Industrial Engineering and Applications
L.-C. Tang (Ed.)

doi:10.3233/ATDE230096

Reengineering Ship Maintenance and Repair Business Processes

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Abstract. Aftersales service/ support has always been a key factor for a company's business development, growth, and a fair advantage to its competitors. In line with this, the project management must be strong and reliable. Problems faced by the project management are fast changing service locations, parts supply delays, manpower shortages and immediate client support/response. The study aims to pin-point, discuss and systematically solve these problems by using historical data analysis, root-cause analysis and failure, modes, effects analysis. Identifying the most suitable project management tools and approaches to improve the management process quality – thus, increasing the competence of the aftersales service the organization can offer. Providing good supply chain forecasting, efficient workload scheduling and proficient problem identification and categorizing. Results of the study aims to provide the organization with a solid system process that can be applied on a larger scale – handling of a fleet with no less than 30 vessels, ranging from 15 meters to 100 meters in length, located and assigned around the Philippines from the most remote locations to highly accessible areas.

Keywords. Maintenance and Repair. Project Management. RCA, Delays, FMEA

1. Introduction

1.1 Background of the Study

Company A is an expansion of a leading Western Aluminum hull shipbuilder, to continue and strengthen its sales and services in Southeast Asia. Company A is involved in building and maintaining patrol and offshore vessels. The company is engaged in ship construction and offers after-sales maintenance of international class vessels that are equipped with the latest technology in terms of marine transportation and navigation.

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Table 1. Company A McKinsey's 7s Framework

McKinsey's 7s Framework	
Strategy	Provide state-of-the-art aluminum hull vessels equipped with the latest technology and provide client support and satisfaction from construction to operation by providing management on maintenance execution.
Structure	Company A is divided into 3 subsystems namely. **Administrative Department** This department is responsible for accounting, human resources, and purchasing related decision making of the office in accomplishing the system's function. **Marketing Department** This department is widely concerned in introducing the product and services the system can provide to the clients residing on public sector. **Maintenance and Repair Department** The maintenance team consists of a Manager, and two supervisors leads a group of diverse engineers (Electrical, Electronics, Mechanical and Marine) who are tasked to implement the vessel preventive maintenance program and rectify corrective maintenance works that may arise during the agreed warranty contract. In addition, the team make sures that the project budget is targeted and attained within limits. More than the maintenance provided the team is also responsible in training the vessel crew (end client) and operational readiness. This will ensure that the vessel seaworthiness is maintained after the warranty contract has ended.
System	**Company Internal Rules, Regulations and Policies** **Occupational Safety and Health standards by Department of Labor and Employment** **Maintenance and Purchase Software**
Skill	**Vessel Management** (Operation and Management) **Development and Trainings** (Maritime education and operational know-how)
Staff	**Country Director** – Managing director, the head who creates and gets to have the last say on company rules, regulations and policies and decisions to be implemented. **Managerial Staff** – Reports summaries and suggests assessed options to the country director before implementation. **Supervisors** – Handles the company technical staffs, addresses the problems and job orders. Outlines the problems to be solved before reaching the management. **Regular Employees** – Technical skilled personnel to execute the job and is in relation firsthand with the end user clients. Reports directly to division supervisor.
Style	**Traditional Management** Company A employees are directed by the influence of the power of its respective reporting superior. **Micromanagement** The head of the company sees to it that he always knows the immediate information down from the technical personnel/.
Shared Values	**Company Mission and Vision**

The figure below shows the process by which the Maintenance Department functions. It starts by classifying the job between preventive and corrective maintenance. The job after categorizing is then thrown to the respective department where the planning is held. The job is executed and documented, all documentation goes back to the Maintenance Management Software, Client Remarks, and Database

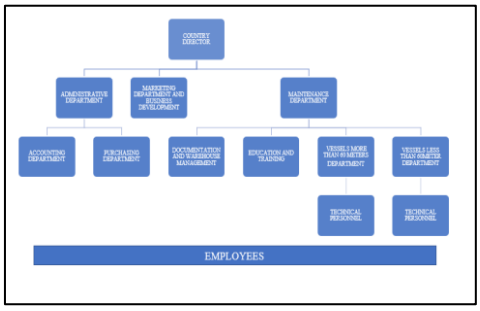

Figure 1. Company A's Departmental Chart

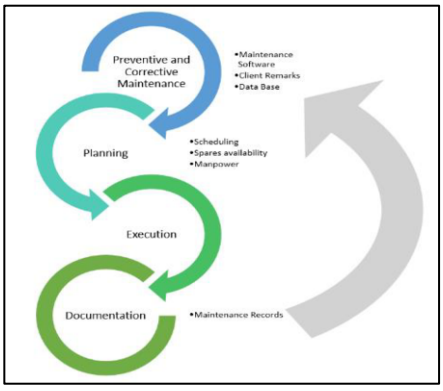

Figure 2. Maintenance Department Flowchart

1.2 Environmental Scanning and Problem Analysis

1.2.1 Prepare SWOT Analysis and Discuss.

Table 2. SWOT Analysis of Company A

Strengths • Competent Employees • Flexibility of employees • 24/7 client support • Product reliability • Shipbuilding techniques	**Weaknesses** • Facility and equipment • Parts availability in local market • Country's archipelagic nature • Distant support from head office
Opportunities • Expansion to private sector • Project/ Contract renewals • Expansion to Shipmanagement	**Threats** • Congested market • Limitations of Aluminum Vessels • Philippine's Economy

Strengths:

- Competent Employees. Employees are skillful and is a mix of professionals with local and international experiences.
- Flexibility of employees. The expertise of people working in maintenance and repair group are majored in mechanical jobs but can troubleshoot and rectify issues arising from electronics and electrical, and vice versa.
- 24/7 client support. Company A offers a strong backbone to the client by helping anytime. This gives the client a worry-free operation of using the ships built by the company.
- Product reliability. Ships made by the company passed international standards and Class Society certified.
- Shipbuilding techniques. The company gave birth to a new ship building process which enables them to fully construct a vessel of no less than 35 meters in length in a matter of 6 months, and 90 meters in length in 12 months.

Weaknesses:

- Facility and equipment. The company is unable to establish its own shipyard and heavy equipment facility locally to support production and machinery breakdown maintenances.
- Parts availability in local market. The vessels are made in Europe, 90% of the equipment installed are from western countries whereas 50% of the makers has no counterpart on Asian/Southeast Asian market. Unexpected equipment breakdown of western branded machinery could mean delay on repairs.
- Country's archipelagic nature. The Philippines as a composite of many islands makes the maintenance services much harder.
- Distant support from head office. Communication and integrated logistic support is hindered by time zone difference and geographical location, respectively.

Opportunities:

- Expansion to private sector. Philippines as an archipelago has a good potential on this market providing vessels for offshore supply operations, tugboat operations, commercial luxuries, and many more.

- Project/ Contract renewals. Rather than ending any pre aged agreed contract on a yearly basis the company can provide a lifelong maintenance contract to its partners and clients.
- Expansion to Shipmanagement. The company can provide good management practices even on vessels that were not built by them.

Threats:

- Congested market. Philippines maritime industry is already vast. There are 118 registered shipyards, 17 of which are medium to large scale. The market competition is already tight, and the company is a new name introducing its western technology in the local shipbuilding industry [1].
- Limitations of Aluminum Vessels. Aluminum hulled vessel has its own advantages and disadvantages from a typical steel hulled vessel. Factors that the market can question are cost, durability, and material strength.
- Philippine's Economy. The country since the pandemic of COVID19 hasn't regained its economic status and is currently facing a large debt overseas.

1.2.2 Analysis of the Company's Sub-Systems Current Situation

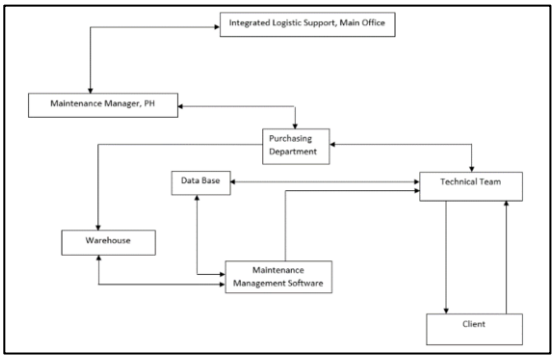

Figure 3. Process Flow of Maintenance Team, Planning and Execution

On the process map illustrated above (Figure 3), the work originates from either the client or the software. The job is scanned by the technical team where the availability of parts is verified in the warehouse or is subject for purchase. The purchasing team enter and checks for local availability of parts and moves the purchased item to warehouse. For international acquisition of spare parts, the country maintenance manager communicates with the ILS main office. The item descriptions and tracking are done on a weekly basis. Only when the parts have arrived, the technical team can execute the job and return the documentation to the database.

Table 3. Defects encountered by Maintenance Team resolved after three or more months.

	2019	2020	2021	2022
Propulsion Control System	6	15	11	12
Navigational Equipment	3	8	8	10
Auxiliary Machineries	7	21	23	26
Life Saving Appliance	6	3	5	7
Living & Interior Arrangements	10	8	13	10

Over the last 4 years, the Maintenance Team has encountered a total of 844 defects and issues of which 93% have been resolved, however, 27% of these resolved problems took at least 3 months with the longest of 3 years to be fixed. Such service gaps are caused by flawed processes inside the system, producing repetitive works and supply chain delays.

1.2.3 Root-cause Analysis

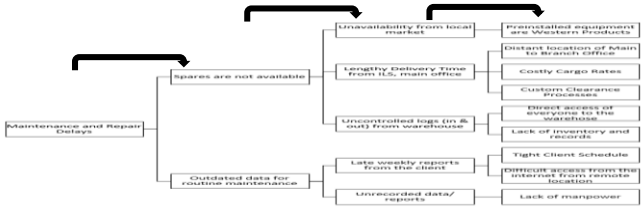

Figure 4. Why-why diagram of the problem

1.2.4 Problem Statement and Objective(s)

The organization is looking for ways to solve problems, particularly, on minimizing and eliminating project setbacks which lowers client satisfaction. The study aims to evaluate and come up with a systematic approach on improving the subsystem's processes - increasing the team's effectivity and efficiency on dealing with the maintenance delays, further, provide business development data to avoid the same problems in the future.

2. Research Methodology

2.1 Data Collection

The research is focused on addressing the maintenance and repair delays encountered by Company A over the last four years. Through historical data analysis the problems are grouped, quantified, and evaluated.

2.1.1 Project Delay Factors Identification

Figure 4 shown in section 2.1.3, a why-why diagram, identified the causes of the project maintenance and repair and delays which are grouped into three main categories, namely, Material Related Factors, Management Related Factors and Client Related Factors.

Table 4. Delay Factors Identification

Maintenance and Repair Delay Factors		
Preinstalled equipment are western products	Unavailability from Local Market	Material Related Factors
Distant Location from the Main Office	Lengthy Delivery Time	
Costly Cargo Rates		
Custom Clearance Process		
Direct Access of everyone on the Warehouse	Uncontrolled Warehouse Management	Management Related Factors
Lack of inventory and control		
Lack of Manpower	Unrecorded data and reports	
Tight Client schedule	Late Client Reports	Client Related
Lack of internet access		

2.1.2 Data Processing and Analysis

Table 5. Criteria Weighing

Criteria	1	2	3	4	5	Weight
Frequency (F)	Very Low	Low	Medium	High	Very High	40%
Impact (I)	Negligible	Minor	Moderate	Major	Catastrophic	40 %
Detectability (D)	Very East	Easy	Moderate	Difficult	Impossible	20 %

The descriptive data of defects encountered by Company A Maintenance and Repair Department were lined up with the identified factors affecting delays on maintenance and repair. The problems were quantified under the factors with the frequency the problem occurs, the impact it has with the ship operation and detectability which means foreseeability of the issue. The researcher then incorporates the weighted scoring on the above table shown. The scores garnered are ranked and the top three factors contributing to repair delays will be addressed using a how-how diagram where the solution is identified. Solutions identified are installed on proposed system process flow.

FMEA or Failure Modes, Effects and Analysis is used to recognize potential issues that may arise during the solution implementation. FMEA is organized by enumerating and analyzing the potential hazards and ranking them with evaluation pertaining to occurrence, severity, and detection.

3. Review of Related Studies

From a series of tasks carried out by operators to maintain (repair) equipment, maintenance has progressed to a strategic level in businesses (proactive maintenance) [2]. It is impossible to ignore the significance of ship upkeep. The importance of the maintenance function to profitability has grown. This is a result of companies' facilities becoming more complicated and sophisticated [3]. Maintenance will never cease as the ship operates at dock or even at sea. Any piece of equipment starts to deteriorate as soon as it is put into service. If nothing is done, the equipment's state will deteriorate over time and different phenomena will be seen, including increasing noise, vibrations, temperature rise, mechanical damage, and, if necessary, catastrophic failure [4]. Ship maintenance and repair ensures the seaworthiness of the vessels to effectively achieve its function and in the end secures the safety personnel on it.

Fleet Project management functions to ensure that the maintenance and repair works are carried out correctly and routinely. However, the project management itself must be organized and systematic to be effective [5]. Effectiveness refers to doing the proper things when the moment is right, in the right order. Understanding the fundamental essence of the need to act in each scenario is necessary for doing the appropriate thing [6]. The technical fleet function's responsibilities include managing ship certificates, dry docking, spare parts inventory, and system [7]. It entails procedures and actions carried out by the performing entity that establish quality standards, goals, and obligations to ensure that the project fulfills the purposes for which it was done [8]. Determining appropriate actions that can maintain machine performance at an acceptable level and prolong machine life is the goal of effective maintenance [9].

To offer solutions of the organization’s identified problem, root cause analysis was used by the proponent of this paper by a why-why diagram and process mapping. Root cause analysis is a method that identifies problems or their root cause step-by-step. An RCA investigation follows the chain of events from the ultimate failure to its underlying

cause [10]. Typically, there are several underlying causes for each given issue. The analysis must identify all known causal links between the root cause(s) and the identified problem for it to be effective [11].

Failure mode and effect analysis is used in this study. The laid solutions at the results and discussions of this study were evaluated under a suitable FMEA table [12]. We can lessen the effects of these failure modes by detecting the potential failure modes at the design stage and enhancing the initial design [13].

4. Results and Discussion

4.1 Decision Analysis

Table 6. Weighted Scoring of Material Related Factors

	Score			Weighted Score			Score
Material Related Factors	Frequency	Impact	Detectability	Frequency	Impact	Detectability	
Preinstalled equipment from West	4	2	2	1.6	0.8	0.4	2.8
Distant Location from the Main Office	3	4	3	1.2	1.6	0.6	3.4
Costly Cargo Rates	2	2	2	0.8	0.8	0.4	2
Custom Clearance Process	2	2	2	0.8	0.8	0.4	2

The table shows that distant location from the main office greatly affects the maintenance delay concerning material related factors which has a rating of 4. Second to it is the preinstalled equipment are of western brands which among the defects describe lies the most frequent cause of material related maintenance delay.

Table 7. Weighted Scoring of Management Related Factors

	Score			Weighted Score			Score
Management Related Factors	Frequency	Impact	Detectability	Frequency	Impact	Detectability	
Direct Access of everyone on the Warehouse	3	3	2	1.2	1.2	0.4	2.8
Lack of inventory and control	4	5	3	1.6	2	0.6	4.2
Lack of Manpower	3	3	3	1.2	1.2	0.6	3

The tabulated scoring shown above shows that the lack of inventory and control over the warehouse affects the project delays with great impact of 5 out of 5 and 4 out of 5 rating in terms of occurrence. This suggests that over the management related factors the importance of spares inventory and control is left unrecognized, yet it contributes greatly to causing setbacks on the team's objectives.

Table 8. Weighted Scoring of Client Related Factors

	Score			Weighted Score			Score
Client Related Factors	Frequency	Impact	Detectability	Frequency	Impact	Detectability	
Tight Client schedule	4	3	2	1.6	1.2	0.4	3.2
Lack of internet access	3	3	3	1.2	1.2	0.6	3

Client Related Factors evaluation shown, suggests that delays also occur because of the client's unresponsiveness in data gathering and collection. The tight client schedule averaged a score of 3.2 with frequency as a major contributor, scoring 4 out of 5.

Table 9. Ranking of the Three Most Significant Factors Affecting the Ship Maintenance and Repair

Top Factors	Score	Rank
Lack of inventory and control	4.2	1
Distant Location from the Main Office	3.4	2
Tight Client schedule	3.2	3

After the evaluation made of the three categories and 12 factors affecting maintenance and repair delays, the evaluation indicates that the three most significant factors are Lack of inventory and control, Distant Location from the Main Office, and Tight Client schedule ranked 1, 2, and 3, respectively.

The lack of inventory and control over the spares of the team has blinded the maintenance schedules into executing them on time. At present, Company A still uses manual log sheet for spares mobility and does monthly inventory of stores traditionally that takes almost half a month to complete and be inputted inside the maintenance software. Uncontrollably, the distance from the company A' head office is a factor to take into consideration even the fact that the support geographically will always remain the same. Lastly, the client schedule and sending of weekly and monthly reports late has also significantly contributed to the maintenance and repair delays. Late reports also mean late encoding to the maintenance software which yields to late assessment and scheduling of the work order.

The diagram mapped in Figure 5 shows the how-how aproach on solving the lack of inventory and control. The issue can be addresses by application of barcoding or QR tagging on spares. By applying these inventory count and encoding will be faster in which in turn would be very helpful for the purchasing team in buying the items specially the fast moving ones.

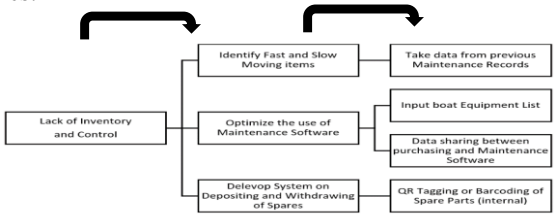

Figure 5. Solution on Lack of Inventory and Control

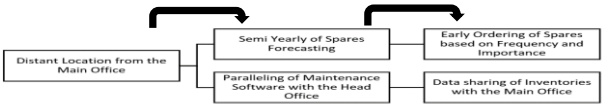

Figure 6. Solution on Distant Location from the Main Office

How-How Diagram of the solutions sighted for head office distant location is presented on the figure above. The distance can be outsmarted by good spare forecasting through conducting semi-yearly ordering of spares and connecting the maintenance software with the head office. All inventory count is on the maintenance software, a critical quantity of stock is set, and alarm is notified both local and on HO logistic support. This will give a backbone on ordering parts early, specifically, ones that are unavailable in the local market.

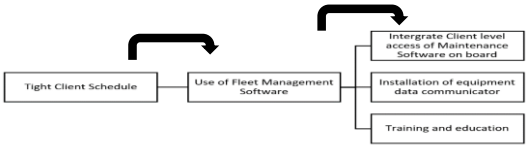

Figure 7. Solution on Tight Client Schedule

In terms of the tight client schedule, figure 7 above shows the solutions depicted by the how-how diagram approach. The company can use fleet management software or fleet connect by using two key components – one is by installation of data collector among the machinery and second is using the maintenance software in the ship with level 0 or client level access. By training and education to the crew of the vessel these setups will communicate and send the data through Inmarsat automatically. Moreover, two-way communication is established between the base and the ship by ordering and taking the crew work orders.

Solutions

Inventory Digitizing – the use of QR tagging and Barcoding to spare will minimize the job of counting manually and encoding it to the system significantly. This significant cut in labor time will provide the data to be processed by the different sections concerned.

Fleet Connect – the use of fleet connect to the maintenance and repair team of Company A will lessen the delay on data gathering to its managed vessels since the data is being transported real-time and accurately. This reduction will allow the maintenance software to promptly update it for upcoming and overdue work orders, which translates to on-time scheduling and execution of jobs aboard.

Table 10. Failure Modes, Effects and Analysis of the Solutions

Process Step	Potential Failure Mode	Potential Failure Effect	SEV	Potential Causes	OCC	DET	RPN	Action Recommended
Digitalizing the Inventory Process	Unreadable tags and barcodes	Back to manual logging of spare movement	6	Low quality of the tagging system	7	3	126	Applying redundant tagging
	desynchronization from maintenance software	Inaccurate Spare Parts inventory	9	Software bugs and malfunction	5	4	180	Timely scanning and upgrading of the Software
Application of Fleet Connect Software to existing Maintenance Software	Malfunction on data collectors	Inaccurate data received	9	Untimely maintenance / defective data collectors	4	3	108	Quarterly checking of the accuracy of data collectors
	Detachment of site processor to the server	Lost of data and communication	9	Defective Computer, Satellite and/or Processor	3	5	135	Provide back-ups on the system

Proposed System Flowchart

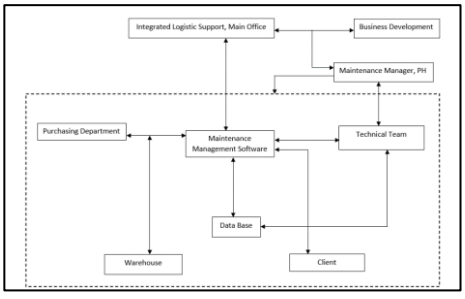

Figure 8. Proposed Flowchart of the Maintenance and Repair Team

The proposed system flowchart for the maintenance and repair team aims to make the process autonomous to reduce the time required on data collection and input. As a center of the activity maintenance management software is utilized to its optimal potential. The data from client is mostly transferred through fleet connect and is directly encoded to the maintenance management software. On the other hand, warehousing will be easily controlled by the scanning of parts going and going out- data is shared with the purchasing department. This sharing will also be reflected at the head office. The data sharing can easily be remarked in the software of weather when, how many and where to order the parts.

4.2 Potential Problem Analysis

The FMEA of the solutions offered by the study indicates the highest risk priority number on digitalization of the inventory process in which failure can occur on desynchronization from the maintenance software. The proponent of the study highly suggests timely upgrade and system checking of the software to avoid the risk brought by its failure.

5. Conclusion

The study therefore concludes that the Company has data processing and encoding backlogs causing delays on requisitions, purchasing, scheduling, and reporting of spare parts and work orders, respectively. The study also suggests that to resolve the issue, digitalization of the inventory process and server-based data collection from its managed vessels must be implemented.

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