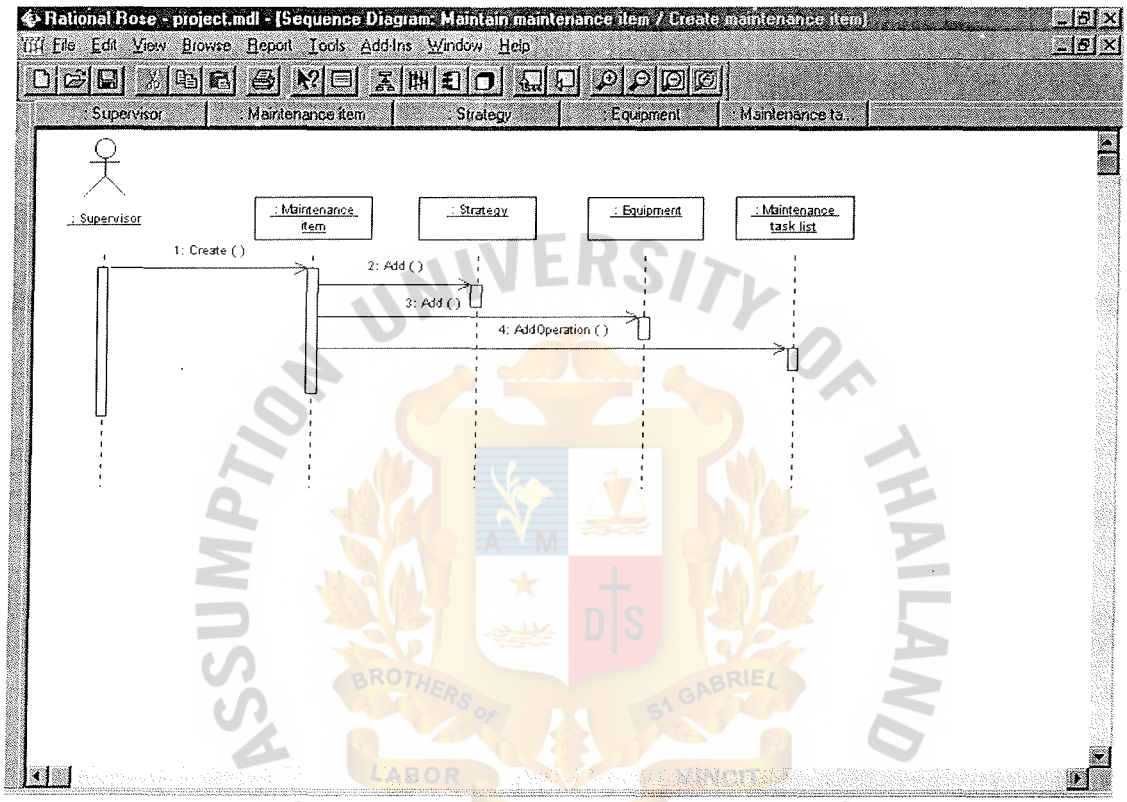

Figure C.10. Maintain Maintenance Item Sequence Diagram.

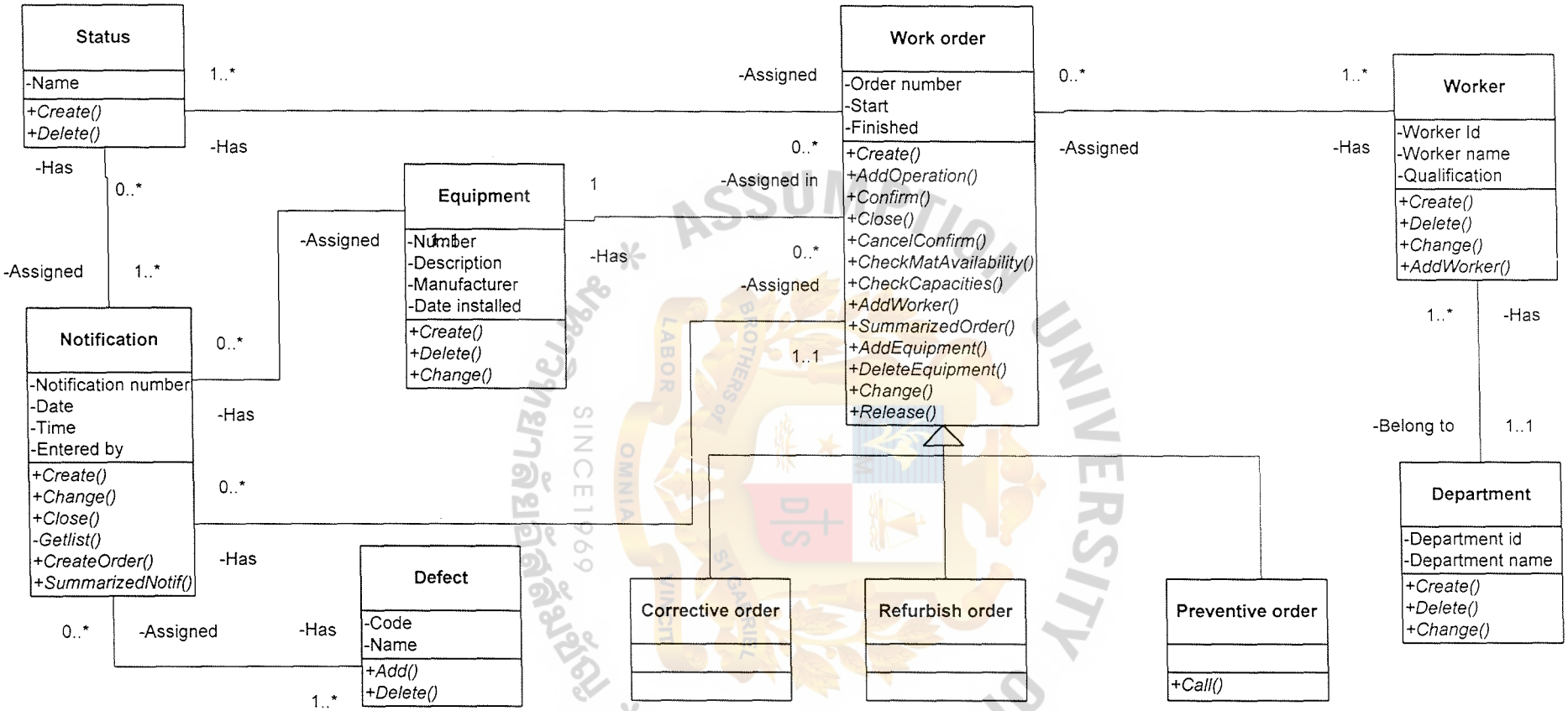

Figure D.1. Class Diagram.

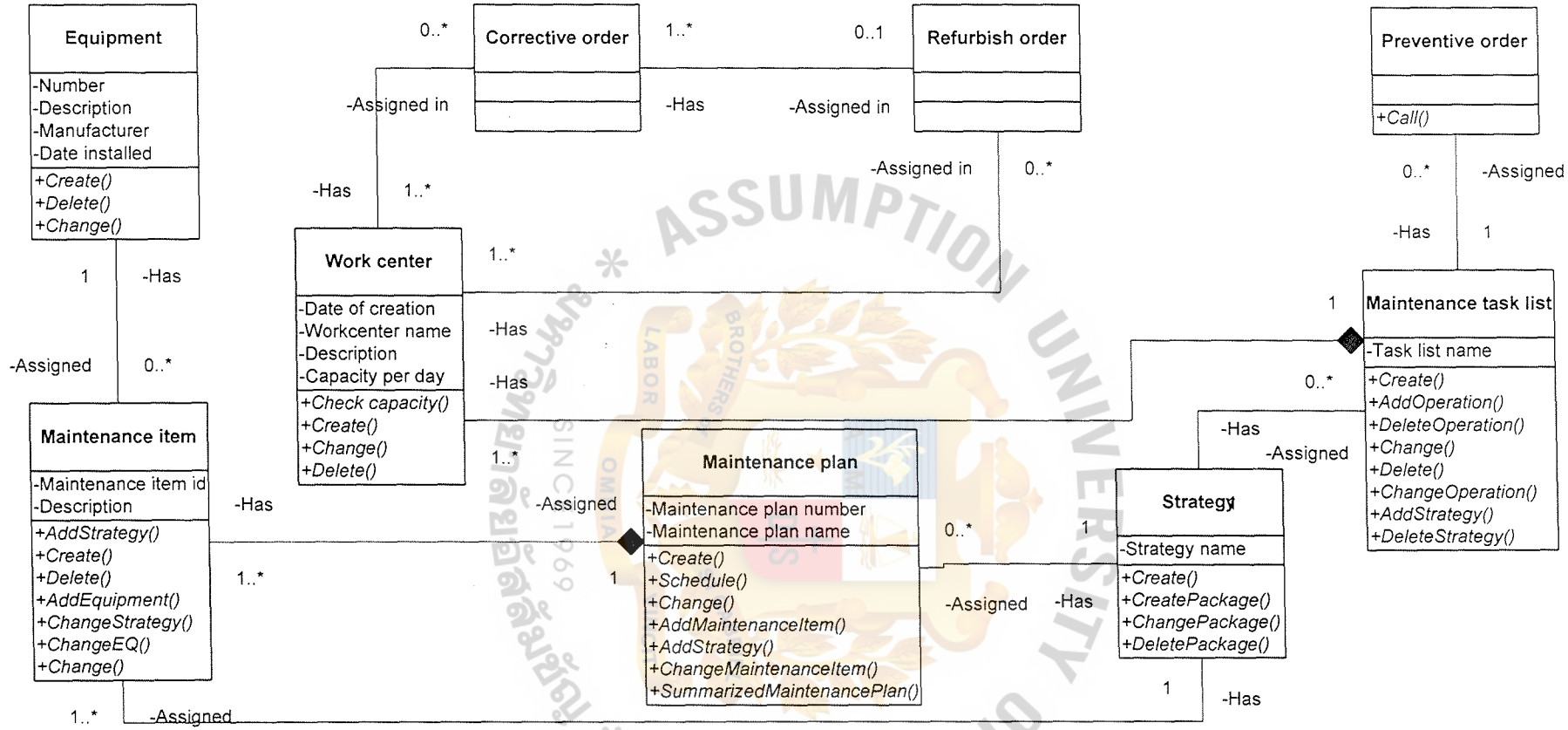

Figure D.2. Class Diagram (Continued).

APPENDIX D

CLASS DIAGRAM

APPENDIX E

STATE TRANSITION DIAGRAM

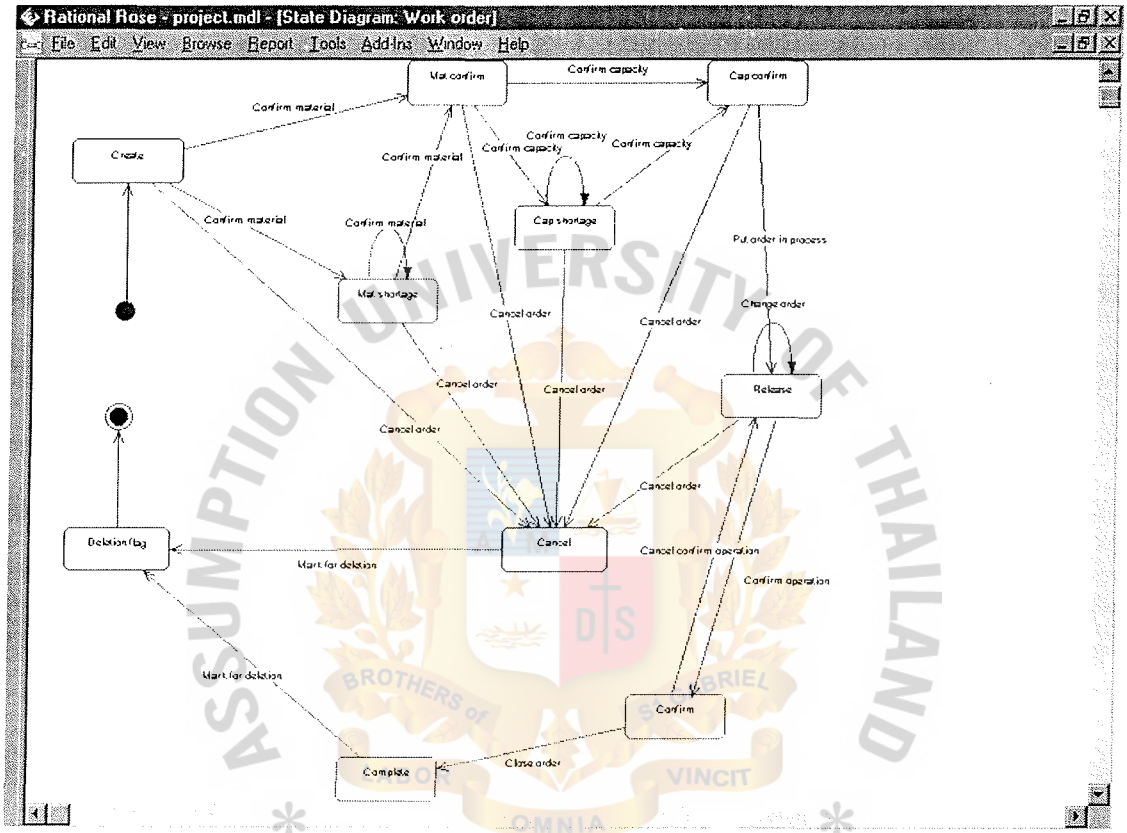

Figure E.1. Work Order State Diagram.

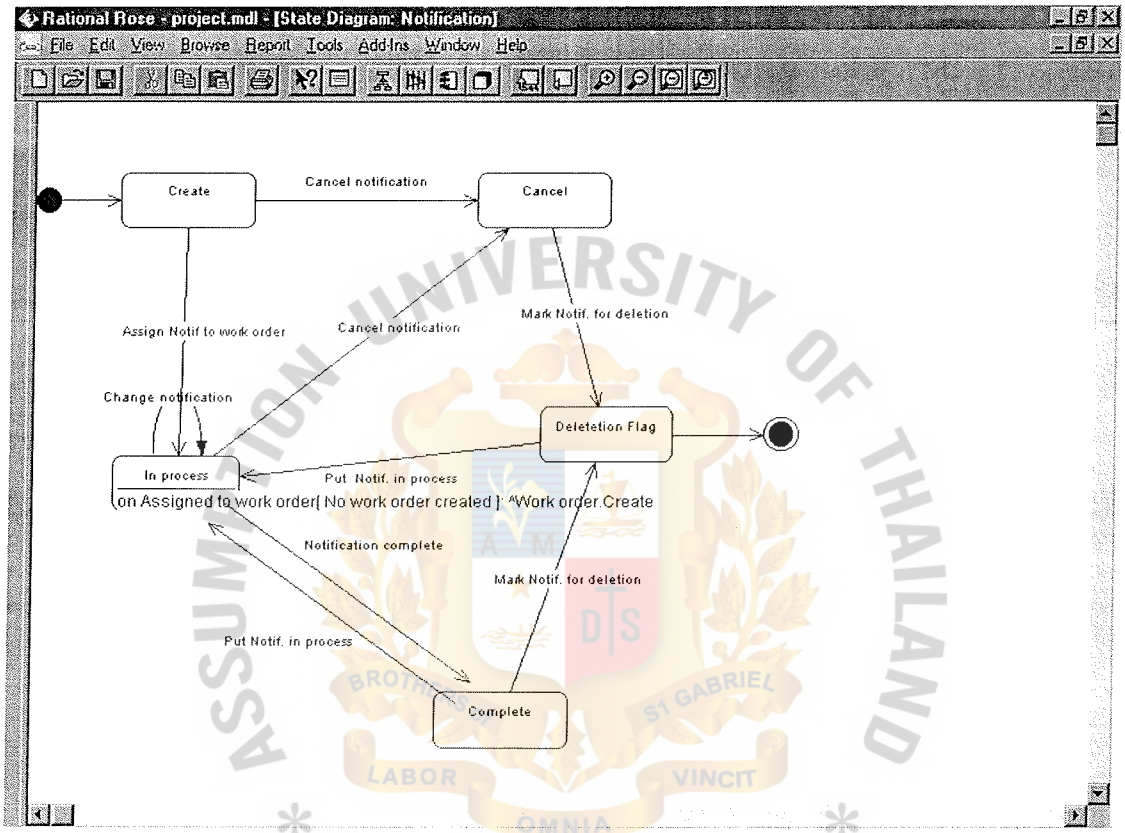

Figure E.2. Notification State Diagram.

APPENDIX F

DIAGRAM SPECIFICATIONS

Class name: Department

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

Has : Worker in association <unnamed>

Public Interface:

Operations:

Create

Delete

Change

Private Interface:

Attributes:

Department Id : String

Department name : String

Implementation:

Attributes:

Department Id : String

Department name : String

State machine: No

Concurrency: Sequential

Persistence: Transient

Operation name:

Create

Public member of: Department

Documentation:

This operation will create the new department in the system. It will prompt the screen with the all of the attributes from class department that required the users to input data. After the users save the data; the system will automatically generate the department Id.

Concurrency: Sequential

Operation name:

Delete

Public member of: Department

Documentation:

This operation will change the status of the department to "deletion flag". Once the department has the status "deletion flag" , it can not be used for the new transactions in the system.

Concurrency: Sequential

Operation name:

Change

Public member of: Department

Documentation:

This operation will prompt the users to enter the department name they want to change. After entering the department name, the system will show the information of such department and users can change the information.

Concurrency: Sequential

Class name: Defect

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

Assigned : Notification in association <unnamed>

Public Interface:

Operations:

Add

Delete

Private Interface:

Attributes:

Code : String

Name : String

Implementation:

Attributes:

Code : String

Name : String

State machine: No

Concurrency: Sequential

Persistence: Transient

Operation name:

Add

Public member of: Defect

Documentation:

This operation will add new defect type to the system.

Concurrency: Sequential

Operation name:

Delete

Public member of: Defect

Documentation:

This operation will delete the defect type in the system

Concurrency: Sequential

Class name: Worker

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

Belong to : Department in association <unnamed>

Assigned : Work order in association <unnamed>

Public Interface:

Operations:

Create

Delete

Change

AddWorker

Private Interface:

Attributes:

Woker Id. : String

Qualification : String

WorkerName : String

Implementation:

Attributes:

Woker Id. : String

Qualification : String

WorkerName : String

State machine: No

Concurrency: Sequential

Persistence: Transient

Operation name:

Create

Public member of: Worker

Documentation:

Create the new worker. This operation will prompt the input screen with the attributes from the class that has the association with worker class and require the users to input data in such attributes. After the users save the data of the new worker, the system will generate the running number of the worker Id.

Concurrency: Sequential

Operation name:

Delete

Public member of: Worker

Documentation:

This operation will change the status of the worker to "deletion flag". Once the worker has the status deletion flag , it can't be used for the new transactions in the system.

Concurrency: Sequential

Operation name:

Change

Public member of: Worker

Documentation:

This operation will prompt the users to enter the worker Id.that they want to change. After entering the worker Id., the system will show the information of such worker and the users can change the information.

Concurrency: Sequential

Operation name:

AddWorker

Public member of: Worker

Documentation:

Refer to AddOrder() operation in work order class

Concurrency: Sequential

Class name: Status

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

Assigned : Notification in association <unnamed>

Assigned : Work order in association <unnamed>

Public Interface:

Operations:

Create

Delete

Private Interface:

Attributes:

name : String

Implementation:

Attributes:

name : String

State machine: No

Concurrency: Sequential

Persistence: Persistent

Operation name:

Create

Public member of: Status

Documentation:

Add the new status into the system.

Concurrency: Sequential

Operation name:

Delete

Public member of: Status

Documentation:

Delete status in the system

Concurrency: Sequential

Class name: Corrective order

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: Work order

Associations:

Assigned in : Refurbish order in association <unnamed>

Has : Work center in association <unnamed>

State machine: No

Concurrency: Sequential

Persistence: Transient

Class name: Refurbish order

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: Work order

Associations:

Has : Corrective order in association <unnamed>

Has : Work center in association <unnamed>

Public Interface:

Operations:

Call

State machine: No

Concurrency: Sequential

Persistence: Transient

Class name: Notification

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

Has : Status in association <unnamed>

Has : Defect in association <unnamed>

Assigned : Work order in association <unnamed>

Has : Equipment in association <unnamed>

Public Interface:

Operations:

Create

Change

Close

Delete

CreateOrder

Private Interface:

Attributes:

Notification number : String

Date : Date

Time : Date

Entered by : String

Description : String

Operations:

Getlist

Implementation:

Attributes:

Notification number : String

Date : Date

Time : Date

Entered by : String

Description : String

State machine: Yes

Concurrency: Sequential

Persistence: Persistent

Operation name:

Create

Public member of: Notification

Documentation:

Create the new notification. This operation will prompt the input screen with the attributes from the class that has the association with notification class (except notification number in the notification class) and require the users to input data in such attributes. After the users save notification the system will generate the running number of notification.

Concurrency: Sequential

Operation name:

Change

Public member of: Notification

Documentation:

This operation will prompt the screen that requires the users to input the notification number they wan to change. It will check the status of the notification first , if the status of the notification is "close" users can't change the data. If the system allows the change of notification., it will show the data in such notification and allow users to change the data.

Concurrency: Sequential

Operation name:

Close

Public member of: Notification

Documentation:

When the users want to close the notification, this operation will cause the status of the notification to change to "close". With status "close", users can't change data in this notification.

Concurrency: Sequential

Operation name:

Delete

Public member of: Notification

Documentation:

When the users want to delete the notifications in the system, this operation will first check the status of the notification. If the status of the notification is "closed" ,this operation will change the status of the notification to "deletion flag".That means such notification is logically removed from the system. After this, the process of archiving will start to physically remove such notification.

Concurrency: Sequential

Operation name:

Getlist

Private member of: Notification

Documentation:

This is the operation used to call the report of the notification. It will prompt the criteria of the selection list to the users to put in and this operation will generate the list of the notifications that match the criteria.

Concurrency: Sequential

Operation name:

CreateOrder

Public member of: Notification

Documentation:

This operation will cause the work order to be created and automatically link to the notification that cause such work order to be created (see create() operation in class "work order' for more detail).

Concurrency: Sequential

Class name: Work order

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

Has : Worker in association <unnamed>

Has : Status in association <unnamed>

Has : Notification in association <unnamed>

Has : Equipment in association <unnamed>

Public Interface:

Operations:

Create

AddOperation

Confirm

Close

CancelConfirm

CheckMatAvailability

CheckCapacities

AddWorker

DeleteWorker

AddEquipment

DeleteOperation

DeleteEquipment

Change

Release

Private Interface:

Attributes:

Order number : String

Start : Date

Finished : Date

Implementation:

Attributes:

Order number : String

Start : Date

Finished : Date

State machine: Yes

Concurrency: Sequential

Persistence: Transient

Operation name:

Create

Public member of: Work order

Documentation:

Create the new work order. This operation will prompt the input screen with the attributes from the class that has the association with the work order class (except order number in the work order class) and require the users to input data in such attributes. After the users save work order, the system will generate the running number for the work order.

Concurrency: Sequential

Operation name:

AddOperation

Public member of: Work order

Documentation:

This operation is to add work center, the required time for doing the job for this operation into the operation of the work order. The time entered will recalculate the start and finish date of the work order.

Concurrency: Sequential

Operation name:

Confirm

Public member of: Work order

Documentation:

This operation is to confirm that the work order is finished. This operation will prompt the screen to enter the time that the worker take to do the job and the name of the worker who does the job. After this operation is done, the order status is changed to "CONFIRM". The precondition of this operation is the work order that has status "RELEASE".

Concurrency: Sequential

Operation name:

Close

Public member of: Work order

Documentation:

This operation will change the status of work order to "CLOSE", user can not make any further changes in the work order. The precondition of this operation is the order status "CONFIRM"

Concurrency: Sequential

Operation name:

CancelConfirm

Public member of: Work order

Documentation:

If there is some mistake in entering the confirmation data, the users can cancel the confirmation data. After this operation is executed the work order status "CONFIRM" will disappear.

Concurrency: Sequential

Operation name:

CheckMatAvailability

Public member of: Work order

Documentation:

This operation check the availability of material that needs to be used in the work order. If the material is available, the status of the order will change to "MATERIAL CONFIRM", otherwise the status will change to material shortage.

Concurrency: Sequential

Operation name:

CheckCapacities

Public member of: Work order

Documentation:

This operation check the availability of capacity that needs to be used in the work order. If the capacity is available the status of work order will change to "CAPACITY CONFIRM", otherwise the status will change to "CAPACITY HORTAGE". The capacity requirement of work order is calculated from the time required in operation for each work center.

Concurrency: Sequential

Operation name:

AddWorker

Public member of: Work order

Documentation:

This operation will add the additional worker who is responsible for maintenance order.

Concurrency: Sequential

Operation name:

DeleteWorker

Public member of: Work order

Documentation:

This operation will delete the worker who is responsible for the work order.

Concurrency: Sequential

Operation name:

AddEquipment

Public member of: Work order

Documentation:

This operation will add the additional equipment into work order.

Concurrency: Sequential

Operation name:

DeleteOperation

Public member of: Work order

Documentation:

This operation will result in the deletion of the operation in work order. After the operation is deleted, The time required in work order will be recalculated.

Concurrency: Sequential

Operation name:

DeleteEquipment

Public member of: Work order

Documentation:

This operation will result in the deletion of the equipment in the work order. The system will prompt the current equipment in the work order and the users will select the equipment and delete it.

Concurrency: Sequential

Operation name:

Change

Public member of: Work order

Documentation:

This operation will prompt the screen that requires the users to input the work order number they want to change. It will check the status of the order first, if the status of the work order is "CLOSE" users can not change the data. If the system allows the change of the work order, it will show the data in such work order and allow users to change the data.

Concurrency: Sequential

Operation name:

Release

Public member of: Work order

Documentation:

This operation will result in the change in the status of work order to "RELRASE". Once this operation is invoked , it will also perform the "CheckMat Availablity" and "CheckCapacities" operation, if either the material and the capacity is not available, the work order can't be released.

Concurrency: Sequential

Class name: Preventive order

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: Work order

Associations:

Has : Maintenance task list in association <unnamed>

State machine: No

Concurrency: Sequential

Persistence: Transient

Operation name:

Call

Public member of: Preventive order

Documentation:

After the operation "schedule" is executed, it will generate the schedule of the next work order. If the users want the work orders to be generated according to the date proposed by the system, the users can "call" such work order. After the call operation is executed the work order will be created based on the scheduled date from the system.

Concurrency: Sequential

Class name: Work center

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

Assigned in : Corretive order in association <unnamed>

Assigned in : Refurbish order in association <unnamed>

<no rolename> : Maintenance task list in association <unnamed>

Public Interface:

Operations:

CheckCapacity

Create

Change

Delete

Private Interface:

Attributes:

Workcenter name : String

Date of creation : Date

CapacityPerday : Integer

Description : String

Implementation:

Attributes:

Workcenter name : String

Date of creation : Date

CapacityPerday : Integer

Description : String

State machine: No

Concurrency: Sequential

Persistence: Transient

Operation name:

CheckCapacity

Public member of: Work center

Documentation:

This operation will check the requirement of capacity from work order at the point of time. It will sum the requirement of time from operation in the work orders

that lies in the same date and compare with the attribute "CapacityperDay" to display the capacity requirement and available capacity.

Concurrency: Sequential

Operation name:

Create

Public member of: Work center

Documentation:

This operation will create the new work center in the system. It will prompt the users to enter all of the attributes in class work center.

Concurrency: Sequential

Operation name:

Change

Public member of: Work center

Documentation:

This operation will prompt the users to enter the name of the work center they want to change. After entering the name of the work center the system will show the information of such work center and the users can change the information.

Concurrency: Sequential

Operation name:

Delete

Public member of: Work center

Documentation:

This operation will change the status of work center to "deletion flag". Once the work center has the status deletion flag , it can't be used for the new transactions in the system.

Concurrency: Sequential

Class name: Equipment

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

Assigned in : Notification in association <unnamed>

Assigned in : Work order in association <unnamed>

Assigned in : Maintenance item in association <unnamed>

Public Interface:

Operations:

Create

Delete

Change

Private Interface:

Attributes:

Number : Integer

Description : String

Manufacturer : String

Date installed : Date

Implementation:

Attributes:

Number : Integer

Description : String

Manufacturer : String

Date installed : Date

State machine: No

Concurrency: Sequential

Persistence: Transient

Operation name:

Create

Public member of: Equipment

Documentation:

This operation will create the new equipment in the system. It will prompt the screen with all of the attributes from class equipment that require the users to input data. If the users do not put the equipment number ,after the users save the data ;the system will automatically generate the number of equipment.

Concurrency: Sequential

Operation name:

Delete

Public member of: Equipment

Documentation:

This operation will change the status of the equipment to "deletion flag". Once the equipment has the status deletion flag, it can not be used for the new transactions in the system.

Concurrency: Sequential

Operation name:

Change

Public member of: Equipment

Documentation:

This operation will prompt the users to enter the number of equipment they want to change. After entering the number of equipment, the system will show the information of such equipment and users can change the information.

Concurrency: Sequential

Class name: Maintenance plan

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

<no rolename> : Strategy in association <unnamed>

<no rolename> : Maintenance item in association <unnamed>

Public Interface:

Operations:

Create

Schedule

Change

AddMaintenanceItem

AddStrategy

ChangeMaintenanceItem

Private Interface:

Attributes:

Maintenance plan number : String

Maintenance plan nanme : String

Implementation:

Attributes:

Maintenance plan number : String

Maintenance plan nanme : String

State machine: No

Concurrency: Sequential

Persistence: Transient

Operation name:

Create

Public member of: Maintenance plan

Documentation:

This operation will prompt the input screen with the attributes from the class that has the association with maintenance plan class (except maintenance number in the maintenance plan class) and requires the user to input data in such attributes. After the users save the maintenance plan, the system will generate the running number of the maintenance plan.

Concurrency: Sequential

Operation name:

Schedule

Public member of: Maintenance plan

Documentation:

This operation will schedule the maintenance plan in order to generate the scheduled maintenance order and let the users make a decision to "call" or "skip" the scheduled maintenance order. The system will prompt the users to enter the maintenance plan and the date for start scheduling.

Concurrency: Sequential

Operation name:

Change

Public member of: Maintenance plan

Documentation:

This operation will prompt the screen to users for enter the maintenance plan number they want to change after this the users can make a change in maintenance plan.

Concurrency: Sequential

Operation name:

AddMaintenanceItem

Public member of: Maintenance plan

Documentation:

This operation will add the maintenance item into maintenance plan. When this operation is invoked, it will show the maintenance item that has not assigned to any maintenance plan and the users will select it.

Concurrency: Sequential

Operation name:

AddStrategy

Public member of: Maintenance plan

Documentation:

This operation will add the maintenance strategy into maintenance plan.

Concurrency: Sequential

Operation name:

ChangeMaintenanceItem

Public member of: Maintenance plan

Documentation:

This operation will let the user change the maintenance item in the maintenance plan. The system will prompt the users to enter the maintenance plan number and it will prompt the list of maintenance item for the users to change the information.

Concurrency: Sequential

Class name: Maintenance task list

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

Assigned in : Preventive order in association <unnamed>

<no rolename> : Work center in association <unnamed>

Has : Strategy in association <unnamed>

Assigned in : Maintenance item in association <unnamed>

Public Interface:

Operations:

Create

AddOperation

DeleteOperation

Change

Delete

ChangeOperation

AddStrategy

DeleteStrategy

Private Interface:

Attributes:

Task list name : String

Implementation:

Attributes:

Task list name : String

State machine: No

Concurrency: Sequential

Persistence: Transient

Operation name:

Create

Public member of: Maintenance task list

Concurrency: Sequential

Operation name:

AddOperation

Public member of: Maintenance task list

Documentation:

This operation will add the work center and the time required for work center to do the job of each operation.

Concurrency: Sequential

Operation name:

DeleteOperation

Public member of: Maintenance task list

Documentation:

This operation will delete the data in the operation that the user wants to delete. The system will prompt the operation in the maintenance task list and user select operations they want to delete.

Concurrency: Sequential

Operation name:

Change

Public member of: Maintenance task list

Documentation:

This operation will prompt the screen that requires the users to input the task list name that they want to change. It will check the status of the maintenance task list first. If the status of the task list is "DELETION FLAG" users can't change data. If the system allows the change of maintenance task list, it will show the data in such maintenance task list and allow users to change data.

Concurrency: Sequential

Operation name:

Delete

Public member of: Maintenance task list

Documentation:

This operation will change the status of maintenance task list to "DELETION FLAG". Once the maintenance task list has the status "DELETION FLAG", it can't be used in the new transaction in the system.

Concurrency: Sequential

Operation name:

ChangeOperation

Public member of: Maintenance task list

Documentation:

This operation will let the users change the data in the operation, for example, work center name, time required in each work center in the operation.

Concurrency: Sequential

Operation name:

AddStrategy

Public member of: Maintenance task list

Documentation:

This operation will prompt the screen of maintenance task list and let users type in the maintenance strategy of this maintenance task list.

Concurrency: Sequential

Operation name:

DeleteStrategy

Public member of: Maintenance task list

Documentation:

This operation will delete the existing strategy from maintenance task list.

Concurrency: Sequential

Class name: Strategy

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

Assigned in : Maintenance plan in association <unnamed>

Assigned : Maintenance task list in association <unnamed>

Assigned : Maintenance item in association <unnamed>

Public Interface:

Operations:

Create

CreatePackage

ChangePackage

DeletePackage

Private Interface:

Attributes:

Strategy name

Implementation:

Attributes:

Strategy name

State machine: No

Concurrency: Sequential

Persistence: Transient

Operation name:

Create

Public member of: Strategy

Documentation:

This operation will prompt the users to enter the name of the new strategy and will invoke the operation "CreatePackage"

Concurrency: Sequential

Operation name:

CreatePackage

Public member of: Strategy

Documentation:

This operation will be invoked after users create maintenance strategy. It will prompt the users to input the data of package for the maintenance strategy.

Concurrency: Sequential

Operation name:

ChangePackage

Public member of: Strategy

Documentation:

This operation will let the users change the package in maintenance strategy. The system will prompt the users to input the strategy name and will prompt the package in this maintenance strategy for user to change it.

Concurrency: Sequential

Operation name:

DeletePackage

Public member of: Strategy

Documentation:

This operation will delete the package that is used in the maintenance strategy.

Concurrency: Sequential

Class name: Maintenance item

Category: Logical View

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

Has : Equipment in association <unnamed>

Assigned in : Maintenance plan in association <unnamed>

Has : Maintenance task list in association <unnamed>

Has : Strategy in association <unnamed>

Public Interface:

Operations:

AddStrategy

Create

Delete

AddEquipment

ChangeStrategy

ChangeEQ

Change

Private Interface:

Attributes:

Maintenence item Id : String

Description : String

Implementation:

Attributes:

Maintenence item Id : String

Description : String

State machine: No

Concurrency: Sequential

Persistence: Transient

Operation name:

AddStrategy

Public member of: Maintenance item

Documentation:

This operation will add maintenance strategy into maintenance item.

Concurrency: Sequential

Operation name:

Create

Public member of: Maintenance item

Documentation:

Create the new maintenance item. This operation will prompt the input screen with the attributes from the class that has the association with maintenance item class (except Maintenance item Id. in the maintenance item class) and requires users to input

data in such attributes. After the users save maintenance item, the system will generate the running number of maintenance item Id.

Concurrency: Sequential

Operation name:

Delete

Public member of: Maintenance item

Documentation:

This operation will change the status of maintenance item to "DELETION FLAG".Once the maintenance item has the status "DELETION FLAG", it can't be used in the new transaction in the system.

Concurrency: Sequential

Operation name:

AddEquipment

Public member of: Maintenance item

Documentation:

When the operation create() is called in class maintenance item, it will invoke the operation Add Equipment() to let users input the equipment for the maintenance item.

Concurrency: Sequential

Operation name:

ChangeStrategy

Public member of: Maintenance item

Documentation:

This operation will let the user change the strategy in maintenance item.The precondition is system can invoke Change() operation in maintenance item class.

Concurrency: Sequential

Operation name:

ChangeEQ

Public member of: Maintenance item

Documentation:

This operation will let the user to change equipment in maintenance item. The precondition is system can invoke Change() operation in maintenance item class.

Concurrency: Sequential

Operation name:

Change

Public member of: Maintenance item

Documentation:

This operation will prompt the screen that requires the users to input the maintenance item name that they want to change. It will check the status of the maintenance item first. If the status of maintenance item is "DELETION FLAG" users can't change data. If the system allows the change of maintenance item, it will show the data in such maintenance item and allow users to change data.

Concurrency: Sequential

Class name: BTSC

Category: Use Case View

Documentation:

BTSC actors are the group of persons who see and analyze the report generated by the system with Siemens actors.

Stereotype: Actor

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

<no rolename> : Generate report in association <unnamed>

State machine: No

Concurrency: Sequential

Persistence: Transient

Class name: Siemens

Category: Use Case View

Documentation:

Siemens actors are the group of persons who see and analyze the report generated by the system with BTSC actors.

Stereotype: Actor

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

<no rolename> : Generate report in association <unnamed>

State machine: No

Concurrency: Sequential

Persistence: Transient

Class name: ECC

Category: Use Case View

Documentation:

ECC is the engineer controller who is responsible for receiving the phone call from the operation workers in the BTS project about the malfunction of the equipment in the BTS project.

Stereotype: Actor

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

<no rolename> : Maintain notification in association <unnamed>

State machine: No

Concurrency: Sequential

Persistence: Transient

Class name: Supervisor

Category: Use Case View

Documentation:

Maintenance supervisor for each maintenance department (from organization chart). It is the primary actor in this system and performs most of the functions(use cases) in this system.

Stereotype: Actor

External Documents:

Export Control: Public

Cardinality: n

Hierarchy:

Superclasses: none

Associations:

<no rolename> : Schedule maintenance plan in association <unnamed>

<no rolename> : Maintain notification in association <unnamed>

<no rolename> : Maintain work center in association <unnamed>

<no rolename> : Maintain equipment in association <unnamed>

<no rolename> : Maintain maintenance task list in association <unnamed>

<no rolename> : Maintain work order in association <unnamed>

<no rolename> : Maintain maintenance strategy in association <unnamed>

<no rolename> : Maintain maintenance plan in association <unnamed>

<no rolename> : Maintain maintenance item in association <unnamed>

State machine: No

Concurrency: Sequential

Persistence: Transient

Use Case name: Generate report

Category: Use Case View

Documentation:

Report for this system is generated and reviewed by BTSC and Siemens.

External Documents:

Abstract: No

State machine: No

Associations:

<no rolename> : BTSC in association <unnamed>

<no rolename> : Siemens in association <unnamed>

Use Case name: Schedule maintenance plan

Category: Use Case View

Documentation:

The supervisor schedules the maintenance plan in the preventive maintenance. After he schedules the maintenance plan, the work orders are generated (see more details of this use case in scenarios part).

External Documents:

Abstract: No

State machine: No

Associations:

<no rolename> : Supervisor in association <unnamed>

Use Case name: Maintain work center

Category: Use Case View

Documentation:

The supervisor maintains work center that is used in the maintenance task list use case (see more details of this use case in the scenarios part).

External Documents:

Abstract: No

State machine: No

Associations:

<no rolename> : Supervisor in association <unnamed>

<no rolename> : Maintain maintenance task list in association <<Uses>> (uses).

Use Case name: Maintain equipment

Category: Use Case View

Documentation:

The supervisor maintains equipment that is used in the BTS project (see more details in the scenarios part).

External Documents:

Abstract: No

State machine: No

Associations:

<no rolename> : Supervisor in association <unnamed>

Use Case name: Maintain maintenance task list

Category: Use Case View

Documentation:

The supervisor maintains maintenance task list that will be used in the maintenance order to show the sequence of the works in the work order (see more details of this use case in scenarios part.)

External Documents:

Abstract: No

State machine: No

Associations:

<no rolename> : Maintain work center in association <<Uses>> (uses)

<no rolename> : Supervisor in association <unnamed>

Use Case name: Maintain work order

Category: Use Case View

Documentation:

The supervisor maintains maintenance work order in the system (see more details of this use case in the scenarios part)

External Documents:

Abstract: No

State machine: No

Associations:

<no rolename> : Supervisor in association <unnamed>

Use Case name: Maintain maintenance strategy

Category: Use Case View

Documentation:

The supervisor maintains maintenance strategy used when maintaining the maintenance plan (see more details of this use case in the scenarios part).

External Documents:

Abstract: No

State machine: No

Associations:

<no rolename> : Maintain maintenance plan in association <<Uses>> (uses)

<no rolename> : Supervisor in association <unnamed>

Use Case name: Maintain maintenance plan

Category: Use Case View

Documentation:

The supervisor maintains the maintenance plan of the equipment for preventive maintenance purpose (see more details of this use case in the scenarios part)

External Documents:

Abstract: No

State machine: No

Associations:

<no rolename> : Maintain maintenance strategy in association <<Uses>> (uses)

<no rolename> : Supervisor in association <unnamed>

Use Case name: Maintain notification

Category: Use Case View

Documentation:

The supervisor maintains malfunction notification when there is malfunction in the equipment (see more details of this use case in the scenarios part)

External Documents:

Abstract: No

State machine: No

Associations:

<no rolename> : Supervisor in association <unnamed>

<no rolename> : ECC in association <unnamed>

Use Case name: Maintain maintenance item

Category: Use Case View

Documentation:

The supervisor maintains maintenance item that is used in the maintenance plan to show which object needs to be performed preventive maintenance.

External Documents:

Abstract: No

State machine: No

Associations:

<no rolename> : Supervisor in association <unnamed>

APPENDIX G

RELATIONAL DATABASE TABLES

Table G.1. Status_Workorder.

	Field name	Data type
PK	Status	String
PK	Work order number	String

Table G.2. Status_Notification.

	Field name	Data type
PK	Status	String
PK	Notification number	String

Table G.3. Defect_Notif.

	Field name	Data type
PK	Defect code	String
PK	Notification number	String

Table G.4. Notification.

	Field name	Data type
PK	Notification number	String
	Description	String
	Malfunction date	Date/Time
	Malfunction time	Date/Time
	Entered by	String
	EQ number	String

Table G.5. Defect.

	Field name	Data type
PK	Defect code	String
	Defect name	String

Table G.6. Equipment.

	Field name	Data type
PK	EQ number	String
	Description	String
	Serial number	String
	Manufacturer	String
	Installed date	Date/Time
	Installed location	String

Table G.7. Maintenance_Item.

	Field name	Data type
PK	Maintenance item id.	String
	Description	String
	EQ number	String
	Task list name	String
	Maintenance plan number	String
	Maintenance strategy	String

Table G.8. Work_Order.

	Field name	Data type
PK	Work order number	String
	Start date	Date
	Finish date	Date
	Work order type	String
	Notification number	String
	EQ number	String
	Worker id.	String

Table G.9. Work_Order_Worker.

	Field name	Data type
PK	Work order number	String
PK	Worker id.	String

Table G.10. Department.

	Field name	Data type
PK	Department id.	String
	Department name	String

Table G.11. Worker_Dept.

	Field name	Data type
PK	Worker id.	String
	Department id.	String

Table G.12. Work_Center.

	Field name	Data type
PK	Work center name	String
	Description	String

Table G.13. Work_Center_in_Workorder.

	Field name	Data type
PK	Work center name	String
PK	Work order number	String
	Operation description	String

Table G.14. Task_List.

	Field name	Data type
PK	Task list name	String
	Strategy name	String

Table G.15. Work_Center_Task_List.

	Field name	Data type
PK	Task list name	String
PK	Work center name	String
PK	Counter	String
	Operation description	String
	Work duration	Number

APPENDIX H

EXAMPLE OF SCREENS AND REPORTS

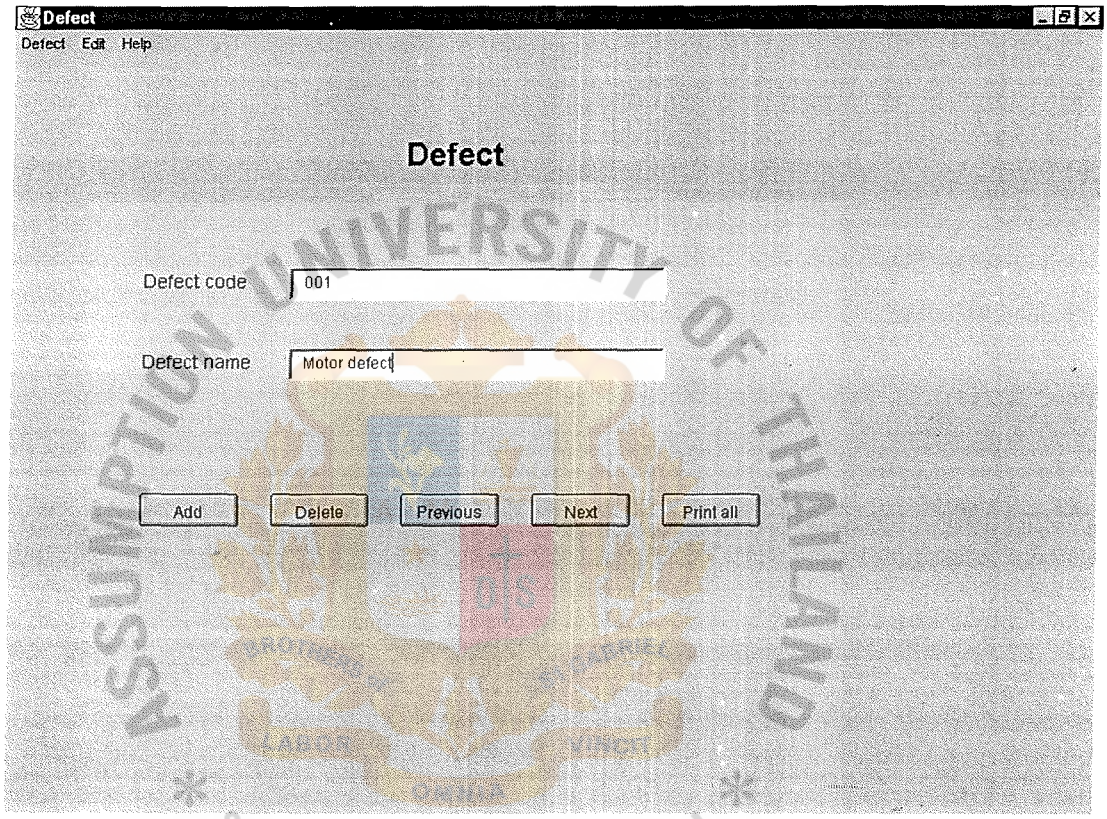

Figure H.1. Defect Code Input Screen.

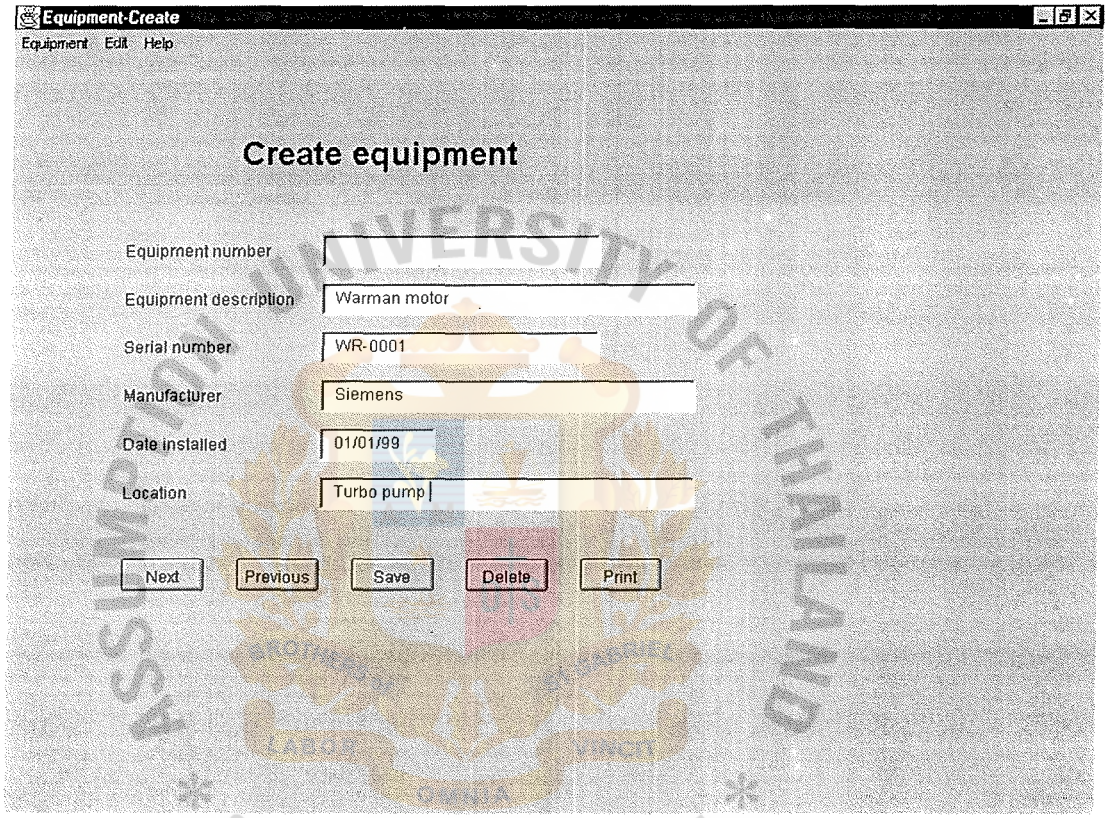

Figure H.2. Equipment Input Screen.

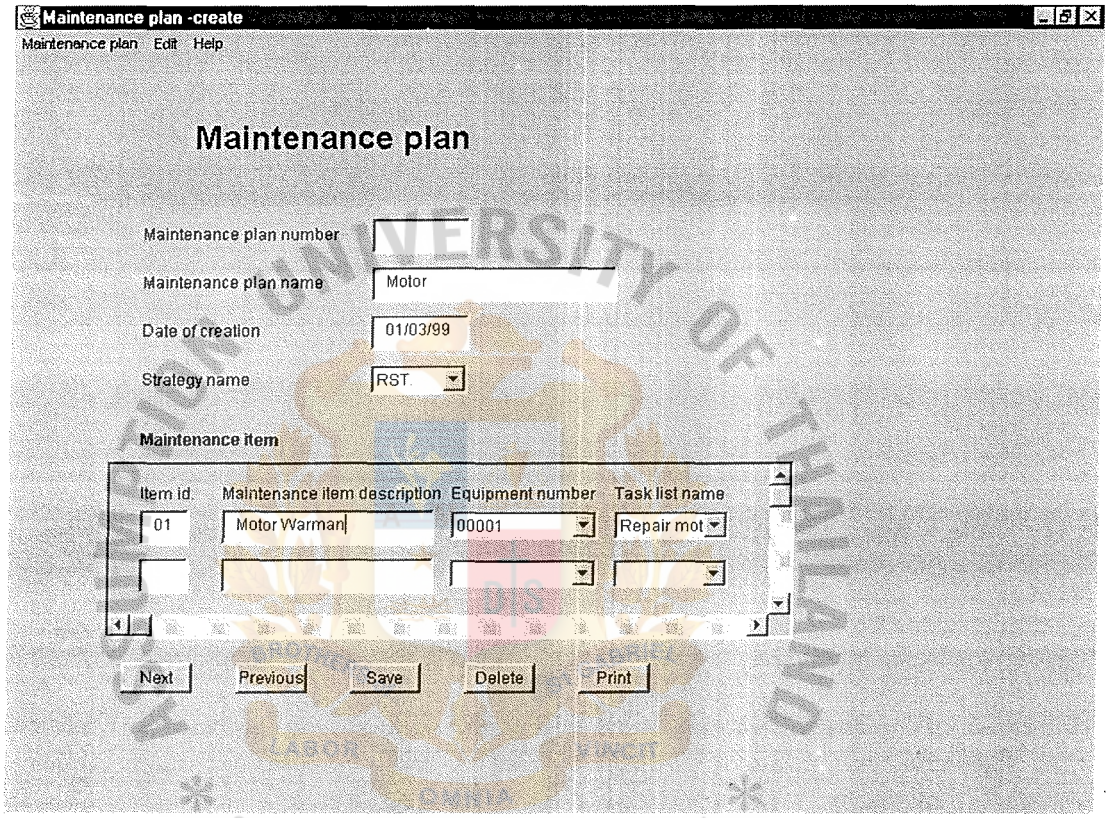

Figure H.3. Maintenance Plan Input Screen.

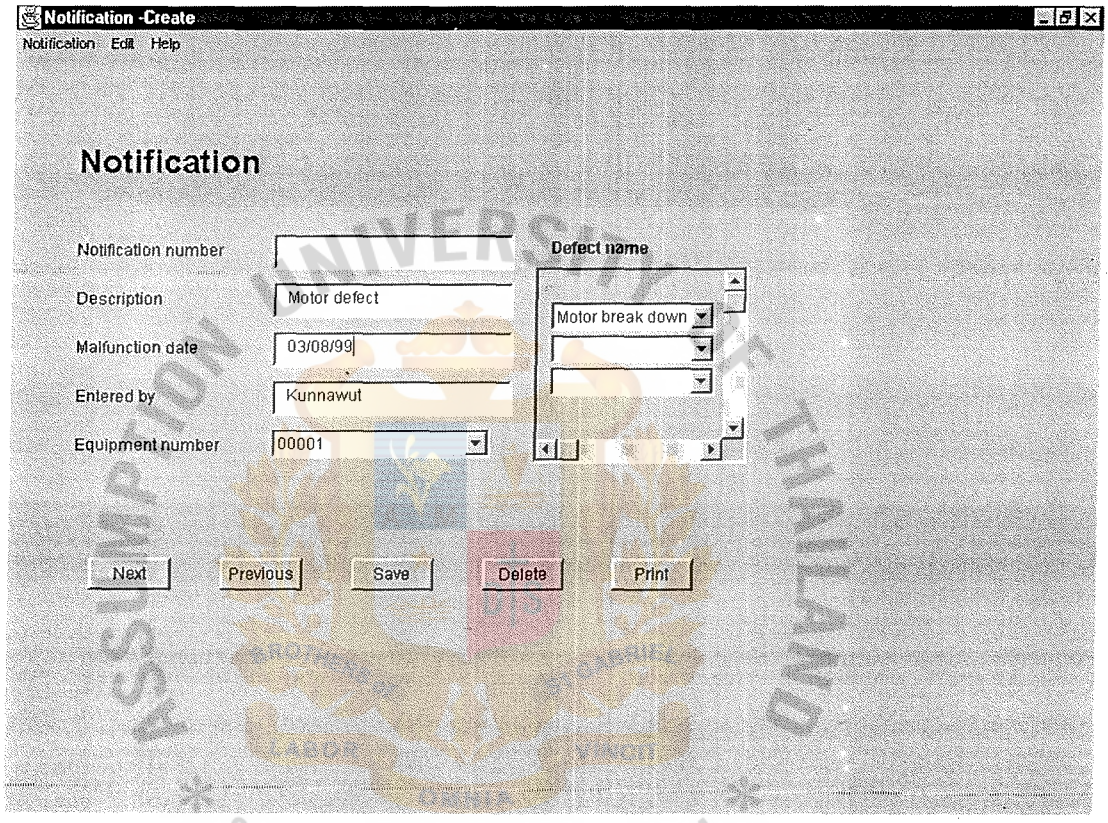

Figure H.4. Notification Input Screen.

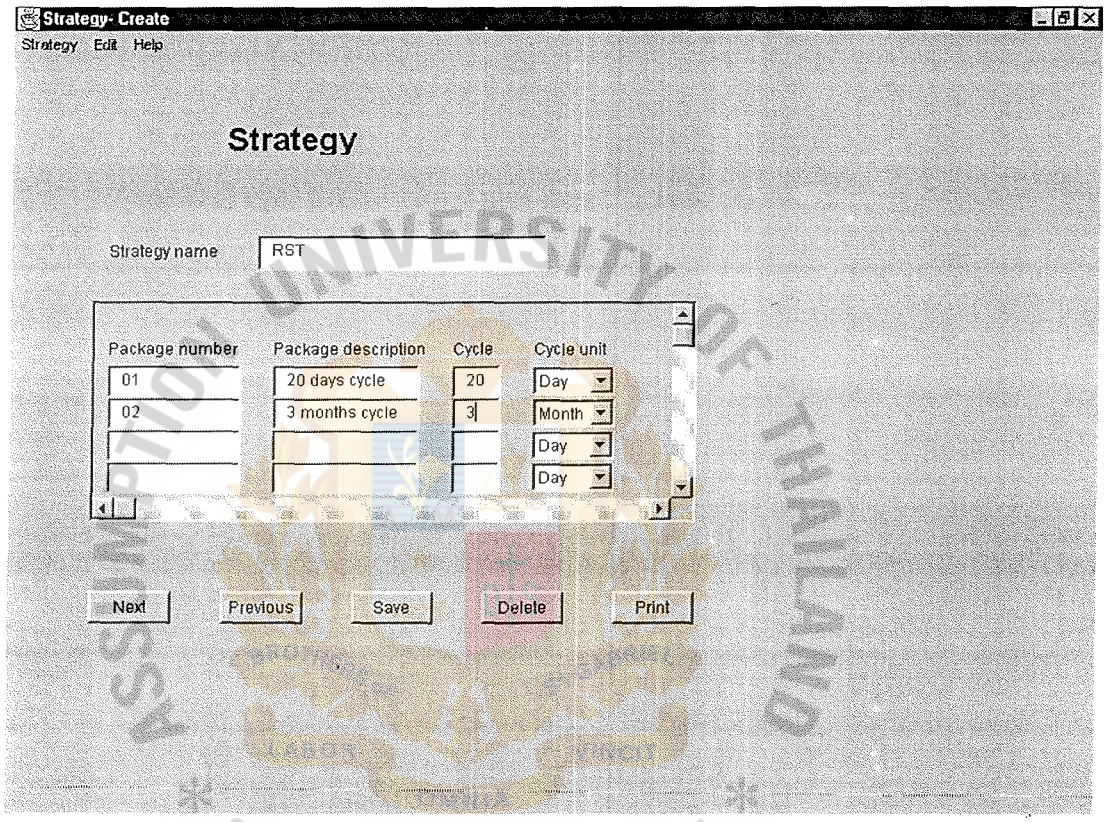

Figure H.5. Strategy Input Screen.

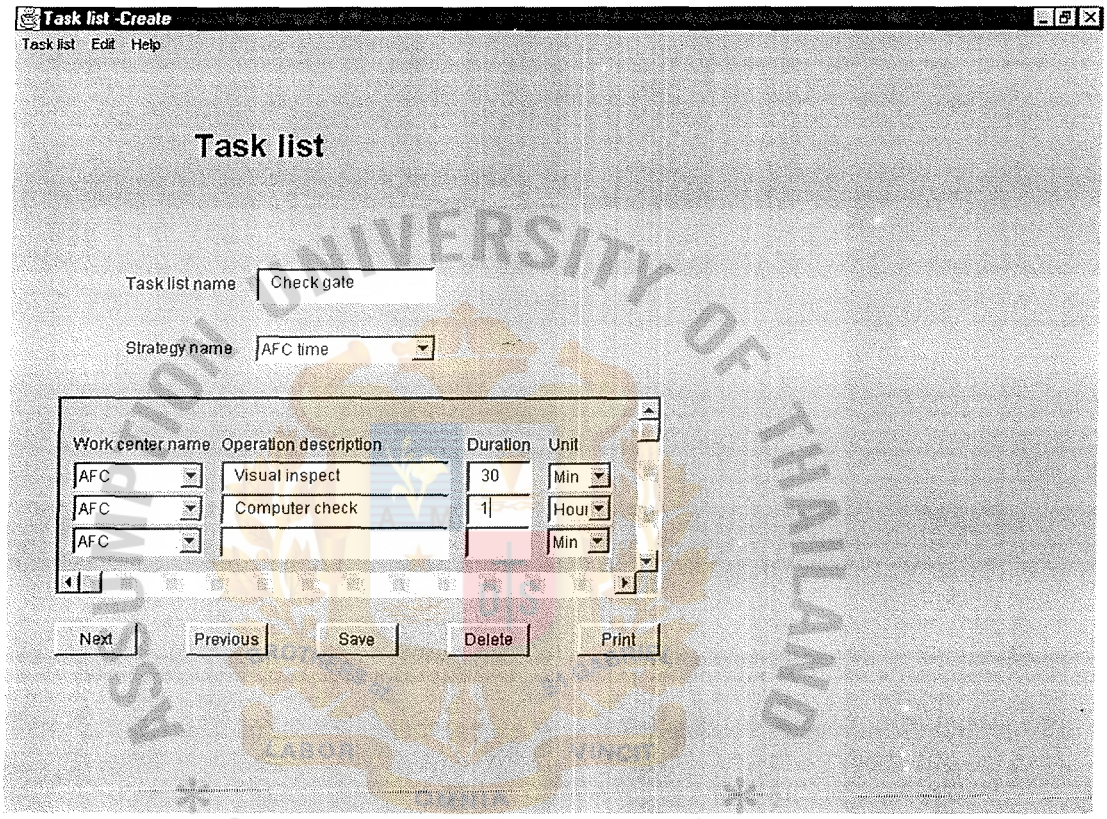

Figure H.6. Task List Input Screen.

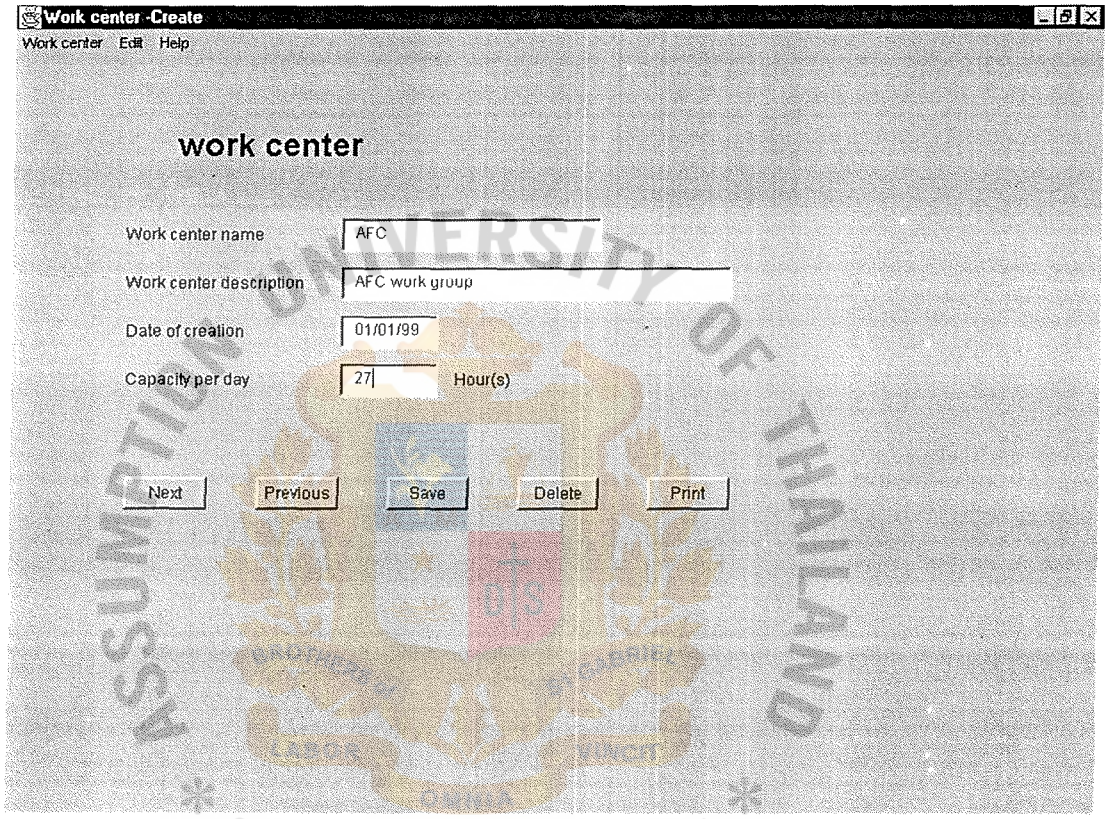

Figure H.7. Work Center Input Screen.

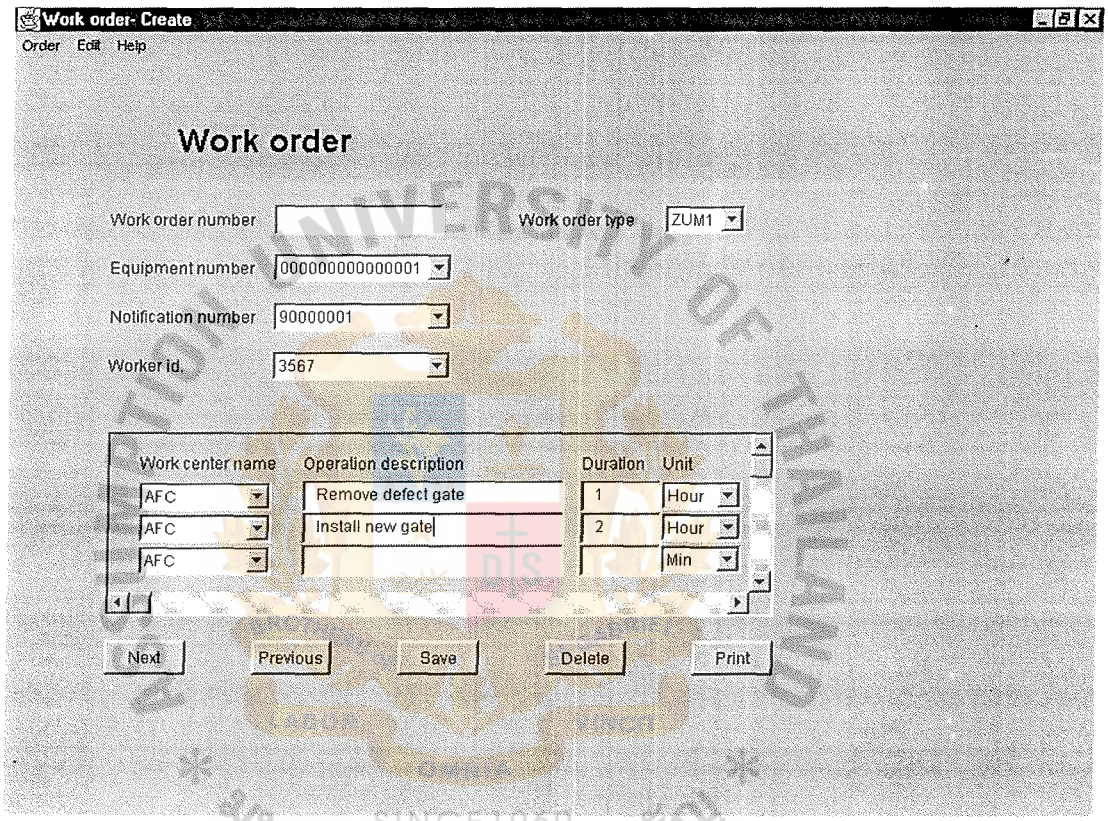

Figure H.8. Work Order Input Screen.

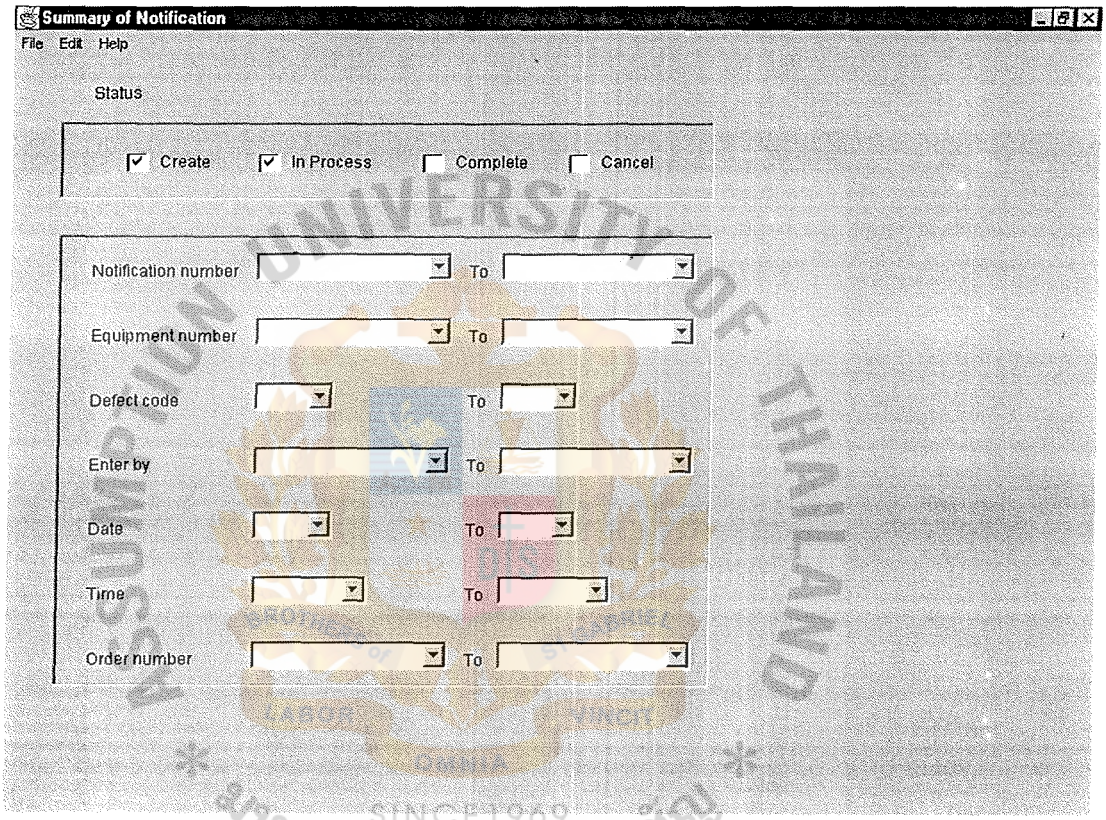

Figure H.9. Notification Summary Report Screen.

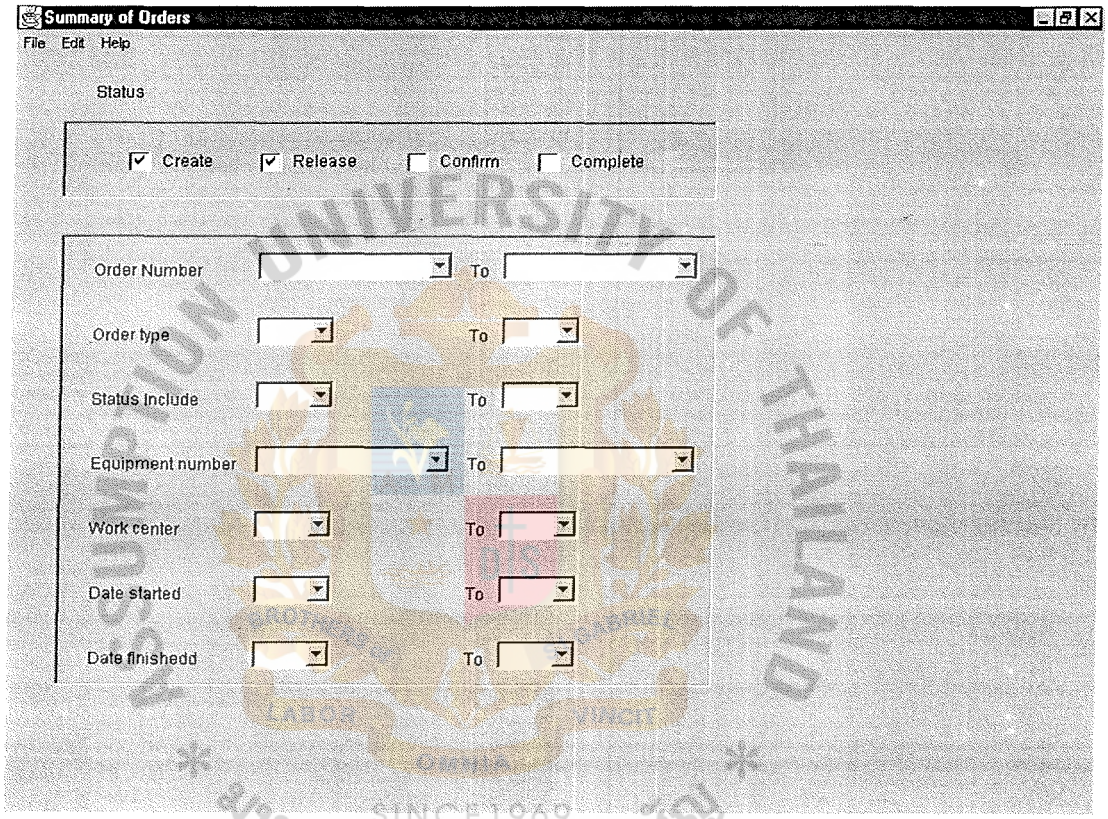

Figure H.10. Order Summary Report Screen.

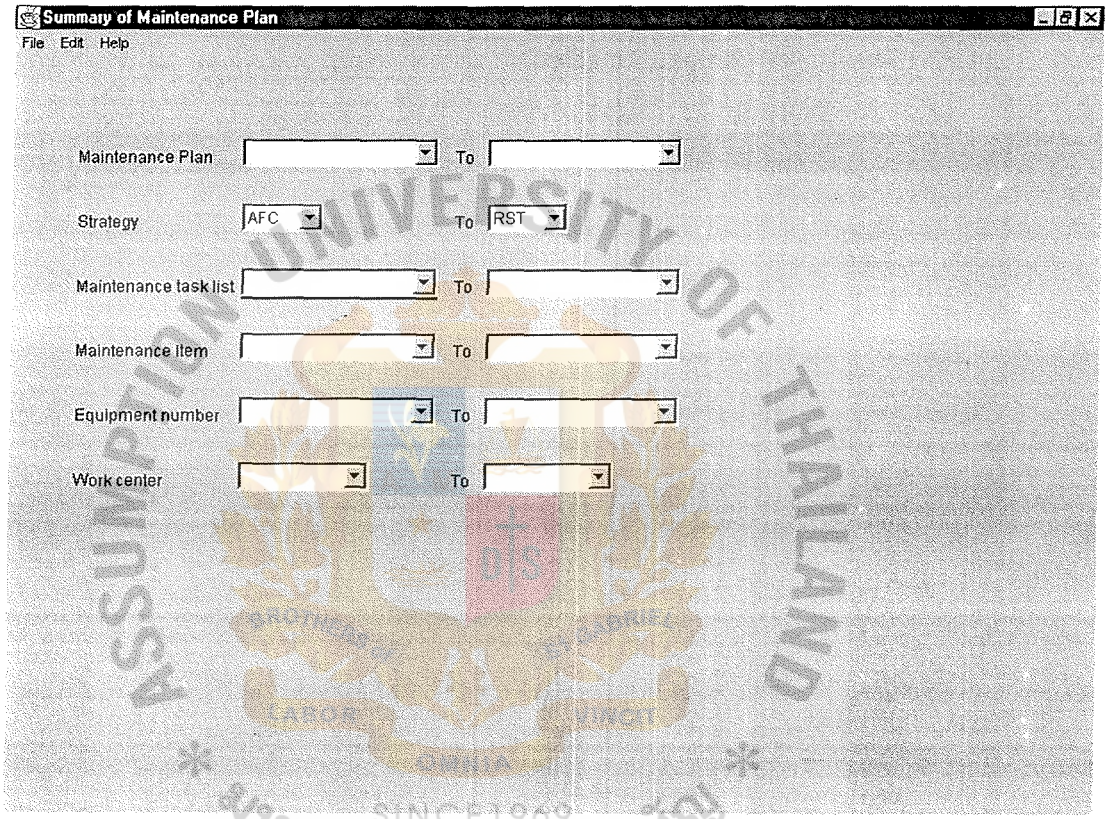

Figure H.11. Maintenance Plan Summary Report Screen.

Equipment analysis report

Equipment number	Month	Total Of Notification created	Clock error	Computer error	Motor overheat
AJ56	Apr.	1	1		
AJ56	May.	1			1
BB123	Aug.	1	1		
JJ8	Dec.	1	1		
JJ9	Oct.	1			1
XC99	June.	1			1
XC99	Sep.	1		1	
XY123	Jan.	1		1	
XY123	May.	1			1
ZS124	Feb.	2		2	
ZZ123	Feb.	2		1	1
ZZ123	Mar.	1		1	
ZZ134	Mar.	1			1

Figure H.12. Equipment analysis Report.

Equipment

Equipment no.	Equipment description	Serial number	Manufacturer	Date installed	Location
1	Motor	XJ1234	Siemens	12/3/98	EMU1 back
2	Motor	XJ1546	Siemens	3/12/98	EMU1 front
3	Gate left	1234567	Siemens	1/1/99	N1
4	Gate right	456778y	Siemens	1/1/99	N1
5	Circuit breaker	XJ1234	Bosch	3/2/99	N2
6	Circuit breaker	CJ3456	Bosch	3/3/99	N2
7	Ticket machine	C345	Comlink	5/5/99	N3 right
8	Ticket machine	C234	Comlink	8/5/99	N3 Left
9	Air condition unit	Xd345	Mitsubishi	1/1/99	EMU1

Figure H.13. Equipment Report.

Location analysis report

Location	Month	Total Of Notification created	Clock error	Computer error	Motor overheat
E1	Jan.	1	1		
E1	May.	2	1	1	
N1	Jan.	2	1	1	
N1	July.	1	1		
N2	Feb.	1	1		
N2	Mar.	1			1
N2	May.	1			1
N2	Sep.	1		1	
N3	Feb.	1		1	

Figure H.14. Location Analysis Report.

Maintenance plan

Maintenance plan number 2

Maintenance plan name RST

Strategy name RST

Maintenance item id	Maintenance item description	Equipment number	Task list name
1	Motor item	1	Repair motor

Maintenance plan number 4

Maintenance plan name AFC

Strategy name AFC time

Maintenance item id	Maintenance item description	Equipment number	Task list name
5	Gate right	4	Check gate

Figure H.15. Maintenance Plan Report.

Summary report of notification by defect code

Defect code	Defect name	Year	Notification created	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
001	Motor overheat	1998	1			1									
001	Motor overheat	1999	6		2	1	1						1	1	
002	Clock error	1998	1				1								
002	Clock error	1999	3			1			1		1				
004	Computer error	1999	5				1	1		1		1			1

Figure H.16. Notification by Defect Code Report.

Notification

Notification number	4	**Entered by**	**kunnawut**	**Malfunction Date**	12/2/99
Description	Motor is malfunction	**Equipment number**	1	**Malfunction Time**	12:00:00 PM

Defect code	**Defect name**
001	Motor overheat

Notification number	7	**Entered by**	**Kunnawut**	**Malfunction Date**	12/3/99
Description	AFC error	**Equipment number**	3	**Malfunction Time**	12:00:00 PM

Defect code	**Defect name**
02	Clock error

Figure H.17. Notification Report.

Notification summary report

Notification number	Status	Entered by	Equipment number	Defect code	Defect name	Date	Time	Order number
0000001	Create	Meeckhai	1000	0008	Motor break	1/19/99	12:00:00 PM	
0000010	Create	Chakri	2000	0003	Gate can not	2/3/99	9:22:00 PM	
0000021	Create	Chart	2100	0005	Tim error	2/3/99	12:09:00 PM	
0000056	Create	Meechai	1001	0001	Motor break	3/4/99	11:56:00 PM	
0000067	Create	Boonma	2300	0009	Brake error	12/12/98	2:30:00 AM	
0000099	In Proc	Veera	23005	0012	Air cond	12/12/99	3:00:00 PM	00002300
0000123	In Proc	Chart	2101	0005	Tim error	3/3/99	4:00:00 AM	00002100
0000154	In Proc	Steve	5000	0020	Breaker	11/10/99	6:30:00 PM	00002200

Figure H.18. Notification Summary Report.

OrderReport

Order number	Order type	Status	Equipment number	Work center	Date started	Date finished	Notification number
00000045	ZUM1	Create	00000204	AFC	01/03/99	02/03/99	000000045
00000056	ZUM1	Create	00000206	RST	02/03/99	02/03/99	000000056
00000078	ZUM1	Create	00000206	RST	03/03/99	05/03/99	000000100
00000080	ZUM1	Create	00000134	PSY	01/05/99	10/05/99	000000456
00000090	ZUM1	Release	00000132	AFC	01/06/99	01/06/99	000000120
00000100	ZUM1	Release	00000444	TEL	04/05/99	06/05/99	000000123
00000123	ZUM1	Release	00000444	PSY	05/05/99	05/05/99	000000344
00000005	ZRF1	Create	00000204	RST	09/09/99	09/09/99	

Figure H.19. Order Report.

Maintenance plan summary report

Maintenance plan number	Strategy	Maintenance task list	Maintenance item number	Equipment number	Work center	Last maintenance order number
1	AFC	AFC	1	999	AFC	000002345
16	AFC	AFC1	2	999	AFC	000002356
10	AFC	AFC2	4	12340	AFC	
13	AFC	AFC	7	999	AFC	000004444
21	RST	RST	59	5432	RST	000004445
24	RST	RST	32	2322	RST	
17	RST	RST1	45	5432	RST	000050555
19	RST	RST2	87	2322	RST	000033345
29	RST	RST1	56	3434	RST	000000556

Figure H.20. Maintenance Plan Summary Report.

WorkOrder Report

Work order number 4

Work order type ZSF1 **Notification number** 4

Equipment number 1

Work center name	Worker name	Operation description	Duration
AFC	Suvit	Repair motor	10

Work order number 5

Work order type ZUM1 **Notification number** 8

Equipment number 2

Work center name	Worker name	Operation description	Duration
RST	Suvit	Remove defect motor	12

Figure H.21. Work Order Report.

APPENDIX I

PROJECT PLAN

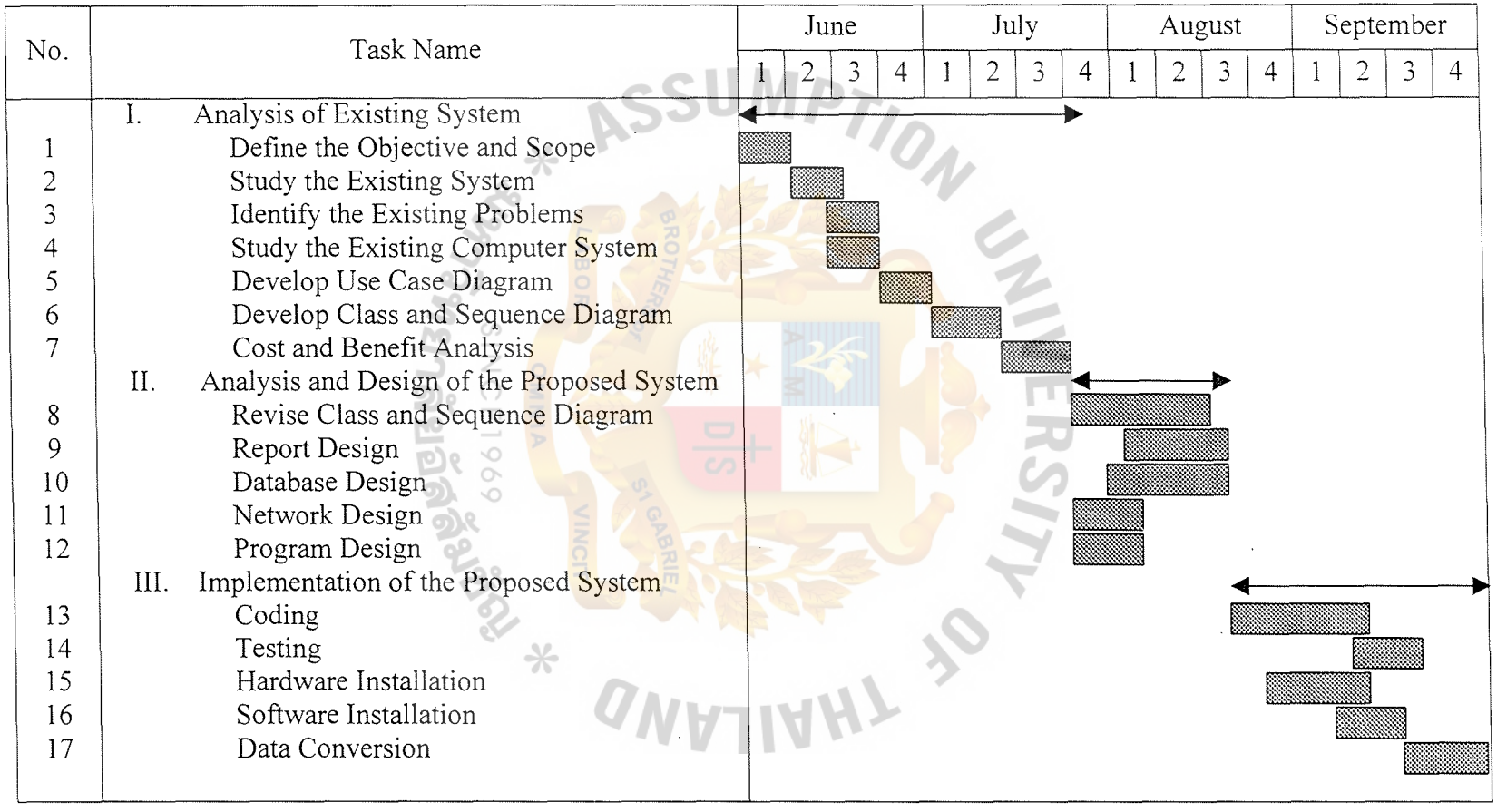

Figure I.1. Gantt Chart for BTS Project.

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Table G.16. Maintenance_ Plan.

	Field name	Data type
PK	Maintenance number	String
	Maintenance plan name	String
	Date of creation	Date/Time
	Strategy name	String

Table G.17. Maintenance_ Package.

	Field name	Data type
PK	Strategy name	String
PK	Package number	String
	Package description	String
	Cycle	Number
	Cycle unit	String

Table G.18. Preventive_ Work_Order.

	Field name	Data type
PK	Work order number	String
	Task list name	String