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The maintenance planning for inspection ships of the Harbour Department of Thailand

Chainarong Bongkarn
WMU

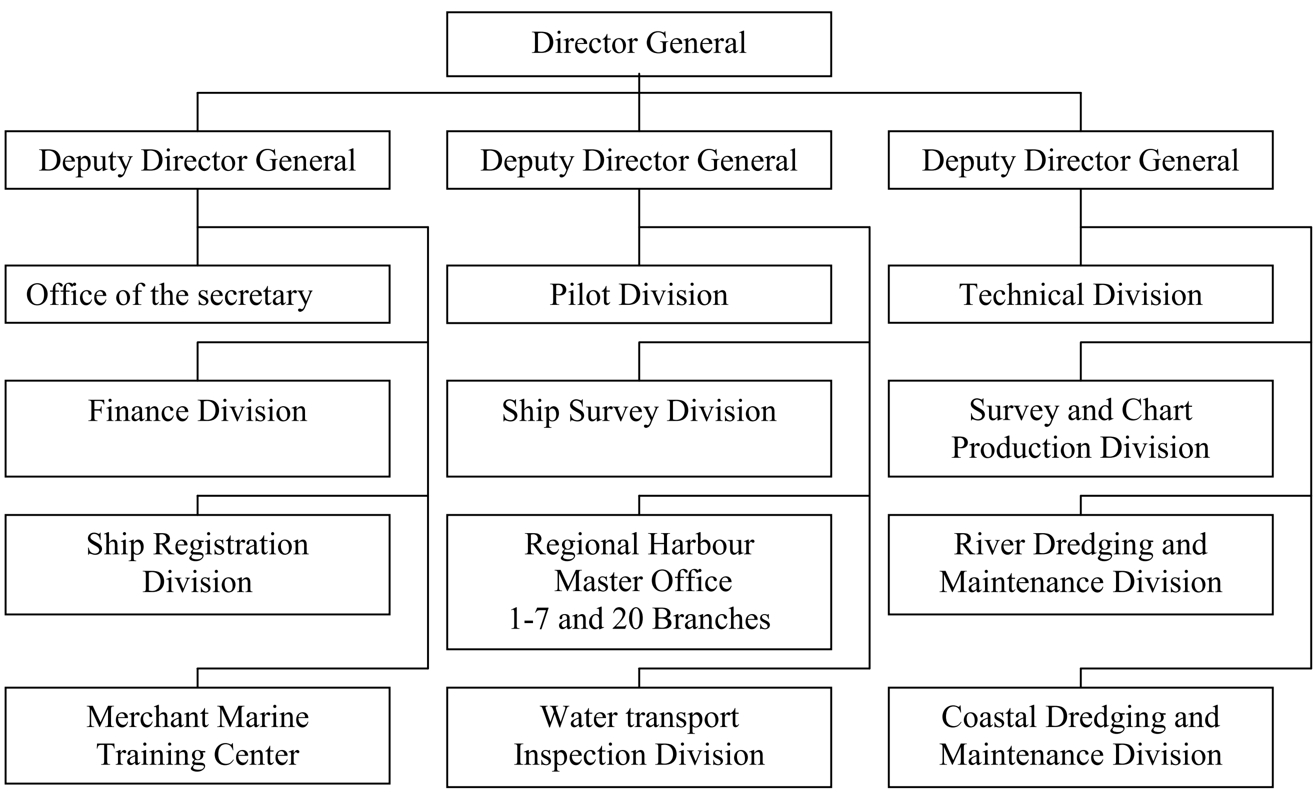
Chapter 1

Introduction

1.1 General review

Thailand is located in South East Asia. The area of the country is 514,750 square kilometers, according to the 1997 census the population of the country is 60 million inhabitants. The ocean waterway is divided in two regions. One region is the East, with 1,200 kilometers of coast bathed by the waters of the Thai Gulf. Another region is the West, with 700 kilometers of coast bathed by the India Ocean. Maritime transport is an important factor determining the growth of economy of the country. Well-established Maritime Administration manages maritime affairs including protection and preservation of human life and properties and prevention of marine pollution. The maritime administration in Thailand namely Harbour Department (HD) is under the responsibilities of Ministry of Transports and Communications. The organization chart of HD is to be shown as following.

HARBOUR DEPARTMEN



The HD is directed by the Director General, assisted by 3 Deputy Director Generals, one for administrative works, one for waterways operation matters and the other for engineering matters. The organization of the Department is divided into one Office of the Secretary, ten Divisions and seven Regional Harbour Master Offices, and 20 Branches.

The important responsibilities of each division are stated in short as follow:

• Office of the Secretary is in charge of correspondence, general administrative work, personnel and legal matter public relations and other services not under the responsibility of any particular division.

• Finance Division is in charge of matters concerning finance, budget, account, and procurement.

• Ship Registration Division is in charge of the issuance and annual renewal of license for ships in accordance with the Navigation in Thai Water Act and Thai Vessels Act.

• Merchant Marine Training Center is in charge of seafarers' education in accordance with international convention and standard including upgrading and refreshing courses to service seafarers.

• Pilot Division' s responsibilities include guiding sea-going vessels of specific size in and out of the port limits where piloting is compulsory or shifting the sea-going vessels within that area and providing pilot services to sea-going vessels outside the compulsory pilotage zone.

• Ship Survey Division is responsible for the inspection of ships' conditions including engines, electric and other equipment for the purpose of issuing or renewing ship license and also responsible for the issuance of certificate of competency on marine engineering.

• Regional Harbour Master Office 1-7 and 20 Branches are in charge of ship survey, ship registration and water transport inspection around both sides of the coast of Thailand. The high sea inspection and defense of sovereignty of the country are the responsibility of The Royal Thai Navy.

• Water Transport Inspection Division is in charge of navigation law enforcement, the control of construction and activities that may encroach on the waterway or obstruct navigation, the inspection and suppression of violation, the legal action against violators, and the issuance of certificate of competency on navigation.

• Technical Division is responsible for maintenance schedule in consultation with the Water Transport Inspection Division and repair refit the HD' s ships.

• Survey and Chart Production Division is in charge of survey and drawing of maps for navigation and collection of data on channel conditions.

• River Dredging and Maintenance Division is in charge of dredging and maintenance of navigation channels in main rivers and installation and maintenance of navigation aid.

• Coastal Dredging and Maintenance Division is in charge of dredging and maintenance of coastal navigation channels and installation and maintenance of navigation aid.

Particular attention of this dissertation will be paid to maintenance planning for 20 ships of Water Transport Inspection Division, which are responsible for inspection of facilities, river banks, prohibitive activities, traffic control, search and rescue, and oil pollution detection in The Chao Phraya River in Bangkok, capital city of Thailand. The Chao Phraya River is useful not only for commercial ships but also for pleasure ships, so it has become a very congested river. Therefore the HD has to reinforce its fleet including the armaments to support its mission. It is necessary that the HD should have an efficient maintenance system for maintaining such armaments in very good condition.

The HD Dockyard is responsible for maintenance of the ships to keep them in the highest degree of readiness at all times in order to ensure availability of the ships to the Water

Transport Inspection Division. Its long-term strategy is to maintain the fleet to make available maximum number of ships, provide a high quality maintenance service along with safety and timelessness. To meet these objectives at acceptable cost, maintenance management has been recognized by the HD Dockyard as one of its important activities.

Technical Division is responsible for schedule and maintenance, which has been facing the problem of the limited resources such as manpower, material and equipment. Therefore to use the limited repair resources effectively it is necessary to determine the best policy of the maintenance of HD's ships.

1.2 Statement of the Problem

The existing situation

• The operational planning and ship' s maintenance planning conflict with each other. The operational planning needs the use of the ships for operation according to the demand of situation.
• The ship takes too much time for maintenance in the dockyard, the ship' s availability would be reduce.

1.3 Objectives of this Dissertation

The overall objectives of this dissertation are to develop an effective maintenance management system for the 20 ships of Harbour Department.

1.3.1 To find an approach for a more efficient maintenance schedule and optimum operational schedule

1.3.2 To generate for each ship a proper maintenance schedule specifying manpower, lay up time and financial budget.

Chapter 2

The Existing Maintenance System in the Harbour Department

2.1 Composition of the Harbour Department Ship's Fleet

All the ships of the department are owned by the HD. These ships were made from steel by The Bangkok Dock Limited in Thailand. The age of ships vary between 8 to 10 years and the average age of ship is nine years. As these ships are not commercial ships, they are not classed with any classification society. The international regulations are not applicable to these ships. The constructional and safety standards are contributed by the Ship Survey Division based on the national rules and regulation.

2.1.1 Classification of the HD' s ships:

These ships were divided into three categories based on the speed of the ships.

Category 1 Low speed ships are those ships, speed of which of are limited to 9 knots. There are 10 ships of this type. These are identified by numbers such as 101, 102, 103 up to 110. The ship's particulars are as below:

Table 2.1 Low speed ships particular.

1.Size of ship	Length over all 11.20 m Breadth 2.60 m Depth 1.80 m Draught 0.80 m
2.Main engine • model • configuration • number of cylinders	YANMAR marine diesel engine 4LH-DTE 4-stroke, vertical, water cooled diesel 4 in-line

• maximum output	125.0 kW/ 3300 rpm (170.0 hp/ 3300 rpm)
• combustion system	direct injection
• aspiration	turbocharged with intercooler
• starting system	electric starting(D.C.12V, 2.5 kW starting motor/ 12V, 55A alternator)
2.1 Reduction and reversing gear	
• model	KM15A
• type	Constant mesh gear with servo-cone clutch, 7 degree angle
• reduction ratio (ahead|astern)	2.57|2.57
3. Electrical engine 2 sets	
• model	3GM30F
• configuration	4-stroke, vertical, water cooled diesel engine
• number of cylinders	3 in-line
• maximum output	20.1 kW
• starting system	electric starting(D.C.12V, 1.0 kW starting motor/ 12V, 55A alternator)
4. Propulsion	Single screw, fixed pitch

Category 2 Medium speed ships are those ships, speed of which of are limited to 15 knots. There are 6 ships of this type. These are identified by numbers such as 201, 202 up to 206. The ship’s particulars are as below:

Table 2.2 Medium speed ships particular.

1.Size of ship	Length over all 10.50 m Breadth 2.50 m Depth 1.76 m Draught 0.82 m
2.Main engine	YANMAR marine diesel engine
• model	4LH-STE
• configuration	4-stroke, vertical, water cooled diesel
• number of cylinders	4 in-line
• maximum output	169 kW/ 3300 rpm (230.0 hp/ 3300 rpm)
• combustion system	direct injection
• aspiration	turbocharged with intercooler
• starting system	electric starting(D.C.12V, 2.5 kW starting motor/ 12V, 55A alternator)
2.1 Reduction and reversing gear	
• model	KM15A
• type	Constant mesh gear with servo-cone clutch, 7 degree angle
• reduction ratio (ahead|astern)	2.57|2.57
3. Electrical engine 2 sets	
• model	3GM30F
• configuration	4-stroke, vertical, water cooled diesel
• number of cylinders	3 in-line
• maximum output	20.1 kW
• starting system	electric starting(D.C.12V, 1.0 kW starting motor/ 12V, 55A alternator)
4. Propulsion	Single screw, fixed pitch

Category 3 High speed ships are those ships, speed of which of are limited at 20 knots. There are 4 ships of this type. These are identified by numbers from 301 to 304. The ship's particulars are as below:

Table 2.3 High speed ships particular.

1.Size of ship	Length over all 9.80 m Breadth 2.50 m Depth 1.75 m Draught 0.84 m
2.Main engine	YANMAR marine diesel engine
• model	6LYA-STE
• configuration	4-stroke, vertical, water cooled diesel
• number of cylinders	6 in-line
• maximum output	257.4 kW/3300 rpm (350.0 hp/ 3300rpm)
• combustion system	direct injection
• aspiration	turbocharge with intercooler
• starting system	electric starting(D.C.12V, 2.5 kW starting motor/12V, 60A alternator)
2.1 Reduction and reversing gear	
• model	KMH6A
• type	Hydraulic multifriction disc clutch
• reduction ratio (ahead|astern)	2.26|2.26

3. Electrical engine 2 sets • model • configuration • number of cylinders • maximum output • starting system	 3GM30F 4-stroke, vertical, water cooled diesel engine 3 in-line 20.1 kW electric starting(D.C.12V, 1.0 kW starting motor/ 12V, 55A alternator)
4. Propulsion	Single screw, fixed pitch

2.2 Maintenance Policies and Objective in The Harbour Department

Technical Division is responsible to maintain the ships and prepare them for the highest readiness stage at all times in order to serve the people. The operating periods of these inspection ships in the Choa Praya River is very high, hence more frequent maintenance on these ships cannot be carried out because of the nonavailability of replacement ships as well as the due to high overhead costs. Thus an efficient maintenance system must be developed to keep the operational plan and the resources and cost limitations.

Technical Division uses periodic maintenance policy for the inspection ships. This policy of ship maintenance is prescribed by a schedule in which a specific number of ships are to be maintained. This is also called fixed-period maintenance (FPM). FPM is preventive maintenance for the HD's ship, which is more economic than corrective maintenance, which is carried out upon breakdown or lack of effeciency.

2.3 Decision Levels For Equipment Maintenance Management

Maintenance operations of the HD are carried out at three different levels:

(1) **End user level** comprises of inspection, service lubrication, adjustment and tuning, and replacement of minor parts. All activities the user maintains.

(2) **Middle level**, the end user level is supported by a maintenance unit whose responsibilities include calibration, repair or replacement of faulty equipment and technical support system.

(3) **Dockyard level**, this level of maintenance is the responsibility of the Technical Division or the dockyard. This maintenance activity level is applied only to critical equipment and includes the complete hull repairs or replacement of spare parts, overhaul, modification, trouble shooting, etc. The division also provides technical support to maintenance unit of lower level.

The type of maintenance operations carried out by the dockyard are classified as follows.

(1) **Limited repair** involves repair of parts or periodic maintenance according to schedule. However, this type of service is applied only to selected components or other components of damage. Limited repair may be done urgently to keep ships in working condition or may be done on emergency basis in case of accidence.

(2) **Periodic maintenance** involves repair of parts according to schedule, such as testing, inspection, tuning, modification, and system improvement.

(3) **Overhaul** involves long-term schedule. The purpose is to maintain the ship in the highest potentiality. The ship is serviced according to schedule, which is done in the dockyard. Some equipment may be sent back to the manufacturers for repair. Maintenance activities done at this level include replacement, steel renewal on hull, testing, calibration, and adjustment.

2.3.1 Strategic Planning

This planning carried out by the Technical Division is separated into two types periodic minor maintenance and major overhaul maintenance. Each year the Technical Division assigns number of ships for maintenance to the dockyard based on this plan.

Since the main engine, depending on the ship displacement, the ship life cycle is derived from the life cycle of the main engine and the overhaul and repair duration.

The major overhaul (major refit) period of the ship is decided base on the major overhaul interval of the main engine

The ship major maintenance cycle = main engine working duration + overhaul and periodic maintenance duration

The main engine overhaul time cycle is specified by the manufacturer, but overhaul and periodic maintenance duration are decided by the Technical Division.

The limited repair for three types of ships is classified as follows.

1.High speed ships : clean and paint the hull at 1 year period.

2 Medium speed ships : clean and paint the hull at 1-1.5 years period.

3.Low speed ships : clean and paint the hull at 2 years period.

The types of inspection ships and maintenance carried out by HD' dockyard are:

Table 2.4 Classification of the ship's maintenance

Type of Ship	Main Engine Duration (year)		Maintenance Duration (weeks)	
	Overhaul Interval (year)	Periodic Maintenance Interval (year)	Overhaul (weeks)	Periodic (weeks)
High Speed Ships	6	3	8	6
Medium Speed Ships	5	2.5	8	6
Low Speed Ships	4	2	8	6

2.3.1.1 <u>Ships' Overhaul Cycle of 4 Years (Low Speed Ships)</u>

Table 2.2 The long-term plan

P ⟷ = Periodic Maintenance

O ⟷ = Overhaul Maintenance

Year Name	1995	1996	1997	1998	1999	2000	2001	2002
HD 101		↔ P		↔ O		↔ P		↔ O
HD 102	↔ O		↔ P		↔ O		↔ P	
HD 103		↔ O		↔ P		↔ O		↔ P
HD 104	↔ P		↔ O		↔ P		↔ O	
HD 105		↔ P		↔ O		↔ P		↔ O
HD 106	↔ O		↔ P		↔ O		↔ P	
HD 107		↔ O		↔ P		↔ O		↔ P
HD 108	↔ P		↔ O		↔ P		↔ O	
HD 109		↔ P		↔ O		↔ P		↔ O
HD 110	↔ O		↔ P		↔ O		↔ P	

2.3.1.2 <u>Ships Overhaul Cycle of 5 Years (Medium Speed Ships)</u>

Table 2.5 The long-term plan

Year Name	1995	1996	1997	1998	1999	2000	2001	2002
HD 201			↔ O		↔ P			↔ O
HD 202		↔ P		↔ O			↔ P	
HD 203	↔ O		↔ P			↔ O		

HD 204		P ↔			O ↔			P ↔
HD 205		O ↔		P ↔			O ↔	
HD 206	O ↔			P ↔		O ↔		

2.3.1.3 <u>Ships Life Cycle of 6 Years (High Speed Ships)</u>

Table 2.6 The long-term plan

Year / Name	1995	1996	1997	1998	1999	2000	2001	2002
HD 301	O ↔			P ↔			O ↔	
HD 302		O ↔			P ↔			O ↔
HD 303			O ↔			P ↔		
HD 304	P ↔			O ↔			P ↔	

2.3.2 <u>Tactical Planning</u>

This plan flows from the long-term plan and is broken down into 4 years and 1 year plan in order to match with operational plan and financial budget. Each year the Technical Division, depending upon which of the ships is to be maintained and the type of maintenance, presents budget to the HD for approval. The plan also determines which equipment is to be serviced or repaired or attended to and its duration.

The sketch of tactical planning is to be shown as below :

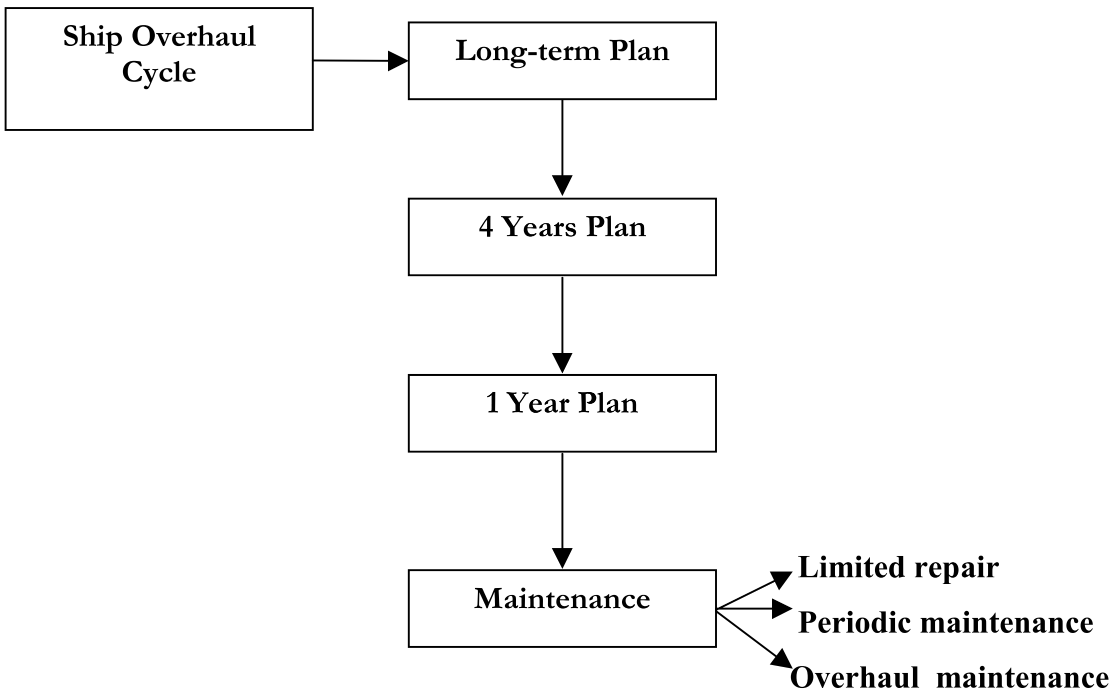


Figure 2.1 Tactical planning

2.3.3 <u>Maintenance Planning</u>

This plan is divided into two levels, the user level and the dockyard level.

2.3.3.1 <u>User level</u>

At this level, the user plans which, when and how to maintain the ship by using the maintenance manual, prepares a list of activities and a time table of activities to be completed. Most of the activities at this level are inspection.

Ship Organization

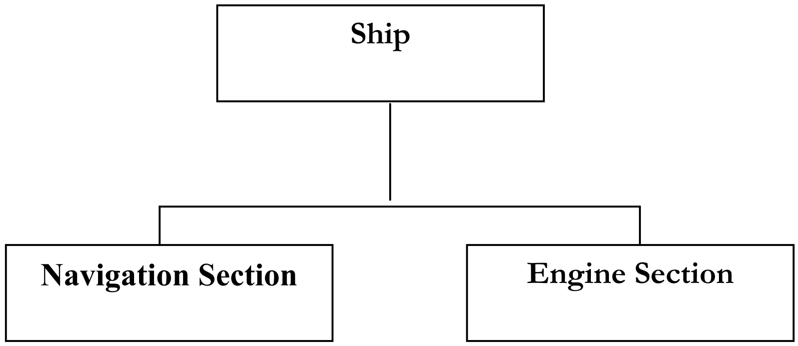


Figure 2.2 Ship organization

The crew of each section responds to maintain equipment under their charge.

The sketch of user level plan is to be shown as below.

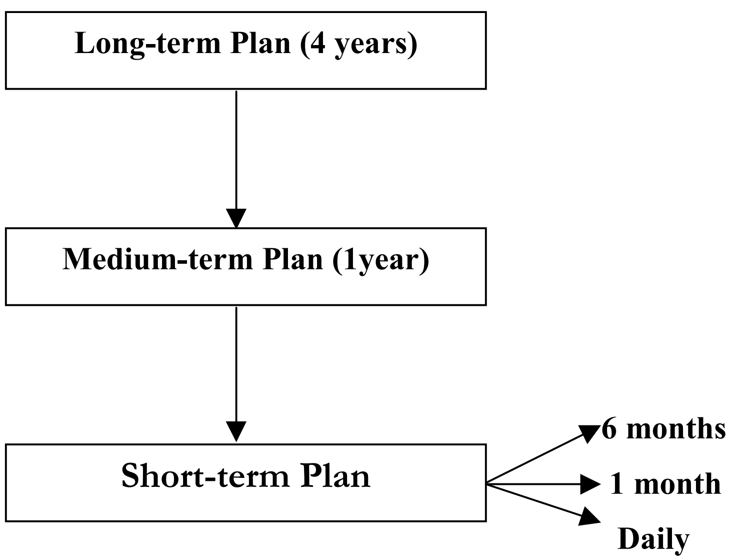


Figure 2.3 User level plan

2.3.3.2 Dockyard level

At the dockyard level, the maintenance of ships is the limited repairing, periodic maintenance and overhaul, which is based on the tactical planning, the job to be performed at each period of time determination. The maintenance planning technique evaluates budgetary provisions, manpower, time, etc.

The maintenance planning is presented by the sketch below.

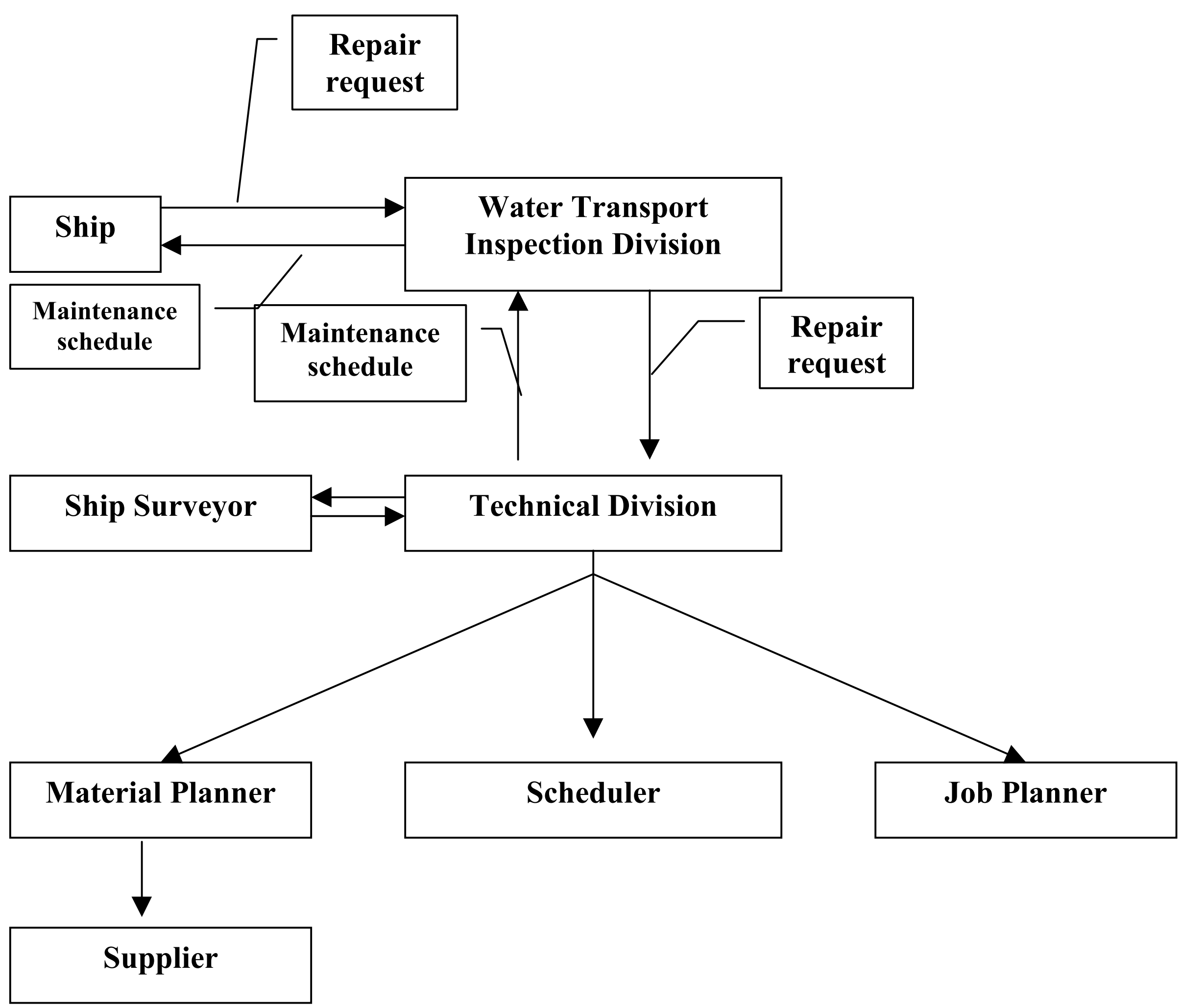


Figure 2.4 Dockyard level plan

The procedure of maintenance planning and scheduling timetable is done as following.

1. Ship reports the deficiency of machine or equipment on board to the Water Transport Inspection Division.
2. The Water Transport Inspection Division considers and reviews the report and after that it reports to the Technical Division.

3. The ship surveyor from the Technical Division inspects and checks the equipment in the ship including the vibration, thermal check and visual inspection after that he reports to the Planning Section of Technical Division (Technical Division organization is shown in figure 2.5).

4. The Planning Section considers which equipment would be maintained and at which levels of maintenance operation and determines whether repair, overhaul and replacement are necessary and provides the spare part for the maintenance.

5. The Production Section of the Technical Division reviews the planning and schedule. After that the job is allocated to each workshop (Technical Division organization is shown in figure 2.5).

6. During maintenance the superintendent of the Planning Section directs and controls the schedule, finds out the scope to maintenance and adjusts the plan and coordinates with the Production Section.

7. Finally, the ship is put to river trial and adjustments before the ship is put back in service again.

The Technical Division Organization

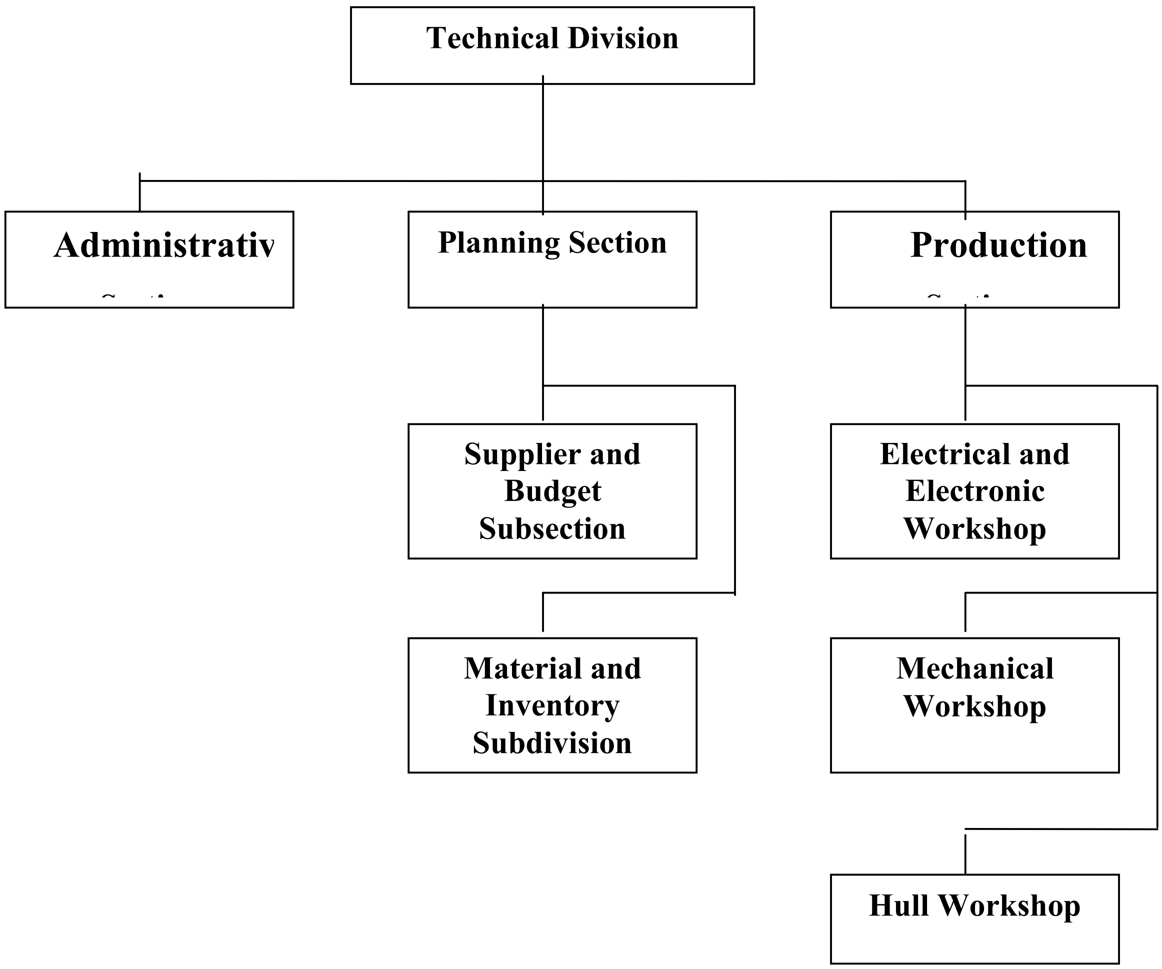


Figure 2.5 Technical Division organization

The responsibilities of the Administrative Section

The duties are general documentation and public relation within and between other division.

The responsibilities of the Planning Section

The duties are ship maintenance planning, material providing, budget estimating, plan control, budget control and information collection.

The Supplier and Budget Subsection provides the spare part and material and also controls the budget.

The Material and Inventory Subsection responds to spare parts, tools, material procurement and control of inventory.

The responsibilities of the Production Section

The duties are to coordinate between sections and subsections, to control schedule and job planning.

The workshops carries maintenance repairs, overhauls and reports the results.

The dockyard capacity

The machine capacity is following.

Table 2.7 Machine capacity

Name	Number	Capacity
Slipway	1	10 tons

The manpower capacity is following.

Table 2.8 Manpower capacity

Workshop (section)	Number (person)	Man-hour (per day)
1. Hull workshop		
1.1 Welding	4	28
1.2. Plating	4	28
1.3 Cleaning and painting	4	28
2. Mechanical workshop		

2.1 Main and electrical engine	5	35
2.2 Auxiliary engine	4	28
2.3 Pipe line and valve	3	21
2.4 Shaft and propeller	4	28
3.Electrical and electronic workshop		
3.1 Electrical equipment	4	28
3.2 Battery maintenance	2	14
3.3 Electronic equipment	3	21

Chapter 3

The Problems of Existing Ship Maintenance System

The objectives of ship maintenance have been set in the first chapter and it is natural to start thinking of alternative ways to address them. But even if the decision seems clearly defined, it is worth pausing at least long enough to set it in a broader context. The minimum pay-off will be a better understanding of the reasons for making the decision in the first place. The most likely reward will be that the nature of the decision is redefined so as to target it more accurately on the root cause of the problem.

No organizational process is ‘ problem free ’. We are all surrounded by problems in need of solutions. Some problems though, are more obvious than others. The hidden problem – the problem behind the problem – is often the one on which the decision – making process needs to be focused.

3.1 <u>A Two – Stage Process</u>

Understanding the problem context of a decision involves two types of activities. First, it is necessary to collect data about the problem area. Some data will be general information, some will be accepted as ‘ hard fact ’ and some will be options – subjective and even contentious. It all goes to building up a picture of the problem. Second, the data needs analyzing or interpreting so as to find the underlying meaning in the picture of the problem. The analysis may be quite simple, like counting how many times a certain event occurs, or more complexes, like building a mathematical model. The only requirement is that the process increases our understanding of the problem.

3.1.1 Data Collection

Input – Output Analysis

The ship maintenance system in the Harbour Department is the process, which is involved in inputs to produce outputs. The inputs are raw materials, component parts, people, money, information, and methods. The outputs are preventive maintenance, safety operation, cost saving and time saving. The input – output model is as follow:

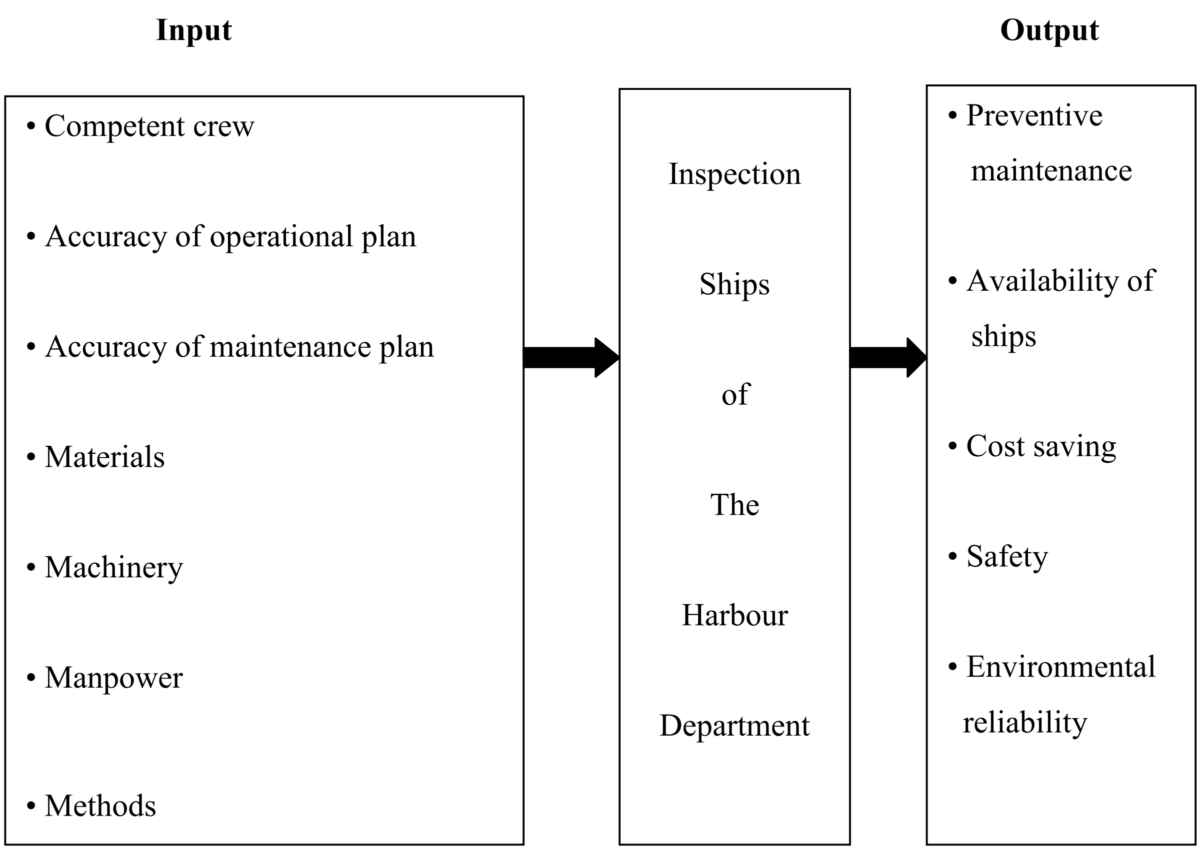


Figure 3.1 Input-output analysis

But in fact the Technical Division is responsible for making schedule and maintenance, which has been facing the problem of limited resources such as manpower, material and equipment. Consequently, the ships have to spend too much time for maintenance in the dockyard hence the other ships, due for maintenance, can not come to the dockyard for following the maintenance schedule, which is major the cause of ship's breakdown. There are two fold delay, first commencement in maintenance and second in completion of maintenance.

3.1.2 Problem Analysis

Cause – Effect Diagrams

Cause – effect diagrams are a particularly effective method of helping to search for the root causes of problems. They do this by asking the questions along with adding some possible 'answer' in an explicit way.

The ship maintenance procedure for drawing a cause – effect diagram is as follows:

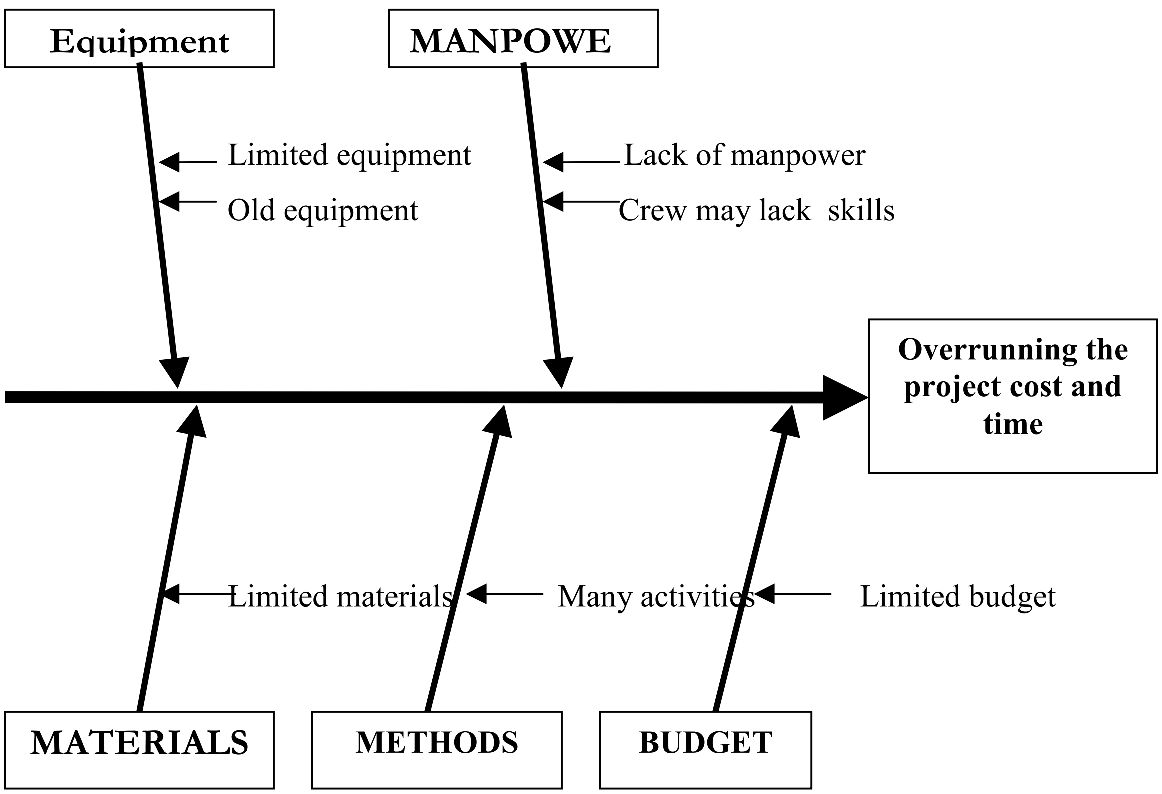


Figure 3.2 Cause-effect analysis

The causes mentioned produce an effect, which is delay in process.

1. waiting for the material and spare parts
2. many of the maintenance activities
3. the crews may lack the skills
4. lack of manpower
5. waiting for slipway

Technical Division is presently tackling the maintenance problem by emphasizing only on the maintenance of ship's main item such as the main engine, electrical system, the generator, and ignoring the scheduled maintenance of minor items. The minor items are maintained only upon their breakdown (corrective maintenance) making the ships extremely unreliable during their operation at the Choa Phraya River.

Therefore to use the limited resources effectively it is necessary to determine the best policy of the maintenance of HD's ships.

Chapter 4

Analysis of Maintenance Problem

This chapter presents the analysis of problem, which is overrunning the project cost and time from the existing maintenance system of the Harbour Department's ships. The effective methodology for helping to understand the reasons for problems occurring. It is an 'expansion' methodology, which starts by stating the problem asking *why* that problem has occurred. Once the major reasons for the problem occurring have been identified, each of the major reasons is taken in turn and again the question is asked *why* those reasons have occurred, and so on. This procedure is continued until either a cause seems sufficiently self-contained to be addressed by itself or no more answer to the question '*why?*' can be generated. The ship maintenance problem for drawing a '*why?*' diagram is as follows:

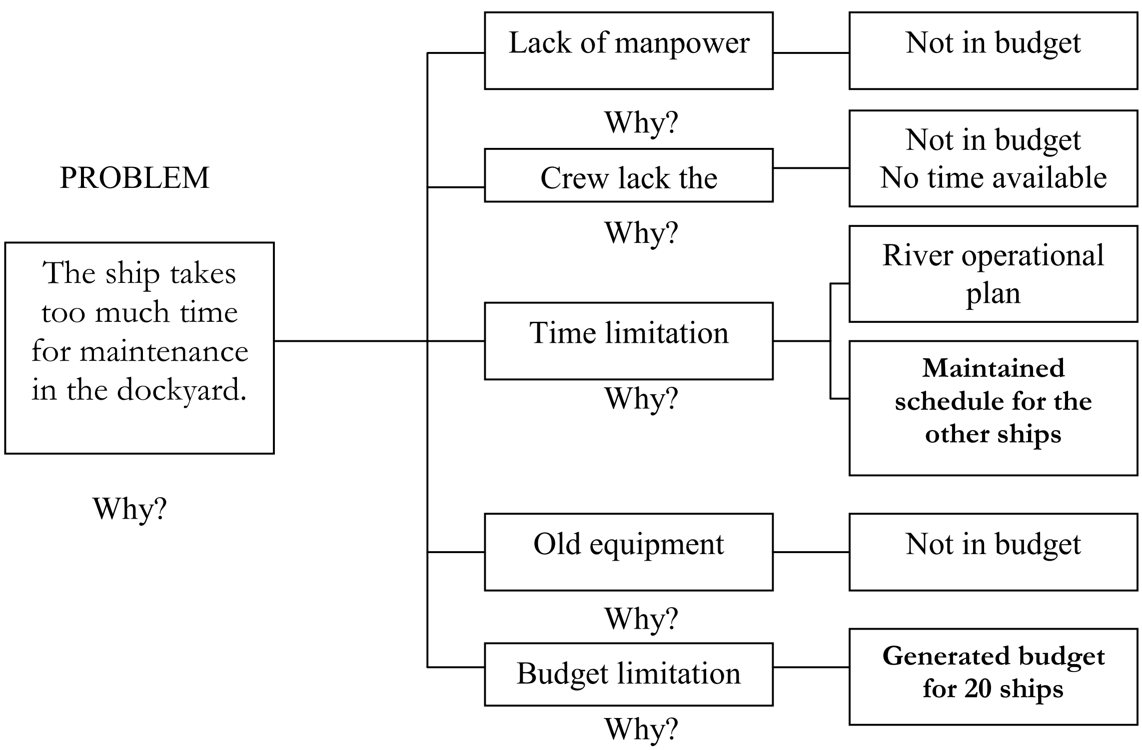


Figure 4.1 Why-why analysis

This analysis has been done by dividing the system into maintenance steps and studying each step by studying the maintenance schedule of the dockyard in 1997 and case study by analysis of period maintenance of HD 203.

The procedure is as follow:

1. maintenance schedule of dockyard in 1997
2. maintenance request from HD 203
3. maintenance schedule for HD 203
4. analysis the maintenance problem

4.1 <u>Maintenance schedule of dockyard</u>

The dockyard determined the schedule by the use of historic data, the maintenance schedule of 1997 was as follow:

Table 4.1 Maintenance schedule of dockyard in 1997

Name of Ship	Types of maintenance	Duration (weeks	Start-finish
HD 102	Periodic maintenance	6	10Mar-18April
HD 104	Overhaul maintenance	8	7Jan-22Feb
HD 106	Periodic maintenance	6	21July-29August
HD 108	Overhaul maintenance	8	9June-1Aug
HD 110	Periodic maintenance	6	6Oct-14Nov
HD 201	Overhaul maintenance	8	11Aug-3Oct
HD 202	Clean and paint the hull	2	20Oct-31Oct
HD 203	Periodic maintenance	6	11Feb-21Mar
HD 205	Clean and paint the hull	2	21April-2May

HD 206	Periodic maintenance	6	10Nov-22Dec
HD 301	Clean and paint the hull	2	25Feb-7Mar
HD 302	Clean and paint the hull	2	30June-11July
HD 303	Overhaul maintenance	8	12May-4July
HD 304	Clean and paint the hull	2	8Sep-19Sep

4.2 Maintenance request from HD 203

After the ship received the maintenance schedule from the dockyard, the ship reports the required maintenance activities with regard to historic maintenance of ship. The maintenance activities identified were as follow:

Table 4.2 Maintenance activities from HD 203 in 1997

Activities
1.cleaning under water line construction
2. upper water line
3. under water line
4. painting under water line construction
5. periodic maintenance of main engine
6. exhaust system
7. unit injection system
8. cylinder head
9. hydraulic pump of rudder
10. hydraulic tube
11. high pressure air pump
12. motor < 5 HP 12.1 lubricating motor pump 12.2 fuel motor pump 12.3 sea motor pump
13. motor > 5 HP 13.1 fire motor pump 13.2 fan motor
14 control panel
15.battery

4.3 <u>Maintenance schedule for HD 203</u>

The maintenance schedule is done after evaluated availability of equipment, material, manpower and budget, the maintenance schedule of HD 203 is as follow:

Schedule from 11Feb–21Mar 1997						
Program (Activity)	**February**			**March**		
	11-15	**18-22**	**25-29**	**3-7**	**10-14**	**17-21**
1. docking						
2.cleaning under water line construction						
3. upper water line						
4. under water line						
5. painting under water line construction						
6. periodic maintenance of main engine						
7. exhaust system						
8. unit injection system						
9. cylinder head						
10. hydraulic pump of rudder						
11. hydraulic tube						
12. high pressure air pump						
13. motor < 5 HP 13.1 lubricating motor pump 13.2 fuel motor pump 13.3 sea motor pump						
14. motor > 5 HP 14.1 fire motor pump 14.2 fan motor 14.3 rudder motor pump						

Figure 4.2 Maintenance schedule of HD 203

Description of maintenance of main engine

Table 4.3 Periodic maintenance operation of the main engine and accessories.

Periodic maintenance for YANMA 4LH-STE
1. Engine in operation: Listen to running sounds Check exhaust gas cooling Check external piping Check engine speed, Temperature, pressure
2. Exhaust gas turbocharger : Check water flow
3. Fuel filter: Check, replace
4. Filter for priming oil: Remove disc package, clean
5. Fuel filter: Check, replace
6. Engine oil filter: Drain oil sludge, check residue
7. Secondary flow filter: Replace insert, sealing ring
8. Lubricating point: Lubricate
9. Air filter: Clean dust, moist collecting box
10. Exhaust system: Check mounting of exhaust piping
11. Raw water: Clean water, check supply
12. Engine cooling water: Check function of cooling water
13. Cylinder heads: Check of tight seal, burners
14. Valve control gear: Check oil supply, hydraulic lash adjustment
15. Unit injectors: Remove test and replace if necessary
16. Engine cooling system: Clean cooing, replace anticorrosion change cooling water
17. Engine actuation: Check function, delay time
18. Monitoring system: Check for proper function
19.Crank drive: Check condition of piston crowns, check running appearance of cylinder liners
20.Valve control gear: Remove cam and rocker housing
21. Engine governor: Replace governor diaphragm, clean strainer in oil feed line
22. Raw water pump: Replace bearing and gaskets
23. Engine cooling water : Check preheating
24. Engine oil heat exchanger: Test of leaking

Table 4.4 Description of maintenance activities.

Component (Activity number)	Description	Program
3. upper water line	Hole or deteriorate	Repair
4. under water line	Hole or deteriorate	Repair
7. exhaust system	Mounting of exhaust, lubrication of bearing	Check or replace if necessary
8. unit injection system	Clogged up, deteriorate	Replace
9. cylinder head	Burners deteriorate	Replace the burners
10. hydraulic pump of rudder	Failure due to shaft seal leak	Fix or replace
11. hydraulic tube	Failure due to tube leak	Replace
12. high pressure air pump	Failure due to ball bearing deteriorate	Replace
13. motor < 5 HP 13.1 lubricating motor pump 13.2 fuel motor pump 13.3 sea motor pump	Failure due to coil burn	Replace
14. motor > 5 HP 14.1 fire motor pump 14.2 fan motor 14.3 rudder motor pump	Failure due to coil burn	Replace

4.4 Analysis the maintenance problem

The analysis has been done by studying the problem consequence of ship maintenance of HD 203. The problem is as follow:

- budget limitation
- priority of the maintenance activities is incorrect
- time limitation

4.4.1 Budget limitation

The maintenance requested from HD 203, activity 14.control and 15.battery from table 4.2 were ignored. Technical Division is responsible for making schedule and maintenance, which has been facing the problem of the limited budget and presently tackling the maintenance problem by emphasizing only on the maintenance of ship's main item such as main engine, electrical system, and ignoring the schedule for the maintenance of minor items. The minor items are maintained only upon their breakdown (corrective maintenance) making the ships extremely unreliable during their operation.

4.4.2 <u>Activities priority</u>

The maintenance activities are necessary to set the priorities for the maintenance activities to be carried out. Figure 4.2 has shown activity 14.3 (rudder motor pump), which was maintained the last one. The importance of equipment to ship's operation can vary depending on when it has failed and its effect on operation of ship. The consequence of incorrect priority was the cause of ship delaying. HD 203 was delayed by shortage of manpower because of the rudder maintenance team were sent to maintain one ship in emergency situation. The result of manpower shortage will be considered to be consuming expenditure for successive maintenance. This expenditure is in form of overtime cost that is a different budget for the maintenance.

4.4.3 <u>Time limitation</u>

As the maintenance schedule must be matched with the ship operational plan, the maintenance period will be restricted to the main engine maintenance. The maintenance activities of the main engine and time for maintenance can be approximated and planned in advance. So the time for main engine maintenance at each level is:

1. Periodical maintenance = 6 weeks
2. Overhaul maintenance = 8 weeks

In figure 4.2, Main schedule of HD 203, has shown activities 1-5, which to be done on the slipway, was started on 11February and must be finished on 22February. However according to table 4.1, HD 301 maintenance schedule required to clean and paint hull between 25Feb-7Mar. If HD 203 did not finish activities 1-5 and undocking on 22Feb, the whole schedule would be affected. In some case under water line maintenance activities could not finish because there were more maintenance activities than forecast before, such as hull corrosion and deterioration.

Chapter 5

Proposed Maintenance Planning for the Harbour Department's Ships

This chapter presents the proposed methodology for the maintenance analysis, planning and scheduling for the Harbour Department's ships. The methodology is used for determine priorities of the maintenance activities. To find the optimal policy, which is achieved maximization of availability and saving cost involved.

The analysis has been done by dividing the system into the components, studying each component for available optimization with planning, priority of maintenance activities.

The procedure is as follow:

1. classification and grouping of the equipment
2. setting of priorities for the maintenance activities
3. planning the preventive maintenance procedure

5.1 Classification and Grouping of Equipment

There is a large number of equipment in the ship. This maintenance policy for the ship's equipment has been classified into two groups:

1. The large, complex and important components should be maintained by using the policy of periodic maintenance. Under this category we can put the main engine, the propulsion system, the control system and electrical engine of the ships.
2. The medium and small engines should be maintained by the policy of the preventive maintenance (such as the auxiliary engine, electrical motor, generator)

5.1.1 **Classification of Equipment by Function**

Since each machine of the ship has several components, we should categorize the engine by function into four major groups.

1. Power system: the system that produces power and electricity for the ship can be divided into four groups.
   • main engine
   • electrical engine including the generator
   • propulsion system such as shaft and propeller
   • control system

2 Auxiliary engine: the engine the assist the power system
   • rudder
   • pump such fire main pump, sewage pump etc.

3. Electrical power system comprises of:
   • electrical motor having power greater than 5 HP
   • electrical motor having power less than 5 HP
   • control motor system

4. Ship structure:
   • hull upper water line
   • hull under water line

5.1.2 **Classification of the equipment by maintenance operation**

1. Main engine
2. Electrical engine
3. Auxiliary engine
4. Electrical equipment

5. Hull construction

5.1.3 **Grouping of Equipment by Function and**

A: Main engine, gear, shaft and propeller

The dismantling cost for this group is high, the overhaul cycle of the items in this group is similar and the process to overhaul of the group is complex. Therefore, all these equipment, which have been grouped together, will follow the policy of overhaul and periodic maintenance.

The given intervals as well as the inspections and maintenance operations are based on results of operational. The operating hours referred to and the planned operations can therefore only be considered as the determining factors. In this case of extraordinary operating conditions an alternation of the maintenance schedule and the individual inspections and maintenance operations may become necessary.

Maintenance Inspection Overhaul

The main inspection requires removal of the engine and total dismantling of latter.

If the engine is not being operated for an extended time, the maintenance cycle has to be carried out according to the time limits.

B: Electrical engine

The suitable plan for maintenance of this engine is based on periodic maintenance policy. The overhaul interval will follow from the maintenance manual. As a matter of fact the restricted budget affects to the overhaul capacity, some component which are not maintained in time may be failed while the ship is operating at river. This study will consider the critical component of this engine only for preventive maintenance.

B1 Exhaust system

B2 Unit injector system

B3 Cylinder head

C: Rudder system

This equipment has 3 critical component.

C1. Hydraulic pump :failure due to shaft seal leak

C2. Hydraulic tube :failure due to tube leak

C3. Solenoid :failure due to circuit burn

D: Fire pump system

The equipment has 2 critical components.

D1 High pressure pump : failure due to ball bearing deteriorate

D2 Shaft seal : failure due to deteriorate

E: Electrical equipment

E1 Motors with power more than 5 HP :failure due to coil burn and ball bearing failed

E2 Motors with power less than 5 HP :failure due to coil burn and ball bearing failed

F: Hull

F1 Upper water line : failure due to the hole or corrosion

F2 Under water line : failure due to the hole or corrosion

5.2 Setting of priorities for The Maintenance Activities

This section will present the priority criteria that can be used as the basis of the maintenance plan. The approach, we propose is to apply the priority criteria for considering the maintenance activities to be done at each opportunity.

The proposed way of planning is also especially suited for each maintenance activity follows directly from priority criteria.

We first introduce the priority criteria.

1. The importance of equipment

2. The time limitation (restricted duration)

5.2.1 <u>The Importance of Equipment (the equipment priority).</u>

The maintenance is priority is fixed base on the budget limitations and restricted duration allowed for maintenance, it become necessary to set the priorities for the maintenance activities to be carried out. The criterion will be presented in this section so as to reduce the number of maintenance activities under restrictive situation.

The importance of the equipment can be determined by AHP (Analytical Hierarchy Process) method. The following criteria for this purpose have been used.

1. Essential for ship's operation

2. Damage to other equipment or parts

3. The technological level requirement

5.2.1.1 <u>Essential for Ship's Operation</u>

The importance of equipment to ship's operation can vary depending on when it has been failed and its effect on operation of ship. Such an information is possible to obtain by interviewing the technician, mechanical engineer or the operational officer.

5.2.1.2 **Damage to Other Equipment**

As the system is large and complex, various equipment operates simultaneously. If any one is failed, it may affect the performance of others and the cause damage to interconnected equipment or part. In order to control such a damage, the equipment should be identified and a high priority be set for its maintenance.

5.2.1.3 **The technological Level Requirement**

The factors have been considered for these purposes are the skill, experience required, and working conditions. The maintenance requirements for each equipment are variable from the technological viewpoint. Some failure can be repaired by the users themselves. It means that such equipment is of minor importance, on the other hand some important but also require the use of high technical expertise.

The equipment, which have been considered in this study are:

A1) Electrical engine

A2) Electrical equipment

A3) Hull construction

A4) Fire fighting system

A5) Rudder system

The steps used for determination of the maintenance hierarchy are as follows:

1. Identify the criteria that influence the behavior of the objective.

2. Structure a hierarchy of the criteria, sub-criteria properties of alternatives and alternative themselves (the hierarchy of this study can be shown in figure 4.5).

3. Prioritize the criteria with respect to their impact on the overall objective called the focus.

4. Comparison judgments and force their reciprocals.

5. Calculate priorities by adding the elements of each column and dividing each entry by the total column.

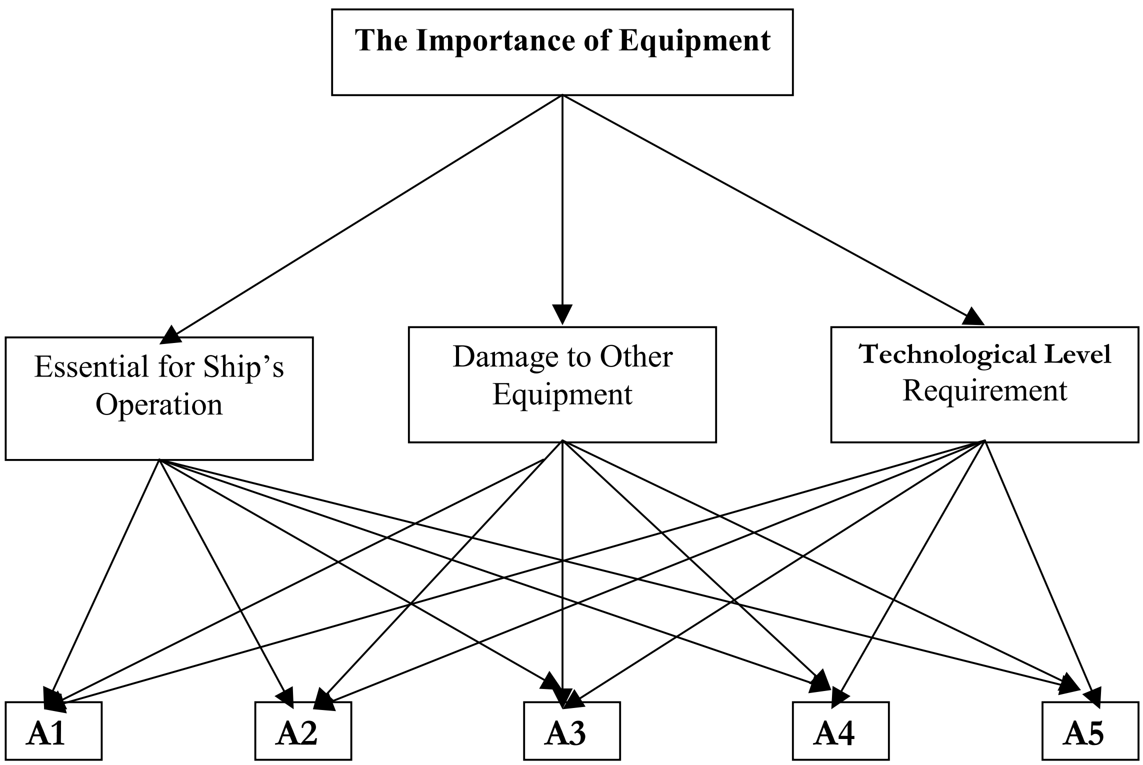


Figure 5.1 The important of the equipment hierarchy

This study uses decision making to evaluate the relative importance of each alternative by using the scale of relative importance as shown table 4.

The following scale, for judging the relative importance of the achieves had been proposed.

Table 5.1 Scale of relative importance

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribut equally to the objective.
3		Experience and judgmen lightly favor one activity over another.
5		Experience and judgmen strongly favor one activit over another.
7		An activity is favor very strongly over another; It dominance dominated i practice.
9		The evidence favoring or activity over another is o the highest possible orde of affirmation
2,4,6,8	Intermediate values betwe adjacent scale valve	When compromise is needed
Reciprocals	If activity (I) has one of th above numbers assigned to when compared with activ (J), then (J) has the reciprocal value when compared with it.	

Table 5.2 The overall ranking

Alternative	Ranking (priority)
A1) Electrical engine	**1**
A5) Rudder system	**2**
A3) Hull construction	**3**
A4) Fire fighting system	**4**
A2) Electrical equipment	**5**

5.3 Planning the Preventive Maintenance Procedure

The procedure to find the optimal policy in each of several equipment's and several maintenance activities is as below:

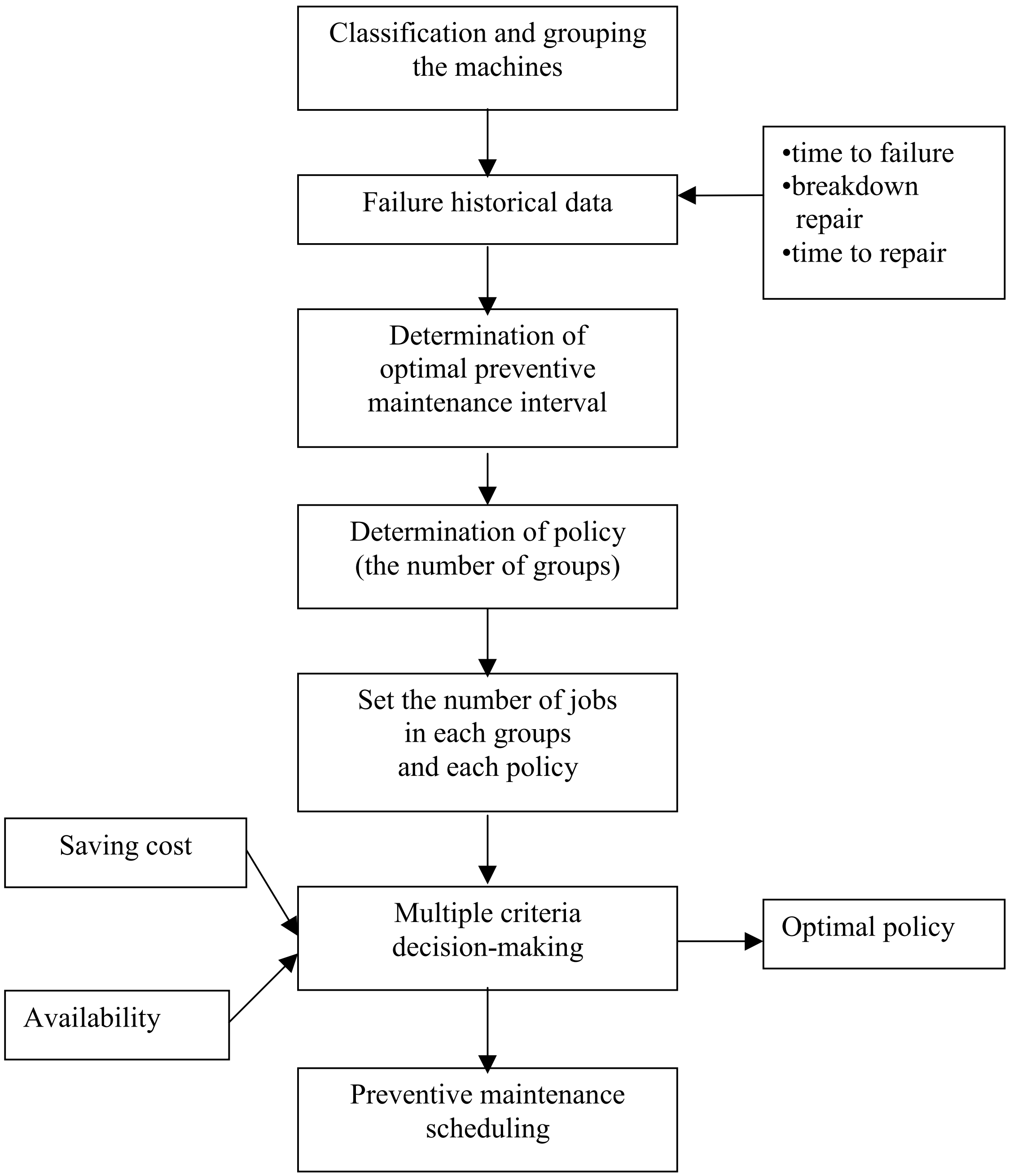


Figure 5.2 Planning the Preventive Maintenance Procedure

Chapter 6

Proposed Maintenance Scheduling for the Harbour Department's Ships

This paper presents the application of network technique (CPM/PERT) and the use of project management for the maintenance planning for the maintenance planning of HD's ships. The following procedures are as below :

Procedure :

1. Preventive maintenance schedules
2. Managing the project by using activities network (CPM)
3. Developing the cost plan, or financial budget
4. Applying the project control

6.1 Preventive Maintenance Schedules

The data collected in this section belongs to scheduling of preventive and opportunistic maintenance or replacement of equipment with more than one component under conditions of positive failure costs and increasing failure rates for all components. The need to maintain the existing budget is patently obvious. The long-term impact of under maintaining this ship is excessive depreciation of the equipment, loss of operation time and general deterioration. The short-term results of over maintaining this ship is high maintenance cost in service and even this ship due to maintenance downtime.

Due to the fact that the result of this study yields a group of jobs to be maintained at the particular opportunity time or the main engine schedule, the most scheduling of the various activities involve will be presented as maintenance project.

Network techniques such as CPM or PERT are useful in turnarounds, and resource scheduling is useful during all phases of maintenance scheduling.
The maintenance schedule of this study is shown figure 6.1.

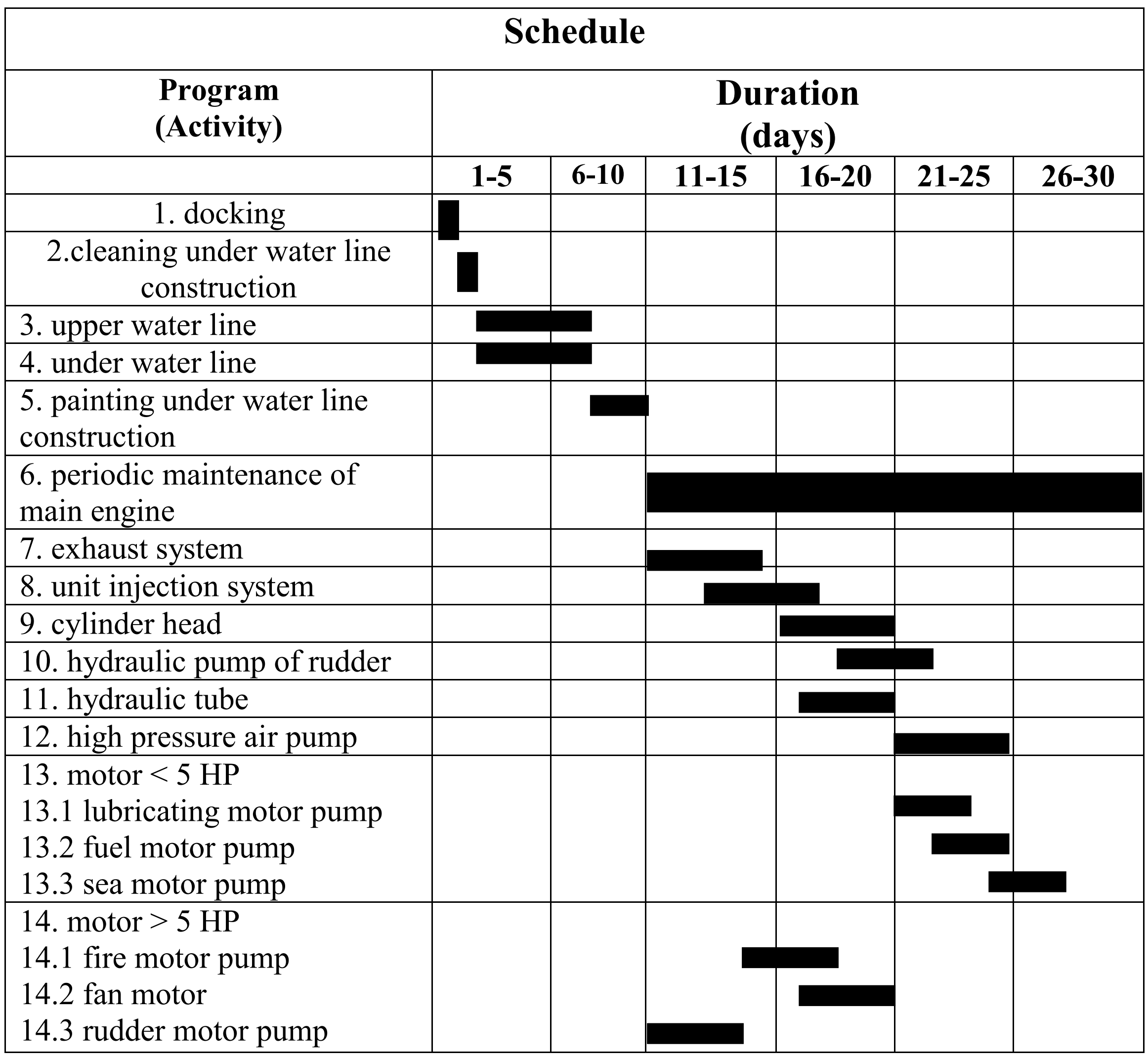


Figure 6.1 Maintenance schedule

The description of maintenance activities were described the detail in table 4.4 but the activity 3 was described the detail in table 4.3 of chapter 4.

6.2. Managing the project by using activities network

Network and network analysis are playing and increasing important role in project management. The case with which the projects can be modeled as network is the fundamental reason for the significant increase of network.

The network techniques of project management are concerned with developing a logical sequence of the various activities, which are taken to carry out the project and the interrelationships of these activities over time.

Summary of network-based project management methodology

Step 1 Project planning The activities making up the project are defined, and their technological dependencies upon one another are shown explicitly in the form of a network diagram. This is the most important step in the entire PERT/CPM procedure.

Step 2 Basic Schedule The basic scheduling computations give the earliest and latest allowable start and finish times for each activity, and as a by product, they identify the critical path through the network, and indicate the amount of slack or float time associated with the noncritical paths. This step is shown in box (3) of Figure 6.2.

Step 3 Time-cost Trade-offs If the scheduled time to complete the project as determined in step 2 is satisfactory, the project planning and scheduling moves on to a consideration of resource constraints in step 4. However, if on is interested in determining the cost of reducing the project completion time, then time-cost trade-offs of activity performance times must be considered for those activities on the critical and near critical paths. This step, shown in box (4) of Figure 6.2.

Step 4 Project Control When the network plan and schedule have been developed to a satisfactory extent, they are prepared in final form for use in the field. The project is controlled by checking off progress against the schedule, as indicated in box (6),and by assigning and scheduling manpower and equipment, and analyzing the effects of delays. Whenever major changes are require in the schedule, as shown in box (7), the network is revised accordingly and a new schedule is computed.

The basic procedures incorporated in Step 1 through 6 can be performed, at least to some extent, by hand. Such methods will be presented in this paper because they are useful in their own right, and also because they are excellent means of introducing the more complex procedures which require the computers. It is particularly important that one be able to perform, by hand, the basic critical path calculations indicated in box (3) of Figure 6.2, since this is the first step in the evaluation of a proposed network plan for carrying out a project.

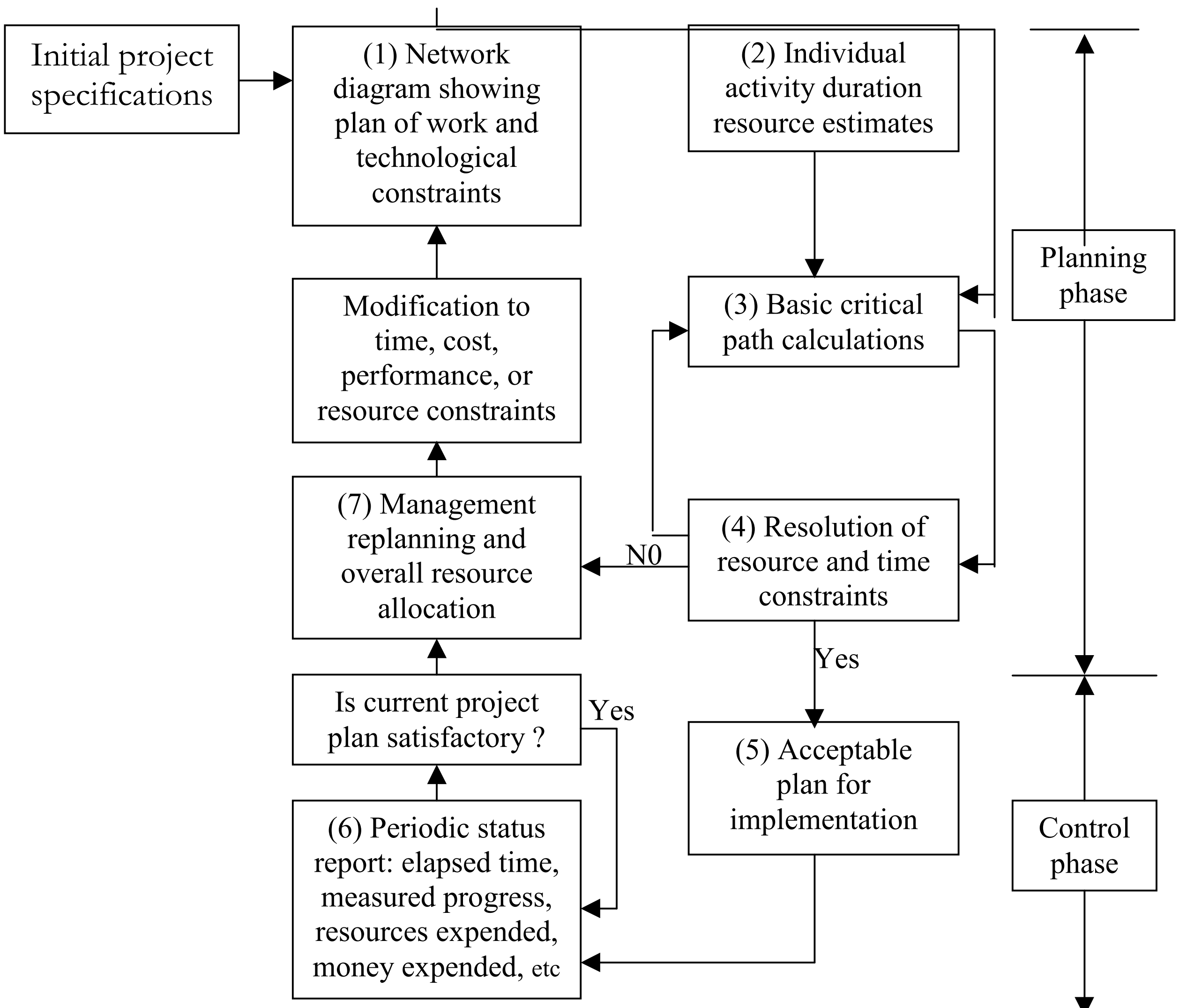


Figure 6.2 Dynamic network-based planning and control procedure.

The advantages of critical path methods

The use of critical path methods in the planning and controlling of projects.

1. **Planning** Critical path methods first require the establishment of project objectives and specifications, and then provide a realistic and disciplined basis for determining how to attain these objectives, considering pertinent time and resource constraints. It reduces the risk of overlooking tasks necessary to complete a project, and also it provides a realistic way of carrying out more long-range and detailed planning of projects, including their coordination at all level of management.

2. **Communication** Critical path methods provide a clear, concise, and unambiguous way of documenting and communication project plans, schedules, and time and cost performance.

3. **Psychological** Critical path methods, if properly developed and applied, can encourage a team feeling. It is also very useful in establishing interim schedule objectives that are most meaningful to operation personnel, and in the delineation of responsibilities to achieve these scheduled objectives.

4. **Control** Critical path methods facilitate the application of the principle of management by exception by identifying the most critical elements in the plan, focusing management attention on the 10 to 20 per cent of the project activities that are most constraining on the schedule. It continually defines new schedules, and illustrates the effects of technical and procedural changes on the overall schedule.

5. **Training** Critical path methods are useful in training new project managers, and in the indoctrination of other personnel that may be connected with a project from time to time.

The project network of figure 6.1 (maintenance schedule) is shown as below:

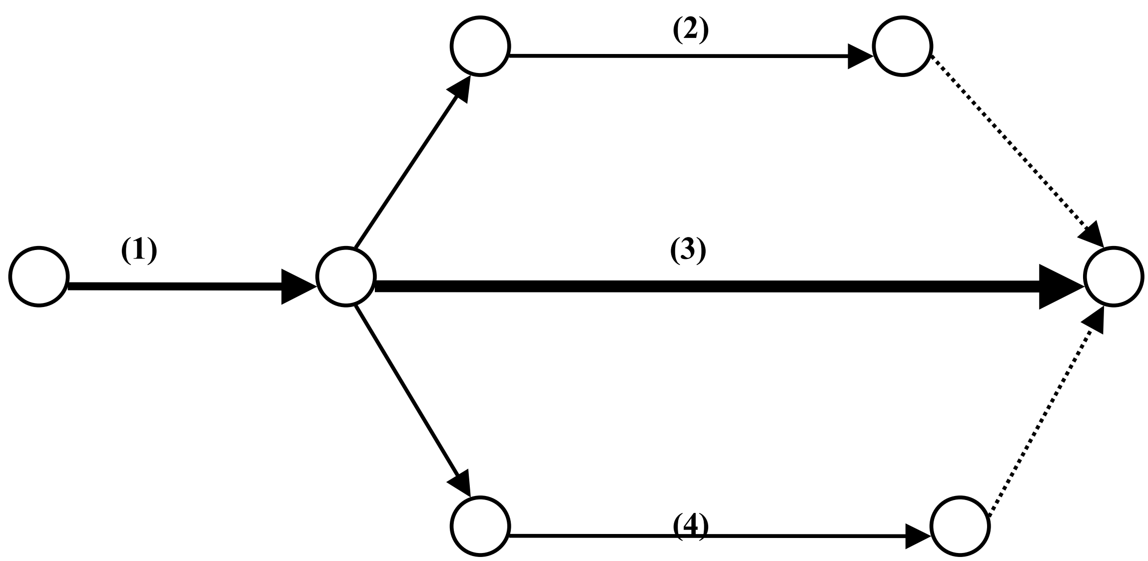


Figure 6.3 Project network

Table 6.1 The description of project network

Code No.	Activity	Start-finish	Duration (days)
(1)	1,2,3,4,5	1-10	10
(2)	7,8,9,10,11,12	11-25	15
(3)	6 (Critical Path)	11-30	20
(4)	13,14	11-27	17

6.3 Developing the Cost Plan or Financial Budget

The main propose of this paper is the development of procedure to determine the schedules to reduce the project duration time with minimum the increasing in the project direct costs, by reducing time along the critical path where it can be obtained at least cost. The estimated cost data for each activity or work package may be added to the network, and the first cost computation is made, which is summation of all estimated cost by time period.

Direct costs of an activity include the costs of the material, equipment and direct labor required to perform the activity in question. In this paper, because this is more or less constant and this cost can be proposed in the budget in advance.

Project indirect cost may include, in addition to supervision and other customary overhead costs, interest charges on cumulative project investment, penalty cost for overrunning the project after a specified date.

The normal activity cost is equal to the absolute minimum of direct cost required to perform the activity, and corresponding activity duration is called the normal time (It is this normal time that is used in the basic critical path planning and scheduling).

The procedure for developing the cost plan is as follow :

1. Obtain the estimates of regular time
2. Determine unit costs of each activity
3. Determine activities on the critical path
4. Reduce time on the critical path (Do not exceed financial budget)

Normal cost = man-hr of normal time * normal hour cost (variable)
= (activity duration * 7 hr/day * number of worker) * normal hour cost
Emergency cost = normal cost + overtime cost
Overtime cost = man-hr of overtime * normal hour cost * 1.5 (normally 3.5 hr/day)

Table 6.2 The maintenance activities cost

Activity	Man-hr (per day)	Normal hour cost (Baht)	Normal		Emergency	
			Days	Baht	Days	Baht
Activity 1	28	29	1	812	0	0
Activity 2	28	29	1	812	0	0
Activity 3	28	32	5	4480	4	4924
Activity 4	28	32	5	4480	4	4924
Activity 5	28	29	3	2436	0	0
Activity 6	35	38	20	26600	17	28595
Activity 7	14	35	4	1960	3	2205
Activity 8	14	35	5	2450	4	2695
Activity 9	14	35	4	1960	3	2205
Activity 10	21	35	5	3675	4	4042.5
Activity 11	14	35	4	1960	3	2205
Activity 12	21	35	5	3675	4	3972.5
Activity 13	28	35	7	6860	5	7840
Activity14	28	35	10	9800	7	11270

Critical path consideration

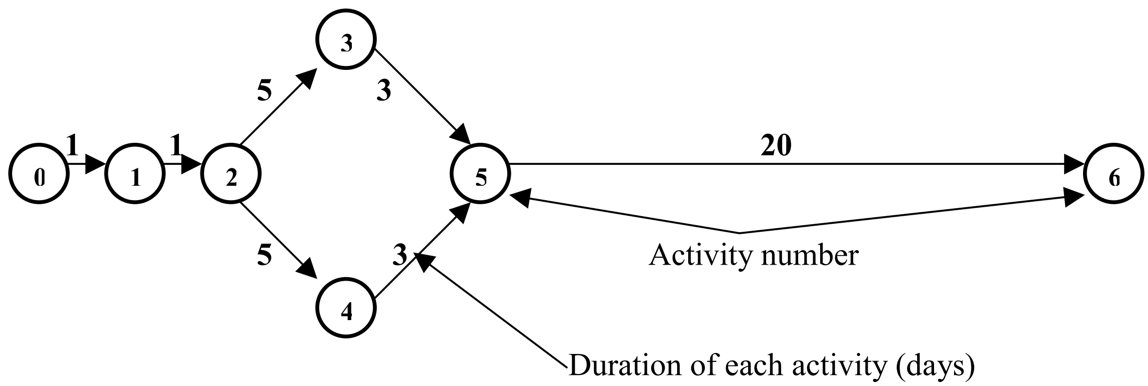


Figure 6.3 Critical path

From figure 6.3 the critical path can be reduced by two ways. First reduction is only one day of activity 3 and 4 from duration 5days to 4 days. Second reduction is 3 days of activity 6 from duration 20 days to 17 days.

Table 6.3 Time reduction on the critical path

Duration of the Project	Cumulative Cost (baht))of Critical Path (from activity No 1 to No 6)	Time Reduction (day)
26	**42503**	**4**
27	**41615**	**3**
28	**40950**	**2**
29	**40285**	**1**
30	**39620**	**0**

Due to the fact the critical path is the activities N0.1-N0.6, the cost of various time alternatives can readily be computed (where the critical path can be reduced maximum 4 days). For example, the following illustrates how this project could be reduced in time from 30 days to 26 days at an added cost of 2883 baht.

30 days schedule-normal duration of project	cost 71960 baht
29 days the least expensive way to gain one day would be reduce activity N0.6 for additional cost 665 baht	cost 72625 baht
28 days	cost 73290 baht
27 days	cost 73955 baht
26days	cost 74843 baht

The project cost is considered only the overtime cost, because the others cost are fixed cost, which can be planed in advance.

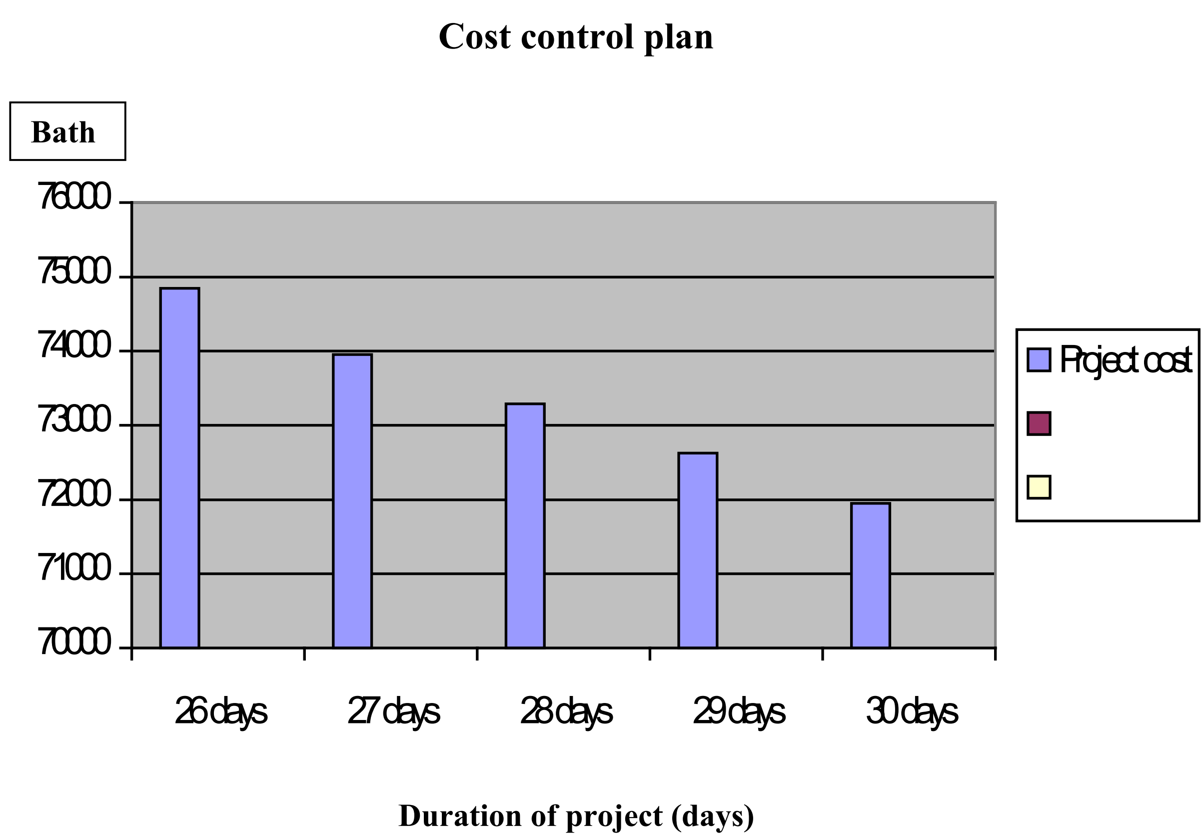


Figure 6.4 Graph of the cost control plan

6.4 Project Control (maintenance unit control)

Project control maintenance unit control focuses on realizing the work orders according to the agreements on timing and efficiency.

6.4.1 Work Order Release

Work order release has to control amount of work in progress by means of setting work order from the portfolio of accepted order to complete for the limited capacities.

Each period, the amount of work released should be proportional to the capacity available in the next period. During this period, however, the remaining workload may drop below a certain level because the amount of rush or additional work can be released. The decision as to which specific work orders from the portfolio is going to be release depend on such aspects as material availability and work order priorities. The sample work order is described in table 6.4.

Table 6.4 Work order form.

Ship. HD 203	**Work order No.2-157-120-01 Date. Feb 11, 97.**	**Work order list. Repair electrical engine**		**Periodic maintenace**
Work shop	**Procedure**	**Man-hr**	**Start**	**Finish**
Mechanical workshop	1.Repair or replace the mounting of exhaust pipe.	14	25 Feb.	28 Feb.
	Total man-hr	**14**		
Normal case	**Maintenance planning officer (signature)**			
Report No.	**Superintendent officer (signature)**			
	Planning and estimating officer (signature)			

Chapter 7

Conclusion and Recommendations

The inspection ships are comprised of several equipment and the maintenance interval of each item are vary widely therefore, the maintenance planning emphasize on the maintenance of the main engine. As a result the minor items are maintained only their breakdown making the ships extremely unreliable during their operation.

The maintenance will affect the time available for operation, the effect of maintenance policy varies with the changes in preventive maintenance schedules. The purpose of this study is to analyze the effects of maintenance actions on the pattern of downtime occurring on the inspection ships. The maintenance policy is defined as the allocation of resources (activities, manpower, time and budget) among the alternative types of maintenance action that are available to management. The effectiveness of a maintenance policy is measured by the amount of time a ship is available for operation in any given period.

This study not only contains the method and results of analysis of effect of planned on downtime but also presented a framework for optimizing model with allow integration with priority setting, planning and combination of activities.

The maintenance planning should compromise between availability and cost saving. The objectives are to maximize availability and maximize cost saving so the Multiple Criteria Decision Making (MCDM) is used to accommodate both objectives.

The insensitivity of cost saving to planned maintenance policy is important in terms of flexibility it gives to the maintenance management in planning shutdown. Therefore, maintenance can be planned to fit in with considerations such as manpower availability and operational plan of inspection ships.