AN ANALYSIS OF TWO TUG PROPULSION SYSTEMS IN THE PORT ELIZABETH HARBOUR.

By

DUMSANI ANDRIESON DLAMINI

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Promoter: Lewis Victor Kaplan

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PREFACE

DECLARATION

This work has not been previously accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed ___________________________

Dated ___________________________

STATEMENT 1

This treatise is being submitted in partial fulfilment of the requirements for the degree of Masters in Business Administration.

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STATEMENT 2

The treatise is the result of my own independent work/investigation, except where otherwise stated. Other sources are acknowledged by giving explicit references. A bibliography is appended.

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I hereby give consent for my treatise, if accepted, to be available for photocopying and for interlibrary loans, and the title and a summary to be made available to outside organizations.

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- Sincere thanks to my dear wife, Thenjiwe, and our sons, Nkosinathi and Mbuso, for their encouragement and support.

DEDICATION

This research paper is dedicated to my wife, Thenjiwe, and our sons, Nkosinathi and Mbuso.

ABSTRACT

The shipping industry is reliant on port authorities for the facilitation of safe entry and departure of ships at the ports. This role can not be fulfilled without the assistance of harbour tugs which are run by the marine operations section of the Transnet National Ports Authority. The tugs have to be safe and efficient in the process of pulling and pushing ships around the harbour.

Harbour tugs are expensive to acquire and to maintain. The marine operations business has to make appropriate choices of tug propulsion design in order to realise the benefits of the tugs acquired by the ports authority. This can be achieved by analysing the current tugs that the operations are using, which will then serve as valuable information when the time for asset replacement is due. The researcher chose to use the two tug propulsion designs currently used by the Port Elizabeth harbour tugs as a basis for this analysis.

The analysis links the three factors of maintenance management, equipment efficiency and equipment safety, to the minimisation of operational costs as perceived by the tug personnel, the pilots and the marine managers. This study seeks to verify the link between these factors and the perceived minimisation of operational costs. Available literature was reviewed and data was collected using a suitably designed questionnaire for this research.

This research paper has led to recommendations that should inform the tug acquisition decisions and raise the awareness of the marine employees to relate the factors set out above to minimise operational costs.

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CHAPTER 1

1.1 INTRODUCTION AND BACKGROUND

The researcher's view is that the most utilised avenue of transportation between South Africa and the global organizations is through the country's harbours. The Marine Services is one of the business units under the port systems of Transnet National Ports Authority, later referred to as TNPA.

Transnet National Ports Authority is a division of Transnet Limited and is mandated to control and manage all seven commercial ports on the 2954km South African coastline. Situated at the tip of the African continent, the South African ports are ideally placed to serve both the eastern and western seaboards. Transnet National Ports Authority is the largest port authority in Southern Africa, controlling seven of the 16 noteworthy ports in the region. These ports are Richards Bay, Durban, East London, Port Elizabeth, Mossel Bay, Cape Town and Saldanha.
(http://www.transnetnationalportsauthority.net)

The port of Port Elizabeth is managed by Transnet National Ports Authority, a division of Transnet Ltd and is situated in Algoa Bay on the south-eastern coast of Africa, midway between the ports of Durban (384 nautical miles north-east) and Cape Town (423 nautical miles west). The port is striving to be a world class port by adhering to international standards such as the ISPS code. The port has integrating systems as this provides a framework for a holistic management system that can embrace all the processes and elements that need to be controlled. The port has the following accreditations: ISO 9001, ISO 14001, OHSAS 18001 and AMS 16001.

The entrance channel to Port Elizabeth is maintained at a depth of -14.5m chart datum and has a generous width of 310m. Limitations on vessels using the port are 11m draught for passenger and dry cargo vessels, 11.2m for container ships, 12.1m for ore carriers and 9.6m for tankers, all according to berthing. Deeper vessels may be accommodated with the permission of the harbour master. Tug assistance and pilotage are compulsory. Ships may anchor outside the port in Algoa Bay provided the approaches to the entrance channel are kept clear.

Photo 1 Tug bringing ship into Port Elizabeth harbour

Source: http://www.panoramio.com/photo/28670

The Port has three powerful tugs, which are fully equipped for navigation, radio communications, fire fighting, salvage and towing. Two tugs, at the most, are used for assisting with docking and undocking of vessels. The attendance of these tugs in the pilotage area as well as deciding as to the number of tugs needed for a particular vessel is at the pilot's discretion. The pilot gives commands through a two-way radio to the tug masters who then carry out manoeuvres on the tugs. Photo 1 shows a tug assisting a vessel that is coming into the port. This is a critical moment where the ship's speed has been reduced so it becomes difficult to steer and the tug plays the role by pushing and pulling the ship around. Photo 2 displays a view of the whole harbour detailing the breakwater, ships docked alongside waiting for tug service, the different cargo terminals and the tug jetty. The shape of the harbour and types of vessels that visit it are some of the factors associated with the type of propulsion selected. The tug jetty is where the tugs are moored while waiting for the next shipping movement.

Photo 2 Port Elizabeth Harbour

Source: Google.co.za/images

The marine engineers and motormen carry out start up procedures and monitor the tugs' engines and other machinery during towage operations. They also ensure proper shutdowns between ship movements and when the tug will be out of use for an extended period. The marine engineers and motormen also do scheduled inspections, preventive maintenance and repairs in response to breakdowns or failures.

1.2 PROBLEM STATEMENT

1.2.1 Main problem

The following problem will be addressed by this research.

To analyse the two propulsion systems used by the tugs at Port Elizabeth harbour in order to minimize operational costs.

1.2.2 Sub problems

The following sub-problems have been identified in order to develop a research strategy to solve the problem.

How will the perceived maintenance factors contribute to the minimisation of operational costs on the two propulsion systems?

How will the perceived efficiency factors assist in the minimisation of operational costs on various propulsion systems?

How are safety factors perceived to contribute to minimising operational costs on the two propulsion systems?

The sub-problems above have led to the following hypotheses

- The choices for particular tug propulsion systems are based on perceived maintenance effects on minimisation of operational costs.
- The tug propulsion choices are based on perceived efficiency effects on minimisation of operational costs.
- The safety factors in relation to minimisation of operational costs form part of the choice for tug propulsion.

1.3 AIMS AND OBJECTIVES OF THE RESEARCH

This research paper examines the analysis of different propulsion systems used by the TNPA harbour tugs in the port of Port Elizabeth to establish how this relates to minimising operational costs. The analysis of the propulsion systems is based on how maintenance must be managed, safety as pertains to reliability and the prevention of failure, and the efficiency of equipment.

The literature study explores the existing theories and models in relation to dealing with maintenance and ensuring safety and efficiency. The data collected from the tug operation personnel helped in determining the gap between the current situation and the existing theories brought forth by the literature study.

The testing of the existing theories using the analysed data paves the way towards formulating conclusions and recommendations that can be optimally implemented for a more cost effective towage operation.

1.4 IMPORTANCE OF RESEARCH TOPIC

Options and choices when buying a product always exist and purchasing a tug is not an exception. A business operation will have an equipment need that forms part of an operational process design. The size and output of the equipment relies on the designed capacity of the process. If the equipment is much bigger in size than its required output, there will be unnecessary expenditure on the purchase price. On the other hand, if the equipment happens to be smaller than the desired capacity for which it is needed, the equipment will not deliver to the expected capacity, thereby defeating the whole purpose of acquiring it.

Tugs are one of many expensive assets in the Transnet National Ports Authority and therefore careful considerations need to be taken before settling for the tug types that optimally meet the needs of the harbour in which they will operate. There are a number of factors that can be examined as advantages and disadvantages on types of tugs. For the purpose of this study, it would have been difficult to scan through all the factors, for that would have made the study to be a complex assignment.

When different tugs are being discussed, their propulsion type or design will be used to distinguish one type from the other. In the port of Port Elizabeth, there are two types of propulsion systems used by the harbour tugs, the Z-pellers and the Voith Schneider Propulsion. The importance of this study is that it will analyse them both with the view of cost minimisation. The cost minimisation can be achieved by focusing on maintenance, efficiency and safety of the propulsion type in question. For instance, one type of propulsion type may be cheaper and more convenient to maintain than the other, enabling the organisation to offer a more reliable service and better asset availability.

Nowadays ships are becoming bigger and heavier because of refined logistics trends in the shipping industry. The challenge that faces a towage company is to increase the bollard pulls or the power of its tugs in order to match the heavier ships that they have to move around the harbour. The increase referred to normally leads to a bigger and more expensive tug. Increasing the power of a tug by proportionately lesser than the client's increase in ship size, can only be achieved by choosing an efficient propulsion design. The study also addresses this subject as one of the criteria for determining the appropriate design of propulsion for a specific port.

The study will also look at outlining the factors that affect the safety operation of a tug. The discussion will be centred on how each type of propulsion contributes to the prevention of failures and collisions during the towage operations. The data collection will also reveal the opinions about the choice of propulsion design according to the experiences of the tug personnel. All of these factors will be critically examined by following the research sub-problems as explained in the preceding subtopic, 1.3.

1.5 DEFINITION OF CONCEPTS

Availability: Availability is defined as the proportion of time that a technical system or machine is operative – in the non-failed state. The uptime or availability of equipment is the proportion of time the equipment is actually available out of the time it should be available.

Maintenance: Maintenance is a process that is triggered by equipment failure or planned repair. This process requires planning, scheduling, control and deployment.

Reliability: Total productive maintenance describes a synergistic relationship between all organisational functions, particularly between production and maintenance, for continuous improvement of product quality, operational efficiency and capacity assurance (Jostes & Helms, 1994:18-20).

Planned maintenance: Planned maintenance aims to have trouble free machines and equipment and defect free products to fully satisfy customers' requirements. This planned maintenance is classified into preventive maintenance, breakdown maintenance, corrective maintenance and maintenance prevention.

Overall equipment efficiency: This is a combination of the uptime (availability of the equipment), cycle time efficiency (production efficiency) and quality output of the equipment.

Efficiency: Efficiency in this study refers to the ratio of useful work done to total energy expended (Fowler and Fowler, 1980:330).

1.6 DELIMITATION OF THE RESEARCH

The research is limited to the following area:

Organization to be researched

This research paper is limited to the Marine Operations business unit of Transnet National Ports Authority in the port of Port Elizabeth, in the Eastern Cape. The focus will be limited to the propulsion systems of the tugs.

Level of management

The research was limited to the marine operations management and the operational employees in the same department.

1.7 THE RESEARCH METHODOLGY PLAN

The research entailed a survey of literature and some academic material from the library and the internet such as journals and other article. This assisted in giving the researcher an edge to start with the discussion.

Questionnaires that were drawn up by the researcher were distributed by e-mail to the key personnel involved in the operation of tugs. Those who had no access to e-mails were called by telephone and the responses were recorded on the same questionnaire. These were the marine engineers, the tug masters, the pilots and the technical staff based in the office. Since the environment where the research is based is well known to the researcher, this helped in giving a sound basis for structuring the questionnaires.

The results of the literature and empirical survey were integrated to analyse the different propulsion systems and how this related to minimizing operational costs. Both the literature study and the empirical survey were aimed at addressing the sub-problems. This entailed maintenance and its management, the propulsion efficiency and the propulsion safety.

The detailed discussion of the research methodology of this study is covered in Chapter 3.

1.8 KEY ASSUMPTIONS

The following assumptions were made:

- The need for harbour tugs will always exist since the service provided by them is linked to shipping, which is a dynamic industry.
- Top management who are involved in the purchasing of tugs for Transnet will always rely on marine operations' employees for choosing the suitable tugs' propulsion design.
- The respondents to the questionnaires are well informed and well qualified to give quality feedback on the information requested.
  The responses are thoughtful and sincere.

Should marine operations become more aware of the relationship between the different types of propulsion design and cost minimisation, there will be a more focused view on the choice of tug propulsion designs.

1.9 STRUCTURE OF THE STUDY

Chapter 1 gives the introduction to the research. This chapter consists of the introduction and the background of Transnet National Ports Authority, the main problem, sub-problems and the importance of the research. Furthermore, it covers the delimitation of the research, the research structure, the key assumptions and the definition of key concepts.

Chapter 2 consists of the literature study. The chapter covers a theoretical overview of maintenance management, equipment safety and equipment efficiency in respect of the operational costs. Different maintenance sub-topics are structured based on the scope described by August, (2004:7).

Chapter 3 discusses the research methodology used for collecting data in relation to the relevant literature. This expands on what was briefly indicated in Chapter 1.

Chapter 4 presents an analysis of research results. In this chapter the gaps were determined between the theories and models discussed, and the actual situation of the analysed propulsion systems in relation to the perceived factors that affect minimising costs.

Chapter 5 consists of synopsis, conclusions and recommendations. The chapter focuses on providing solutions based on the best known management practices in the disciplines of maintenance management, efficiency and safety.

CHAPTER 2

THE LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is a review of the literature that relates to maintenance management, equipment efficiency, and equipment safety. The views of the literature regarding the problem at hand are also presented. The chapter seeks to discuss the key principles of maintenance management, equipment efficiency and equipment safety and how they can be applied to minimise costs in a business operation. A variety of sources from different researchers has been used to study some of the best practices in these fields. The chapter is divided into three sub-sections, which are:

- the literature review of maintenance management;
- the literature review of equipment efficiency and
- the literature review of equipment safety.

2.2 LITERATURE REVIEW OF MAINTENANCE MANAGEMENT

Maintenance systems are responsible for keeping equipment fit, safe to operate and well configured to perform its task. Therefore maintenance has a major impact on delivery, quality and cost and also plays a key role in the long-term profitability of an organization in the private or public sectors. Maintenance is a process that is triggered by equipment failure or planned repair. This process requires planning, scheduling, control and deployment (Journal of Quality in Maintenance Engineering, Vol. 7 No. 3, 2001:207). This section focuses on maintenance management and its impact on the minimisation of operational costs.

Coetzee Jasper (1998:22) states the following with regard to the need for maintenance:

> As all equipment is prone to breakdown, there must be some function in existence to replace or repair such unit(s) so that the production can be rescued. This function is called maintenance.

The notion above shows the importance of maintenance as one of the factors for selecting a specific type of tug propulsion system. Further, one can draw a link between replacement or repair of equipment and the costs involved.

2.2.1 The objectives of maintenance

Equipment is an important resource that is constantly used for adding value to products. So, the equipment must be kept at the best operating condition. Otherwise there will be excessive down time and also interruption of production in the case of a mass production line. Poor working of equipment leads to quality related problems. Hence, maintaining the equipment in good operating conditions with economical cost is an absolute necessity. Hence, we need an integrated approach to minimize the cost of maintenance. In certain cases, the equipment will be obsolete over a period of time. If a firm wants to be in the same business competitively it has to take decisions on whether to replace the equipment or to retain the old equipment by taking the cost of maintenance and operation into account (Panneerselvam 2006:440).

The managers of tug fleet, therefore, need to be decided as to how long they want to keep the tugs for, taking into consideration the escalation of repair costs and the operation interruptions.

> Coetzee (1998:24) formulates the objectives of maintenance thus: "It is the task of the maintenance function to support the production process with adequate levels of availability, reliability and operability at an acceptable cost." He also lists four sub-objectives of maintenance:

1. Availability – availability is defined as the proportion of time that a technical system or machine is operative – in the non-failed state. The maintenance function must provide at least an acceptable level of availability to production (that level which adequately supports the production plan) to maximise maintenance management to provide maximum economically viable levels of availability.

Availability is one of the main measures that are used to ensure minimal disruptions to the rendering of tug services to the client's ships. The levels of availability have to match or supersede the delays tolerances as stipulated in service level agreements between ship owners and the harbour operations. Reliability, as another objective of maintenance as explained below, also ensures optimum levels operating capacity.

2. Reliability – reliability is a measure of the number of times that the technical system or machine experiences problems. It provides an indication of the continuity of the production process. A technical system or a machine can have high availabilities without being reliable. While availabilities are important to ensure sufficient operating capacity, a low level of reliability will lead to a high proportion of nuisance stoppages, with a corresponding loss due to stop-start effects. Therefore both high availabilities and high reliabilities are necessary to ensure that the maintenance function contributes significantly to company success.

3. Operability – operability is defined as the technical system's or machine's ability to sustain adequate (limited by the design) production rates. While high availability and reliability of equipment are of prime importance, they cannot produce the

required result without being supported by adequate levels of operability.

The objective of operability can be linked to the original design of the tug propulsion systems in terms of capabilities and the maintenance that ensures that those capabilities are not compromised as the equipment ages.

4. Cost – any maintenance action should be carried out only if its cost implications are acceptable. Therefore all maintenance policies, strategies, objectives and plans should have as a basis the optimisation of cost (with the emphasis on long term costs).

The bottom line of the function of maintenance is the costs which in turn become the deciding factor for the selection of tug propulsion types. A reasonable approach would be to get some balancing medium between the peak of maintenance costs and the cost of replacing the whole tug.

2.2.2 Types of maintenance

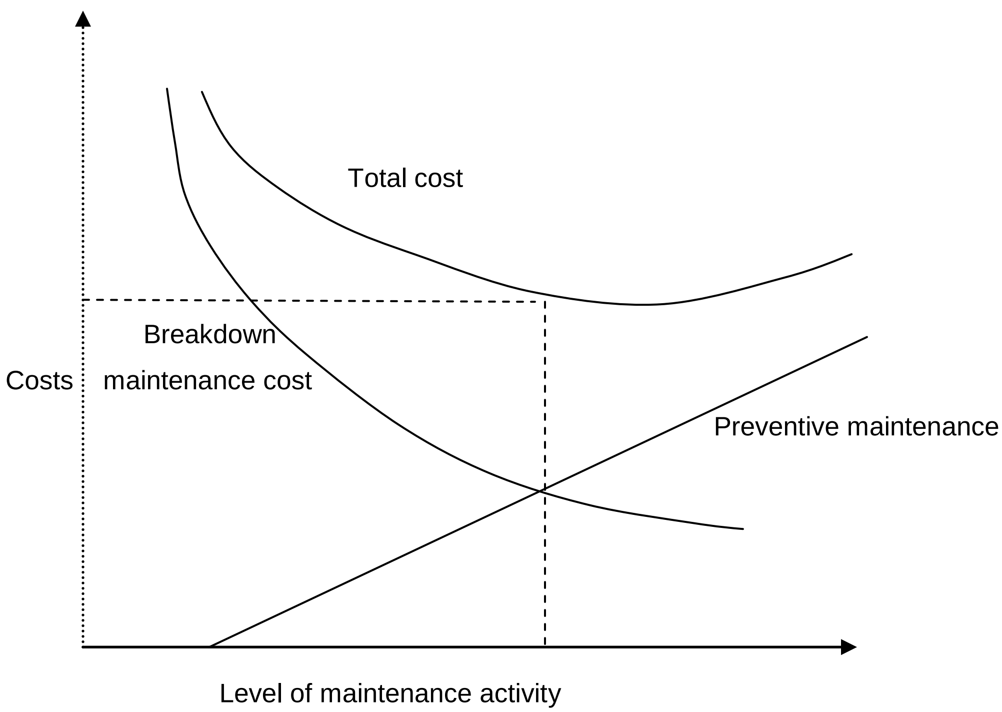
According to Panneerselvam (2006:440), maintenance activity can be classified into two types; preventive maintenance and breakdown maintenance. Preventive maintenance (PM) is the periodical inspection and service activities which are aimed to detect potential failures and perform minor adjustments or repairs that will prevent major operating problems in future. Breakdown maintenance is the repair that is generally done after the equipment has attained down state. Breakdown maintenance is often of an emergency nature, which will have associated penalties in terms of expediting cost of maintenance and down time cost of equipment. Preventive maintenance will reduce such cost up to a point. Beyond that point, the cost of preventive maintenance will be more when compared to the down time cost. Under such a situation, a firm can opt for break-down maintenance. These concepts are shown in Figure 2.1.

Practically, there could be a combination of maintenance activities. Slack, Chambers and Johnston (2001:656) point out a combination of three basic approaches to maintenance as follows:

- Run to breakdown (RTB)

As its name implies, this approach involves allowing the facilities to continue operating until they fail. Maintenance work is performed only after failure has taken place. Failure in these circumstances is neither catastrophic nor so frequent as to make regular checking of the facilities appropriate.

Figure 2.1: Maintenance costs



Source: Panneerselvam (2006:440)

The relationship between the run to breakdown approach and the minimisation of maintenance costs is the evaluation of the cost outcomes of the breakdown. The longer the interval between component replacements, the more cost savings. The interval has only to be shortened if costs of breakdown repairs are high compared to the costs accumulated due to shorter replacement intervals. A scenario can be considered as an example where the casings of propulsion units could leak because of erosion, corrosion or fatigue. Picking the right time to do replacement or repair in these instances is impossible.

- Preventive maintenance

Preventive maintenance attempts to eliminate or reduce chances of failure by servicing (cleaning, lubricating, replacing and checking) the facilities at pre-planned intervals. For example, the engines of passenger aircraft are checked, cleaned and calibrated according to a regular schedule after a set number of flying hours. Taking aircraft away from their regular duties is clearly an expensive option for any airline. The consequences of failure while in service are considerably more serious, however. The principle is also applied to facilities with less catastrophic consequences of failure.

- Condition-based maintenance (CBM)

Condition based maintenance attempts to perform maintenance only when the facilities require it. Stopping the machine to change, say, a bearing when it is not strictly necessary to do so would take it out of action for long periods and reduce its utilisation. Here condition-based maintenance might involve continuously monitoring the vibrations, for example, or some other characteristic of the line. The result of this monitoring would then be used to decide whether the line should be stopped and the bearing replaced.

Preventive and condition-based maintenance types are mostly used for optimising savings on the maintenance of tug propulsions. In both the types, the right time to conduct equipment service or replacing a component is gauged by the history of failures in the case of the preventive type and by the condition which is known from experience to indicate imminent failure.

2.2.3 Good maintenance in a nutshell

Everyone involved in the operations or production would like to claim that they have a good approach to maintenance. There is more to good operation than sticking to simple maintenance rules, such as not to fix anything on a machine that is running well and fixing only what is broken on a machine that is not running well. Bloch (1988:315) highlights these few important facts about good maintenance:

> *The design must be right*. The machine must be capable of pumping the required quantity of gas over the range of discharge conditions without overloading either the driver or the compressor end.
>
> *Correct materials must be used* in order to realize success from a good design.
>
> *Assembly* in the shop and in the field must be completed *without error.*
>
> The compressor must be *maintained properly.* Maintenance is the responsibility of both the process operator and the mechanics. For example, the process operator is exercising poor maintenance if he operates the machine outside its design limits or neglects lubrication. Likewise, the mechanic is not practising good maintenance if he “fixes” a machine by the trial and error approach.

The right design ensures that the equipment does what is expected effectively and efficiently. The built of tugs and their propulsion units are awarded to the best known entities that have a proven record of producing reliable and robust units. This manner prevents unnecessary failures that result in overspending against maintenance budgets. The example used above of a mechanic and an operator displays the common mind-set that must be shared between the tug operators and the marine engineers in terms of using the equipment correctly and conducting repairs correctly to avoid repetitions of failures.

2.2.4 The elements of maintenance

The fact that maintenance costs money is evident as expenses are incurred in buying materials, consumables and labour. This easily gets overshadowed by the importance of maintenance as one appreciates what is actually involved in the maintenance of equipment such as tug propulsion systems. Bloch (1988:315) highlights the elements of maintenance as follows:

> *Evaluation of the condition* of a running machine to determine what needs to be done, if anything, for the machine to safely and economically continue to operate for a prescribed period of time subject to the specific restrictions:
>
> *Determination of corrective measures* necessary to return a machine which is down to safe and economical operation.
>
> *Development of efficient work execution procedures* and tools if the desired level of maintenance is to be provided as inexpensively as possible. Included in this area are:
>
> a. Proper scheduling of condition monitoring.
> b. Tune-ups or their equivalent.
> c. Improved materials.
> d. Planned streamlined procedures to minimize oversights or errors in assemblies.
> e. Special tools.
> f. Controlled spare parts.
> g. Maximum standardization and interchangeability of parts.
>
> *Safety of personnel*. This is the number one consideration in maintenance and operation, as in any other field of endeavour. General guidelines to safety must be developed, issued, and discussed with all operating and maintenance personnel.

2.2.5 Predictive versus periodic inspection maintenance

The descriptions of predictive and periodic inspection maintenance are provided by Bloch. The term “predictive maintenance” is used to identify the maintenance philosophy described previously. To sum up this philosophy in slightly different words, predictive maintenance evolves from two basic facts:

a) Certain vital parts last longer and operate better if not frequently taken apart.
b) Operation until complete destruction is not only foolish but costly.

From an economic viewpoint, there has to be a point where the equipment must be opened up for inspections. If it happens too early, it is not economically sound. The results from periodic inspections should in turn be informative to the maintenance planner in order to determine the right time preventive maintenance.

For a comparison, let us review the principles of periodic inspection maintenance. In this type of maintenance the assemblies constituting the entire engine are torn down, inspected, and cleaned after they have run a specific number of hours. The number of hours between inspections is established by the engine manufacturer on the basis of experimental and development tests, or they are established by the experience of the operators. (Bloch, 1988:317)

2.2.6 Total productive maintenance (TPM)

a) Objectives of total productive maintenance (TPM)

- Aim at the creation of a collective culture relating to the attainment of maximum efficiency throughout the production process.
- Use the system so as to prevent losses and to reach “zero accident”, “zero defect” and “zero breakdowns”, in the manufacturing process.

The utilisation of a tug involves different pieces of equipment that operate mostly at the same time while the service is being rendered to a client's ship. As the culture of optimising efficiency exists with all personnel on the tug costly accidents and breakdowns are eliminated and costs are kept to a minimum. The benefits of TPM as listed below have a bearing on the minimisation of operational costs.

b) Benefits of TPM

- Increased equipment productivity
- Reduced equipment downtime
- Increased equipment capacity
- Lower maintenance and production cost
- Approaching zero equipment-caused defects
- Improved return on investment
- Rectified customer complaints
- Reduced accidents
- Better understanding of the performance of equipment
- Better understanding of critical equipment and the worth of deploying improvement effort for potential benefits.

2.2.7 Planned Maintenance

The term 'planned maintenance' has become a buzzword in production and operations according to the researcher's observations. Panneerselvam (2006:473) explains that planned maintenance aims to have trouble free machines and equipment to produce defect free products to fully satisfy customers' requirements. This planned maintenance is classified into preventive maintenance, breakdown maintenance, corrective maintenance and maintenance prevention.

The explanation of the above mentioned classification of planned maintenance or equipment maintenance techniques is stipulated below according to Panneerselvam (2006:473):

Preventive maintenance. It involves cleaning, inspection, oiling and re-tightening of parts which help retain the healthy condition of equipment and prevent failure through the prevention of deterioration, periodic inspection or equipment condition diagnosis to measure data about deterioration.

This preventive maintenance is further classified into periodic maintenance time based maintenance, (TBM) and predictive maintenance. Time based maintenance consists of periodically inspecting, servicing and cleaning equipment and replacing parts to prevent failures and process problems. Predictive maintenance is condition based maintenance, which manages trend values by measuring and analysing data about deterioration and employs a surveillance system, which is designed to monitor conditions through an online system.

Corrective maintenance is to modify or improve equipment for increased reliability and easier maintenance. This means that the equipment with design weaknesses is redesigned to improve reliability or maintainability.

Maintenance prevention is to design and install new equipment that is maintenance-free based on the study of the weaknesses of current equipment.

Breakdown maintenance is to repair equipment quickly after break down.

Preventive and corrective maintenance techniques are based on the history of failures and the associated intervals. Repairs and servicing of equipment take place before the likely point of failure in the case of preventive maintenance. The information about failures and the machinery hours at which the equipment failed is shared among colleagues and even among various harbours so that proper planning can be put in place to avoid unanticipated failures. Components are upgraded where possible in order to lengthen the intervals between services and that is referred to as corrective maintenance. The shipyard personnel invariably receive feedback from harbour operations in respect of the equipment they manufacture so that they can effect design corrections for better equipment reliability.

2.2.8 Maintenance management options

The first and most obvious option is to try to handle the entire plant maintenance operation with captive, or "in-house", manpower capability. The second option is to employ full contract maintenance, and the third option is to employ the "peak shaving" maintenance concept.

Bloch (1988:299), alludes to some advantages and disadvantages of both these approaches to maintaining machinery.

2.2.8.1 In-house maintenance

The harbour systems have always adopted the concept that resembles merchant shipping with regard to manning the tugs. Among other employees that are required by the regulatory authorities on board a tug, are marine engineers. They are trained to operate, monitor and conduct maintenance and repair work on most of the tug machinery. Often, a line has to be drawn between the types of work that the onboard engineers can do and that which requires specialised outside contractors. The deciding factors on this are based on an attempt to achieve savings on costs, attaining the best work quality, and to ensure timely delivery.

Advantages:

- Under most normal circumstances, you are dealing with craftsmen who are loyal employees, who respect the objectives of your maintenance program, who have a vested interest in the continued success of your company, and who can be trusted with any propriety features of your process.

- They are aware of your company, aware of your company rules and procedures and recognize the threat of termination of their employment in case of proven incompetence.
- Captive employees must live with the results of their work – they can not just walk away and expect someone else to pick up the pieces.
- Should an emergency arise, captive personnel are right there, ready to go to work.

Disadvantages:

- What size crew is required to maintain your plant? While a full-time base-load staff is essential, manning in excess of the base-load work force is demonstrably inefficient.
- This method of maintenance tends to encourage and justify overstaffing.
- It is more difficult to train and upgrade an existing maintenance force to keep up with current technology. Daily maintenance generally does not require in-depth inspection of, and familiarization with, sophisticated machinery. Planned shutdowns are scheduled for minimum duration and are usually not the time to run a training course.

Furthermore, even a trained captive staff will be short of in-depth experience if they seldom encounter problems on the same equipment at each shutdown. They will not have the ability that comes from years of successfully handling the unusual.

2.2.8.2 Full contract maintenance

Under this type of maintenance program, you are simply hiring an outside maintenance contractor to plan, supervise, and handle your entire maintenance operation.

Advantages:

- The size of your maintenance force is constantly matched to a given workload: it is tailored to your needs, and you are only paying for what you need.
- The maintenance manager may also find that he can delegate tiresome detail and routine work to the outside contractor management and concentrate his efforts on the more important aspects of his job.
-

Disadvantages:

- There is always the chance after signing a long-term contract with a maintenance contractor, you find you are stuck with a vendor who is not performing up to standards.
- Most important, there is always the possibility that a crisis of one type or another will occur, and that your independent contractor will be unavailable - he won't be able to "jump on" your problem due to lack of people or his present logistical shortcomings.

The full contract maintenance may sound appropriate in the situation of tug operations, especially considering that harbour marine personnel are mainly operational and the manning for each tug is regulated. Most maintenance activities take place when the tug is berthed alongside rather than during towing activities. The ideal situation would be to have a spare tug that is berthed alongside and to have a contractor to carry out maintenance. The contractor will also have to prove that they are acquainted with the type of propulsion system they have to provide contractual service on. In this approach more volume of services and repair work will be achieved resulting in reduced breakdowns and minimising of costs.

Both the disadvantages listed above would be counteracted by detailed and mutually understood service level agreements between the business unit and the contractor. There is usually a prime price linked to the availability of a contractor for breakdown calls.

2.2.8.3 Peak shaving maintenance

Advantages:

- This method of operation allows you to hold your maintenance to the most cost effective level at all times.
- You can maintain a planned and systematic work schedule, keeping overtime (resulting from turnarounds and emergencies) to a minimum. This will allow you to operate within the contractual guidelines agreed to by company management and unions.
- You are able to forecast and budget your annual maintenance costs with a degree of accuracy.
- You can minimise the duration of your turnaround and the attendant loss of operating time, which will yield significant economic advantages.
- There is no need to keep equipment specialists employed full-time, and you can insist on, and get productivity from, suitably qualified outside maintenance personnel.

Disadvantages

- There is a tendency of your maintenance bargaining personnel to feel that a fully trained maintenance complement should be employed full-time.
- Resentment may arise from having outsiders come in periodically and "take-over" which may be seen as criticism of your captive workforce.
- Then there is the "love 'em and leave 'em" syndrome. In this case, after the subcontractor has completed his contract and left, the regular maintenance force may have to resolve possible problems that crop up later. This could cause resentment, and result in comments like: "Why didn't they let us do it in the first place?"

2.2.9 Key considerations in designing the maintenance system

The management of production or an operation are expected to play a role in selecting the suitable type of equipment for the business they are involved in. In the case of tugs, a suitable propulsion system that is relevant to the harbour and the types of ships visiting the port needs to be selected. This brings the discussion to the key considerations in designing the maintenance system for the type of propulsion selected.

The author of the *Journal of Quality in Maintenance Engineering*, Vol. 7 No. 3, 2001, pp. 207-219, lists the main features and activities of the maintenance system below:

- maintenance load;
- maintenance resources;
- maintenance planning, scheduling and execution;
- maintenance support functions; and
- reports and performance measures.

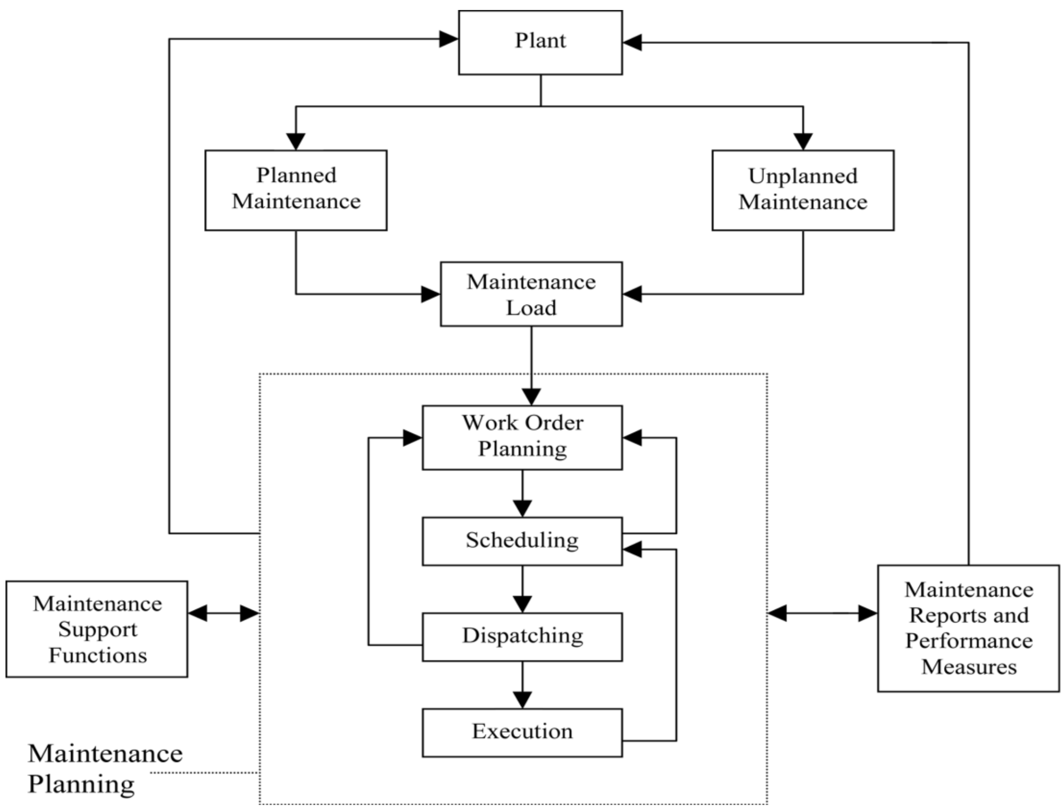
The maintenance function can be represented as a process that links the above elements of the maintenance systems as shown in Figure 2. The input to this process is generated by production/operation processes and constitutes the maintenance load. The maintenance load is made up of two major components:

Planned maintenance.

Unplanned maintenance (unexpected failures).

The work orders generated from the maintenance load are planned, scheduled, and then executed utilizing necessary maintenance resources and according to prescribed maintenance policies.

Figure 2.2: Maintenance Process



Source: *Journal of Quality in Maintenance Engineering*, Vol. 7 No. 3, 2001, pp. 207-219.

The rapid pace of change in the contemporary manufacturing and processing industry environment calls for innovative responses that freely jettison some old customs and institutions that are no longer relevant. The PM system is particularly aware of the need for plants to cope with a rapid change.

The following is a discussion of several items pertaining to the fundamentals of maintenance systematization according to Takahashi & Osada (1990:160):

a) Sufficient weight should be given to simplifying the elements of the system

The successful round trip of the Apollo moon rocket required the complex, consecutive interaction of many parts and the overcoming of multiple problems. When we think of such a large and complex system and its supporting technologies, there is a tendency to fall into the trap of thinking that systematization means making a complex system consisting of many parts. On the contrary, systematization should be thought of as technology for making complex things into a simple whole.

b) The reliability of components and of the whole system

The next step emphasizes the importance of the individual and component functions that together comprise the system as a whole. At first, this may appear diametrically opposed to the philosophy that emphasizes the idea of total system. This however, is not so. The intent here is to emphasize the need for each individual component to be on a solid footing, thus avoiding anxiety about the stability of a system comprised of individual components.

c) The system design and determination of its objectives

A common trap may ensnare people who are well-versed in various aspects of systems and system engineering. They might make an exhaustive analysis of the system requirements confronting them, and then design and develop a system or systems. The catch however, is that their systems are not responsive to the very objectives for which they were designed .From the administrative and management point of view, these people tend to operate systems without a clear direction or, where clear directions are given, directions for action are often abstract, holistic, and lack relevance to specific individual management objectives.

When the Apollo rocket was launched, a specific objective existed: to reach the moon and return. Likewise, system design and development should have specific and clear-cut objectives. If high goals are set, measures should be taken to cope with the situation by bridging the gap between the aim and its accomplishment. On the other hand, if the objectives can be accomplished without making efforts to narrow this gap, we can say that the means chosen may not even need to be managed. Depending on the kind of objectives to be accomplished, widely differing methods need to be applied.

d) When a system fails to function

When a system fails to function as desired, it is often because there was no investigation or analysis of what the system really needed to do or what it was ultimately designed to provide. Two aspects should be focused on here: (1) short–term goals for PM, i.e., for reducing current period costs, and (2) the long–term perspective, i.e., ambiguities regarding the future PM promotion program for archiving qualitative improvements in the plant. In the latter case, the system design should take into consideration from the outset the ultimate state of the plant in which it operates.

e) The system and its standards

If the view is of a system as a kind of theatrical stage on which actions or groups of actions are taken, a set of action standards must be set to keep the whole plant moving along. Sometimes, however, such standards are found to be merely theoretical, or they are often too cumbersome and convoluted to be well understood. This indicates the absence of a consistent yardstick for evaluating the action unit as a whole, which in turn causes instability in its momentum. It is therefore necessary to identify, define and adhere to the role and values of assigned tasks for each individual.

f) The key to an efficient system

There are variations of this rule, depending upon the characteristics of various enterprises. The efficiency of system-related activities, however, is inextricably intertwined with the function of the enterprise and with the functions and roles of individual subsidiary organization units within each business enterprise. The situation is similar to the role of electrical control circuits in the design of machinery, equipment, or mechanical systems for machines. The difference with management systems is that the elements of which they are comprised are not mechanical parts or electrical components, but people. Therefore even if the standards for actions to be taken within the framework of the system are clearly defined, the act of judgment determining behaviour is made by human beings. When there is a need to act in response to dynamically changing specific problems that may undergo an unpredictable number of permutations, the final choices of action are determined by human will. Understanding this is an indispensable and necessary condition for the system to make any goal orientated inferences or be aware of actions leading to success management.

Ultimately, this refers simply to the problems of raising the overall level of awareness and discipline, creating the motivation to be self-starting and thinking in terms of the systems perspectives.

People must perceive themselves in a holistic manner with respect to that which precedes and follows their actions. This perception includes for example, awareness of the relationship between the individual’s work environment and the total environment, awareness of the extent to which one’s colleagues give credence to the reliability of each other’s work, what kind of organization is effective with regard to communication with one’s peers, subordinates, or other department, what kind of impact or effect will the making of a particular procedure move have others. These factors pertain to creditability and to goal directedness and awareness. In sum, a revolution in human awareness must first be achieved before efforts at systematization and human revolution are essentially inseparable.

Efforts to advance systematization must be made through the collaboration of all plant departments. There must be clearly defined institutional and organizational arrangements to promote cooperation among the staff, project leaders, and line workers on the floor. Establishing cooperative organizational arrangement is the key to successfully advancing systematization and to acculturating the enterprise in a systematized manufacturing method. To achieve this, people's awareness is focused on a specific set of goals. At the same time, various job functions within the enterprise are also given a goal to focus on.

g) Design and operation of the maintenance system.

PM activities should be pursued in such a way that each of the sub-goals is organically linked to every other. Unless these activities are integrated and applied practically in daily routine management methods as part of the ordinary "business as usual" mode - whether they are planning, implementation, evaluation, or reactive measures or not - they cannot really be called PM activities.

This section illustrates the flow of activities originating from the annual maintenance calendar linked to the implementation and review of monthly and weekly activities. Connected to this is the management of spare parts and maintenance activities . (Takahashi & Osada,1990:156).

In consideration of the above, the planned maintenance system for the harbour tugs should be adopted from the industry's planned maintenance norms. The maintenance design should be such that it minimises the costs of running the tug machinery, especially the propulsion system concerned. The whole of Transnet National Ports Authority, including tug operation sections or maritime, invested in the SAP system that incorporates a PM component. This undertaking was to ensure the formal planning and scheduling of maintenance and the ease of producing reports that are linked to costs.

2.3 LITERATURE REVIEW OF EQUIPMENT EFFICIENCY

2.3.1 Propulsion efficiency

The choice of propulsion systems when designing or purchasing tugs is mainly based on the categories of ports, environmental conditions, the ships concerned, services required in and around the harbour, assisting methods in use, available experience and safety requirements, to mention but a few.

The basic principles of a variety of propeller designs are briefly discussed by Hensen (1997:22):

> The propellers of conventional tugs can be fitted in open frames or fitted in nozzles. Going full astern, an open fixed pitch propeller will – in general – develop about 60 percent of its maximum ahead thrust. An open cpp (controllable pitch propeller) going astern develops some 40 percent to 45 percent of maximum ahead thrust.
>
> Nozzles increase thrust and consequently bollard pull significantly. The effect of a nozzle is most pronounced with high propeller loads at low speeds. If harbour tugs have to perform in that way nozzles increase thrust by 15 to 25 percent in towing and pushing conditions.

Stokoe (1996:145) states that the Voith-Schneider propeller is typical of a vertical axis propeller and consists of a series of vertical blades set into a horizontal rotor which rotates about a vertical axis. The rotor is flush with the bottom of the ship and the blades project down. The efficiency of a Voith-Schneider propeller is relatively low but it has the advantage of high manoeuvrability and is useful in harbour craft and ferries.

As the need for high safety standards and the reduction of incident rates rises, there is a considerable move to the Voith-Schneider designs. The other approach would be to opt for more efficient propulsion while compromising on manoeuvrability, and then trade-off by acquiring highly sharpened handling skills.

2.3.2 Overall equipment efficiency

The quest for efficiency is to meet the management and its stockholders' focus on improving the return on fixed assets of the company. To meet this challenge, production management is striving to operate the equipment at its highest efficiency, which enables the company to meet current demand without expensive expansion projects. The management of a tug fleet need to acquaint themselves with the availability potential and the time expected to carry out maintenance for various propulsion systems, because these factors have a direct bearing on the overall equipment efficiency.

To improve profitability, the production manager is looking for ways to reduce operating costs. He can do this by understanding how each machine operates depending on the product being produced. Alternatives can then be tested to find lower cost materials for production or more efficient ways to run the machines.

Overall equipment efficiency (OEE) is a combination of the uptime (availability of the equipment), cycle time efficiency (production efficiency) and quality output of the equipment. The uptime or availability of equipment is the proportion of time the equipment is actually available out of the time it should be available.

One can appreciate the fact that improved efficiency would minimise the cost of doing business and that is the reason the concept of efficiency has to be considered from the literature viewpoint.

2.4 LITERATURE REVIEW OF EQUIPMENT SAFETY

The Marine Services has a significant role to play as far as ensuring safe arrivals and departures for ships that visit the harbour. While the harbour tugs are utilised to assist the docking and the undocking of ships, all facets of safety have to be ensured. The safety referred to includes that of humans and assets in the form of machinery, among other things. All injuries and damages due to unsafe tug handling and unsuitable equipment give rise to enormous costs emanating from damage claims and loss of man-hours. Once safety standards are raised to an acceptable level with regards to equipment, the minimisation of operational costs will surely be recognised.

Bloch (1988:316) has the following to say about safety:

> This is the number one consideration in maintenance and operation, as in any other field of endeavour. General guidelines to safety must be developed, issued, and discussed with all operating and maintenance personnel.

2.4.1 Classification of harbour tug types

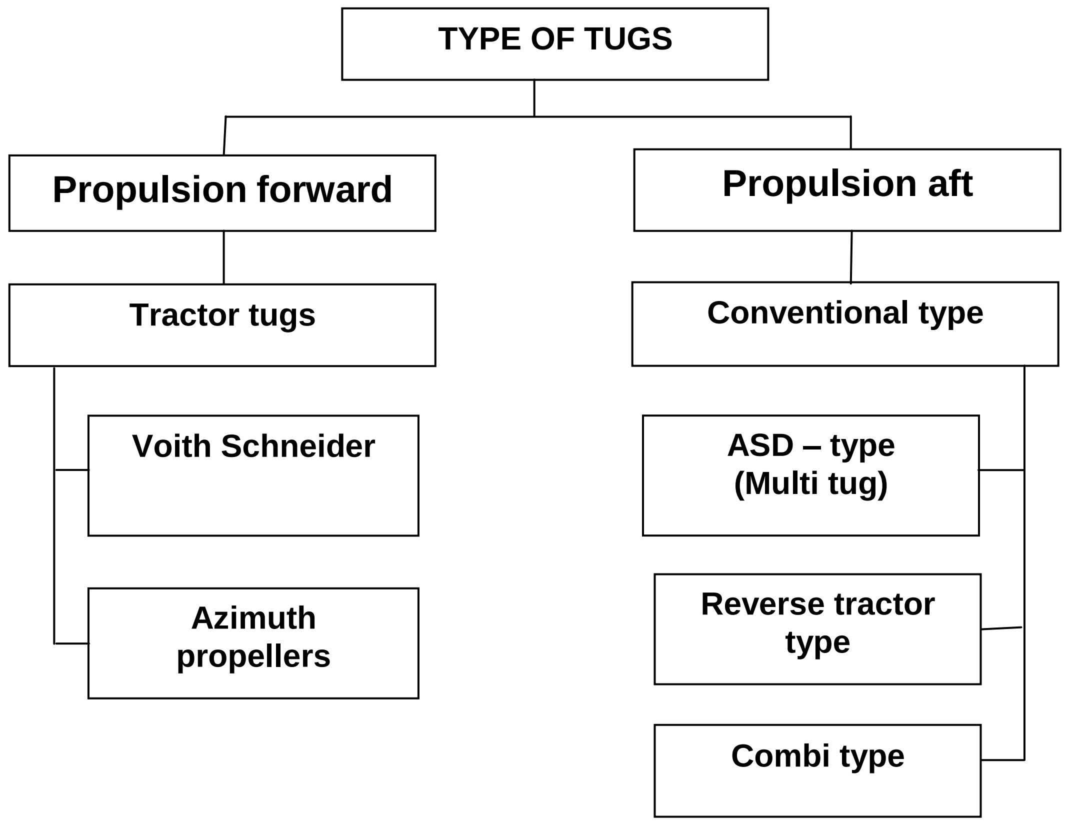
For any tool or piece of equipment that needs to be purchased there must be careful considerations about the safety aspect of that equipment. Port operations can not select a tug that is safe for their respective harbour without appreciating the fact that there are several classifications of harbour tugs and their impact on the minimisation of operational costs is diverse.

Hensen (1997:17) explains the types of tugs as follows:

> The types are named after their main characteristics, i.e. the type of propulsion, propulsion manufacturer, location of propulsion or steering system. Names include conventional tugs, Voith Schneider tugs, Z-peller tugs, Kort nozzle tugs and tractor tugs, among others.

As will be seen later, it is better to classify tugs according to their location of propulsion and towing point. It makes things easier to understand.

Figure 2.3: Main Types of Harbour Tugs



Source: Hensen (1997:16)

As shown in Figure 2.3, for the purpose of understanding the difference in the classification of the Voith Schneider and Z-peller propulsions, there are two classifications of tugs, which are:

Tugs with their propulsion aft and towing point near midships. These are conventional types of tugs.

Tugs with their towing point aft and propulsion forward of midships. These are tractor tugs.

Hensen (1997:17) emphasises the following factors as being vitally important for good harbour tug safety and performance:

a) Response time

Harbour tugs should have a short response time and their manoeuvrability should be such that the tug can react in a minimum of time. It is therefore important that measures are taken to increase the manoeuvrability of tugs and shorten their response time. Not only is a short response time required when assisting a vessel, but also for making fast. Due to ever decreasing numbers in a ship’s crew, the time taken to make tugs fast is increasing. Thus the requirement for tugs regarding fast and easy handling of towing equipment becomes an element of increasing importance in order to improve their response time.

b) Effectiveness and safety of operations

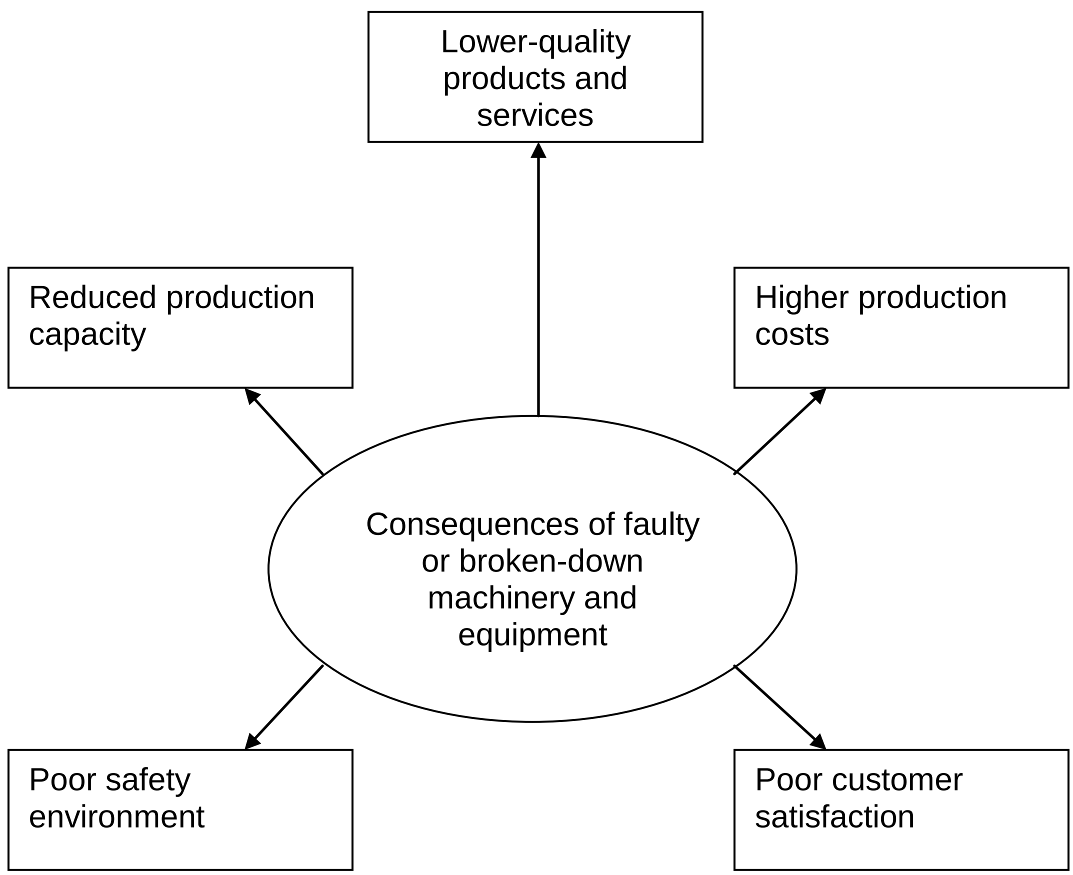
Not only manoeuvrability, but also bollard pull and underwater shape make a tug effective and therefore suitable for the job. For example, large ships with containers stacked six high on deck need powerful tugs in case of strong winds. When a ship is underway at speed, loss of tug’s effectiveness due to the ship’s speed and/or towing direction should be as small as possible. The effectiveness and safety of a tug is also related to factors such as the tug’s stability and suitability of towing equipment.

c) Required manoeuvring space

The manoeuvring space required by assisting tugs should, depending on the situation, be as small as possible. This can be achieved by good tug dimensions and proper equipment.

The smaller the space required for the tug to move the less the chances of collisions. There is therefore a link between the type of propulsion selected and the ability of a tug to operate safely. As accidents are costly and time wasting, minimisation of operational costs is possible with a propulsion type that is suitable for its use.

Figure 2.4: Consequences of Faulty or Broken-down Machinery and Equipment



Source: Kruger, De Wit & Ramdass (2005:515)

2.4.2 Poor safety environment

An analysis of safety in relation to the equipment and its impact on operational costs is one of the objectives of this study. An escalation of the rate of accidents on tugs leads to higher operational costs as remedial interventions are put in place. Accidents on tugs often result in structural damage, damages to the clients' ships and injuries on duty with subsequent claims.

The failure recovery mechanisms differ from one propulsion design to another. The example can be made of the Voith Schneider Propulsion units which can be utilised to propel and steer the tug to a safer position even after a power failure. On the other hand, Z-peller propulsion units whose designs are factored to a large extent by electrical and electronic controls, will put the tug operator in an awkward position in the event of a power failure because the tug will not be steerable.

Kruger, de Wit and Ramdass (2005:516) allude to the effects of a poor safety environment:

> The breakdown of machinery and equipment results in the occurrence of accidents that can cause serious injuries and even death. Machines with unprotected working parts are illegal and can also cause accidents. Proper maintenance policies can ensure that organization's machinery and equipment adhere to safety laws and regulations.

The consequences of equipment failure are illustrated in Figure 2.4 above and they all translate to operational costs. There is possible minimisation of operational costs if suitable equipment is used and maintenance is done to prevent failures.

2.5 SUMMARY

This chapter reviewed the literature on the themes of maintenance management, equipment efficiency, and equipment safety. This approach served to seek answers to the research objectives that were drawn up in Chapter 1. The views of the literature regarding the problem at hand were presented. The chapter sought to discuss the key principles of maintenance management, equipment efficiency and equipment safety and how these principles can be applied to minimise costs in the marine business operation. A variety of sources from different researchers has been used to study some of the best practices in these fields.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter explains the research methods, the research design and the tools used to acquire data for analysis. The chapter also describes the targeted population and the fieldwork done. Chapter 1 introduced the main problem and its sub-problems that were to be resolved by this research study.

The procedures and techniques employed during this study are discussed in this chapter. The main focus is on the steps taken in the construction of a theoretical basis for the study, the method of data collection and the sampling methodology. Regarding the techniques used in data collection, the choice of the measurement technique and its limitations are examined. The procedure used in the analysis and interpretation of the data are also discussed.

3.2 DEFINITION AND CONCEPT OF RESEARCH

The concept of research needs to be defined clearly since the whole study is based on its scientific reasonableness and its success. The Oxford Dictionary (1995:1169) and Hawkins (1994:433) define research as the systematic investigation into sources in order to establish facts and reach new conclusions or collate old facts by the scientific study of the subject or by a course of critical investigation. However, various definitions of the concept research can be given. Mouton and Marais (1992:7) define research as a collaborative human activity in which social reality is studied objectively with the aim of gaining a valid understanding of it.

Another definition states that research can be seen as a process of expanding the boundaries of one's ignorance (Melville & Goddard 1996:14). Finally, Leedy (1993:11) and Leedy and Ormrod (2001:4) define research as studious inquiry or examination, having for its aim the discovery of new facts and their correct interpretation. There are different modes of acquiring knowledge through research. However, the scientific approach differs from others in the assumptions on which it is based and its methodology. The scientific methodology is a system of explicit rules and procedures on which research is based and against which claims for knowledge are evaluated (Frankfort-Nachmias & Nachmias, 1992:14).

According to Frankfort-Nachmias and Nachmias (1992:16), scientific methodology explains the logical foundations of reasoned knowledge and is the essential tool of the scientific approach, along with factual observations. The scientific methodology is also a system of valid reasoning about factual observations that permits reliable inferences to be drawn from the factual observations. This research is also based on factual observations and explicit rules of research were applied throughout the research process.

3.3 RESEARCH DESIGN

Hawkins (1994:141) states that design is a preliminary plan, concept or purpose. Supporting and expanding on this, Yin (1994:20) defines design as the preparation of a working plan aimed at systematically assembling, organising and integrating data, in order to solve the research problem. Leedy and Ormrod (2001:91) state that research design includes the planning, visualisation of the data and the problems associated with the employment of the data in the entire research project.

Leedy (1997:3) defines research as the systematic process of collecting and analysing information in order to increase the understanding of the subject the researcher is concerned with or interested in. Collis and Hussey (2003:113) use the concept of “research” to refer to the art of planning procedures for conducting studies to get valid findings.

Collis and Hussey (2003:114) suggest and explain the process design as in Figure 5.

Figure 3.1 Overview of research design

Identify research problem
↓
Determine purpose of research
↓
Develop theoretical framework
↓
Define research questions/hypotheses
↓
Define terms
↓
Identify limitations of study
↓
Decide methodology
↓
Determine expected outcome

Source: Adapted from Collins and Hussey (2003:114)

Welman and Kruger (1992:2) explain the concept of research as the process in which scientific methods are used to expand knowledge in a particular field of study. They conclude that research as a process involves the application of various methods and techniques in order to create scientifically obtainable knowledge by using objective methods and procedures.

- Identify research problem

Collis and Hussey (2003:115) assert that research must address a specific research problem or issue. They further claim that identifying a research problem is always an exploratory and relative phase in research and they conclude that identifying a research topic can be lengthy as the researcher has to keep revising his or her initial ideas and referring to the literature until he arrives to a business problem which will lead to a researchable project.

- Determine purpose of the research

The purpose of the research is stated in a separate section, initially in the research proposal (Collis and Hussey 2003:120). As quoted by Collis and Hussey, Creswell (1994) postulates scripting when preparing a purpose statement. Scripting is the process of filling in blanks in a piece of text based on cues in the sentence (2003:120)

- Develop theoretical framework

Collis and Hussey (2003:122), state that theory is a set of interrelated variables, definitions and propositions that presents a systematic view of phenomena by specifying relationships among variables with the purpose of explaining natural phenomena. A theoretical framework according to Collins and Hussey is a collection of theories from the literature, which underpins a positive research study.

- Defining research questions or hypothesis

Collis and Hussey (2003:124), regard this topic as a crucial stage in the research. In a positivistic study a specific recommendation is that there must be a specific research question (Black, 1993) as quoted by Collis and Hussey. Keringer (1986) as quoted by Collins and Huusey (2003:125) argues that the following holds for the positivistic study. It must:

» Express a relationship between variables;

» Be stated in unambiguous terms in question form;

» Imply the possibility of empirical testing.

- Defining terms

Collins and Hussey (2003:127) state that it is important to define terms especially when they are used for the first time to ensure consistency.

- Identifying limitations and delimitations

A limitation identifies potential weaknesses in the research for example, when you have finished your investigation, you may consider that it is inappropriate to generalise from your research findings. Delimitations explain how the scope of study is focused on one particular area for example, to confine interviews to employees in one company, or restrict questionnaires to a particular geographical area (Collis and Hussey, 2003:129).

- Deciding the methodology

The choice of methodology should be clear and restricted by the chosen paradigm (Collis and Hussey. 2003:129).

- Determining the expected outcome

Collins and Hussey (2003:130) point out that determining the expected outcome is to refer to the purpose of the research, since the outcome should complete the circle and will achieve what you intend to achieve.

Fouche (in De Vos 2002:108) states that a research goal refers to a dream while objectives are the steps one has to take, realistically within a certain time-span in order to attain the dream. The same approach was adopted in this research. The aim of the research was to analyse the various propulsion systems used by tugs in the Port Elizabeth harbour. In order to respond to the main problem, the following sub-problems needed to be formulated and be addressed.

Sub-problem one

How will the perceived maintenance factors contribute to the minimisation of operational costs on the two propulsion systems?

Sub-problem two

How will the perceived efficiency factors assist in the minimisation of operational costs on various propulsion systems?

Sub-problem three

How are safety factors perceived to contribute to minimising operational costs on the two propulsion systems?

The basic format of all research

Leedy and Ormrod (2001:91) contend that the research process follows a basic format and that no matter which academic discipline gives rise to the research endeavour, the general research procedure is fundamentally the same. Table 3.1 below shows the basic format:

Table 3.1: The basic format of the research

- A question that has no known resolution is posed in the mind of a researcher.
- The researcher converts the question to a clearly stated problem.
- The researcher poses a temporary hypothesis or a series of hypotheses.
- The literature is searched for a possible solution to the problem.
- If the search leads nowhere, another avenue must be found to resolve the problem.
- The researcher looks for data that may relate to the problem, analyzes and interprets the data to suggest a conclusion.
- Either the data seemingly resolve the problem or they do not, or either the data support the hypotheses or they do not.

Source: adapted from Leedy & Ormrod (2001:92)

Leedy and Ormrod (2001:91) further state that in planning a research design, the researcher in quest of new knowledge and understanding cannot be shackled by discipline-specific methodological restraints. They argue that the research project will frequently lead the investigator to new unfamiliar territories that have historically been associated with other academic disciplines.

Research reports for most quantitative studies are similar in their organisational format. After their preliminary pages which include title page, acknowledgements, table of contents etc, Leedy and Ormrod (2001:297) state that they typically have five major sections:

- An introduction, which includes the statement of the main problem, assumptions, definition of terms, etc,

- A review of related literature
- A description of research methodology
- Discussion of results and
- Conclusions including implications and suggestions for further research.

This research study is based on the design that has been laid out. This research report is composed of five chapters which are briefly outlined in Chapter 1.

3.4 RESEARCH DATA COLLECTION

Leedy and Ormrod (2001:94) define data as *manifestation* of reality. According to this definition data are not reality itself or “naked truths” as Leedy and Ormrod put it. Wegner (2001:12 -14) points out that there are two classifications of data sources, namely:

- Firstly, internal data sources which refer to the availability of data which are generated during the course of normal business activities, from within an organisation. Contrary to this, external data sources are outside an organisation.
- Secondly, primary data sources where data are captured at a point where they are being generated for the first time with a specific purpose. Secondary data are data collected and processed by others for a purpose other than the problem at hand. Leedy and Ormrod (2001:95) state that primary data are closest to the truth and are truth-manifesting. Contrary to this, secondary data are derived from primary data and not from the truth itself.

Focusing on primary and secondary data types, Table 2 highlights some of the advantages and disadvantages of the two.

Table 3.2: Advantages and disadvantages of Primary and secondary data

	Primary Data	Secondary Data
Advantages	• Directly relevant to the problem at hand. • Offer greater control over data accuracy.	• Already exist thus access time is short. • Less expensive to collect.
Disadvantages	• Time consuming to collect. • Expensive to collect.	• Data may not be relevant to problem at hand. • It may be difficult to assess data accuracy.

Source: Wegner (2001:13-14)

As can be noticed from Table 2 both of these two data types have advantages and disadvantages. However, in order to resolve the main problem of this research study, data had to be collected. This included the employment of the following:

- literature review
- site observations
- sampling
- quantitative research methods
- questionnaires and
- interviews

3.4.1 Literature review

Leedy and Ormrod (2001:70) state that the literature review describes the theoretical perspectives and previous research findings related to the problem at hand. The researcher has used literature in this research study for that purpose and to find possible solutions to the problem. The Internet was also used for the research for more information. Without exploring the literature and the internet, it would be impossible to distinguish the gap that the responses to the questionnaire would be expected to close.

3.4.2 Site observations

According to Lawrence and Pasternack (2002:11), those performing a management science analysis should make every effort to observe the problem from various points of view within the organisation, with the goal of understanding the problem at least as well as, if not better than, those individuals directly involved. In the maritime environment, the opinions or perspectives of managers, pilots, tug masters, marine engineers and motormen may be solicited.

The researcher would have appreciated the idea of paying a few visits to the field being surveyed had he been unfamiliar to the field. The researcher is in the employ of TNPA and has worked in Port Elizabeth in the marine business unit for eight and a half years. This is why an extra visit was not necessary for the purpose of getting some understanding of the environment. It was during this period that the question in research came to the researcher’s mind, leading to occasional discussions among colleagues as well as the careful reading of manuals, brochures and internet articles.

Direct observation is one of the three approaches used for data collection (Mouton 2001:105; Wegner, 2001:14). Wegner (2001:15) states further that observation is advantageous in that the respondent is generally not aware of being observed and therefore behaves naturally. This reduces the likelihood of gathering biased data. The disadvantage, however, is that it is a passive form of data collection. There is no opportunity to probe for reasons or investigate behaviour further.

3.4.3 Sampling

Leedy and Ormrod (2001:221) state that generally, the basic rule is that the larger the sample, the better. However, this does not fit all situations. To some extent the size of an adequate sample depends on how homogenous or heterogeneous the population is, in other words how alike or different its members are. A heterogeneous population requires larger samples and smaller samples are adequate for a homogenous population.

Gay (1996:125) suggests that if the population is less than 100, then there is little point in sampling it as the entire population should be surveyed. If a population is about 500, then 50 percent should be sampled. The researcher took note of these guidelines in order to determine an adequate sample for this research study. Therefore the researcher targeted the whole population that has relevant knowledge to the research in focus as explained below.

The marine operations business unit of the Transnet National Ports Authority in Port Elizabeth adopts a quad shift. Each tug is manned by a minimum of six people - one tug master, one chief marine engineering officer (CMEO), three general purpose ratings (GPRs) and one motorman. In order to provide vessel assistance service, two tugs have to be manned all the time, which means 48 (6 x 2 x 4) people are needed all around the clock to man the two tugs. The general guide suggests that there should be two employees added for every eight in order to provide for relief capacity. This leads to 12 more people to be added to the 48, giving an ideal number of 60 employees.

The GPRs were excluded from the targeted population because of their limited exposure to the situation being researched. This left twenty eight employees, which are ten tug masters, ten CMEOs and eight motormen. The marine engineering officers (MEOs) were also targeted for the survey and there must, ideally, be five of them to cover the quad shift. This brought the number of the targeted population to 33. Two managers and three pilots were also part of the population and this brought the number of the population to 38 and this is considered sufficient considering the manning levels and the specific selection of candidates that have relevant knowledge to the field of study.

Table 3 presents the respondents according to their categories:

Table 3.3: TNPA Marine Operations' Summary of Targeted Respondents

	Male	**Female**	**Total**
Manager	2	0	2
Pilot	2	1	3
Tug master	6	4	10
Chief Marine Engineering Officer	10	0	10
Marine Engineering Officer	4	1	5
Motorman	8	0	8
Other	0	0	0
TOTAL	32	6	38

3.4.4 Quantitative research method

Mouton and Marais (1992:159) define quantitative research as more highly formalised as well as more explicitly controlled, with a range that is more exactly defined, and which, in terms of the methods used, is relatively close to the physical sciences. This definition once again shows a preference for the positivist approach.

Quantitative research seeks to quantify, through numbers, observations about human behaviour. The emphasis is on precise measurement, the testing of hypotheses based on a sample of observations and a statistical analysis of the data. Relationships among variables are described mathematically and the subject matter is, as in the physical sciences, treated as an object (Van Biljon 1999:40). Variables play key roles in quantitative research. Variables take on two or more values. Attributes, on the other hand, are the values of categories of a variable and people sometimes confuse variables with attributes.

A quantitative research project would usually test the most important causal links to be found in the research domain. This relationship between variables is usually expressed as a hypothesis, and hypotheses are tested to answer the research question or to find empirical support for a theory (Neuman 1994:99).

3.4.5 Qualitative research method

Qualitative research relies on interpretative and critical approaches to social sciences. The aim of qualitative research is to study individuals and phenomena in their natural settings in order to gain a better understanding of them. It is also evident that qualitative research does not follow a fixed set of procedures. The researcher will, however, need to develop a set of strategies and tactics in order to organise, manage and evaluate the research (Neuman 1994:317; Dooley 1995:258).

Scientists who wish to describe everyday life from the point of view of the phenomenological perspective prefer qualitative research. Quantitative researchers manipulate figures and statistics; the data of the qualitative researcher is in the form of words, sentences, and paragraphs. Qualitative research is more at risk in terms of validity and reliability (Miles & Huberman 1994:2). Mouton and Marais (1992:155) define qualitative research projects as those in which the procedures are not strictly formalised, while the scope is more likely to be under-defined, and a more philosophical mode of operation is adopted. The researcher found this method to be unsuitable for the purpose of the study in question.

3.4.6 Quantitative versus qualitative research

Quantitative research is usually associated with positivism and qualitative research with interpretativism. It is best to visualise the distinction between quantitative and qualitative research as a continuum. All research methods could be placed somewhere between the extremes of pure quantitative and pure qualitative research (Jackson 1995:13).

There is, however, reasonableness in indicating whether research projects have a more qualitative or more quantitative nature. This in turn would play an important role in decisions on process to follow and measuring instruments to select (Van Biljon 1999:37). A summary of the main differences between qualitative and quantitative research is given in Table 4. The researcher chose the quantitative research for this study as the feature of the research are displayed in the table.

3.4.7 Questionnaires

Questionnaires were used to gather quantitative data. Wegner (2001:17) contends that the design of the questionnaire is critical to ensure that the correct research questions are addressed and that accurate and appropriate data are collected. The researcher designed the questionnaire such that it consists of the following sections:

- The *demographic section,* which described the respondent by a number of characteristics which includes position held, age, gender, and years of experience.
- The *information sought,* which made up the major portion of the questionnaire as it included all the questions needed to extract data from respondents to address the objectives of the research.

Leedy and Ormrod (2001:202) argue that questionnaires can be tricky to construct and administer. Frankfort-Nachimias and Nachimias (1992:239) recommend that question sequence, content and structure be given a particular consideration. To optimize cooperation from respondents, a few guidelines that were followed during the questionnaire design of this research which are outlined by Leedy and Ormrod (2001:202-204) are given below:

- Questionnaires should be as brief as possible.
- Simple, clear, unambiguous language should be used.
- Questions should not give clues of preferred or more desired responses.
- A respondent task should be kept as simple as possible by creating a user-friendly questionnaire with clear instructions.
- A questionnaire should be attractive and professional-looking.

According to Allison, O'Sulvan, Owen, Rice, Rothwell and Sauders (1996:83 the Likert type scale is the most frequently used scale, where the respondent chooses a response that best suits his or her view. The following example of the Likert scale was used in the questionnaire designed for this study, namely:

1 = Strongly agree, 2= Agree, 3 = Uncertain, 4 = Disagree and 5 = Strongly disagree.

3.5 CONCLUSIONS FROM ANALYZED DATA

Robson (1997:372) believes that regardless of the research method used, the major task is to resolve the main problem of the research by finding answers to the question posed. Trustworthy answers result from unbiased, fair treatment of data.

In the case of qualitative research, to order and interpret raw data Robson (1997:384) recommends firstly, preparing research notes from interview transcripts or a structured questionnaire; secondly, searching for categories and patterns or themes and thirdly, drawing conclusions from patterns discovered.

On completion of the data collection process, Robson (1997:390) contends that data should be analyzed accurately and verified in order to draw reliable conclusions. The researcher has done just that during the data analysis phase of the research. Since the questionnaires used were structured, the researcher was able to identify patterns and ultimately make conclusions based on the findings.

Table 3.4: Differences between qualitative and quantitative research

Quantitative Research	Qualitative Research
• Test hypothesis that researcher begins with. Hypotheses are stated explicitly and are formulated beforehand. • Concepts are in the form of distinct variables. Concepts have an ambiguous meaning. • Measures are systematically created before data collection is standardised. The researcher remains largely aloof. • Data are in the form of numbers from precise measurement. • Theory is largely causal and is deductive. • Procedures are standard, and replication is assumed. • Analysis proceeds by using statistics, tables or charts and discussing how what they show relates to hypotheses.	• Capture and discover meaning once the researcher becomes immersed in data. Hypotheses are frequently undeclared or stated in the form of a research goal. • Concepts are in the form of themes, motifs, generalisations, taxonomies. Concepts can be interpreted in a number of ways. • Measures are created in an ad hoc manner and are often specific to the individual or researcher. The researcher is involved with the events/ phenomena. • Data are in the form of words from documents, observations and transcripts. • Theory can be causal or non-causal and is often inductive. • Research procedures are particular, and replication is very rare. • Analysis proceeds by extracting themes or generalisations from evidence and organising data to present a coherent, consistent picture.

Source: Neuman (1994:317); Mouton and Marais (1992:159).

3.6 RESEARCH QUALITY

For good research quality it is important that the researcher keeps track of the research from the field. Mouton (2001:107) suggests that the researcher records key decisions and activities during the research process as a form of quality assurance. These include:

- dates when access was granted in the field
- dates when interviews were conducted
- keeping track of the length of interviews
- recording of information on interviews
- keeping track of factors that influence the fieldwork adversely; and
- keeping track of refusal rates.

The points listed above, are of great significance in ensuring the quality of the research. The researcher kept a track record of these items and recorded some difficulties encountered during the entire research study process. Records were kept of dates the questionnaires were e-mailed to targeted respondents. Telephonic interviews were done and dates and times were noted for future records. Both telephone and face to face interviews took an average time of 15 minutes each. The difficulties included postponement of interviews owing to work pressure of the respondents and some difficulty in getting the timely return of the maximum questionnaires posted to the respondents.

3.7 SUMMARY

This chapter explained the research methods used to acquire data for analysis. It also described the population targeted, the reason therefore and the fieldwork done. Two sources of information were employed during this research. The first source of information was the primary data accumulated from the responses to survey questionnaires sent to the selected marine personnel, with a particular focus on the profession related to tug handling and maintenance. The second source of information was a review of the available literature in order to analyse different propulsion types in relation to minimising operational costs.

CHAPTER 4

RESEARCH RESULTS AND ANALYSIS

4.1 INTRODUCTION

This chapter presents the analysis of the data that was collected as explained in Chapter 1 and Chapter 3. The chapter involves a process of identification of patterns in order to evaluate the data and to relate the data to the framework created for this report. The report of the findings is based on the data collected through literature surveys and questionnaires. The procedure and the methods used for measuring the analysis of the two propulsion systems on the tugs of the Port Elizabeth harbour are presented. The results obtained are presented in tables and comments are made based upon the findings from the questionnaire. The results of this research study are presented and analyzed in this chapter and this will enable the researcher to draw conclusions that are presented in Chapter 5.

4.2 RESEARCH RESULTS

Out of the targeted 38 marine employees, 32 were available during the time of the survey and 27 were willing to respond. The marine industry, in particular the towage unit of the Transnet National Ports Authority (TNPA), is a unique business and the marine skills involved are both scarce and require specialised knowledge. Although 27 out of 38 respondents may sound small for a sample, the data is valuable considering the expertise of each individual involved.

4.3 INTERPRETATION OF THE RESULTS

The results obtained from the questionnaire presented to the employees who are involved in the operation of tugs at TNPA, marine operations in Port Elizabeth were analysed in this section. An analysis of the biographical information is presented first followed by the responses obtained in section two of the questionnaire. The results from the second section of the questionnaire are grouped into maintenance, efficiency and safety.

The grouped results were analysed using the Cronbach's alpha, which is a measure of internal consistency measure and the relevant tables. The analysis of each question was done using graphs of the frequency of responses and bar charts to check the goodness of fit. In cases where there was a lack of agreement among the questions of the same group, the researcher dealt with the individual questions and in some instances used cross-tabulations to explore the differences in responses.

4.4 BIOGRAPHICAL DATA ANALYSIS

4.4.1 Respondents by position

The percentages reflected in Table 4.1 show that 18.5 percent of the respondents were not directly involved in operating or handling a tug, while the other 81.5 percent were directly involved in handling a tug. The lower percentages indicate that there were normally fewer managers than the people they were managing and each ship assisting operation needed only one pilot. The 81.5 percent of respondents comes mainly from the fact that there were usually two tugs involved in assisting a ship which led to a need for a larger number of personnel. The situation reflected by the results is benefiting this study since the larger number of respondents is more likely to be experts in the field.

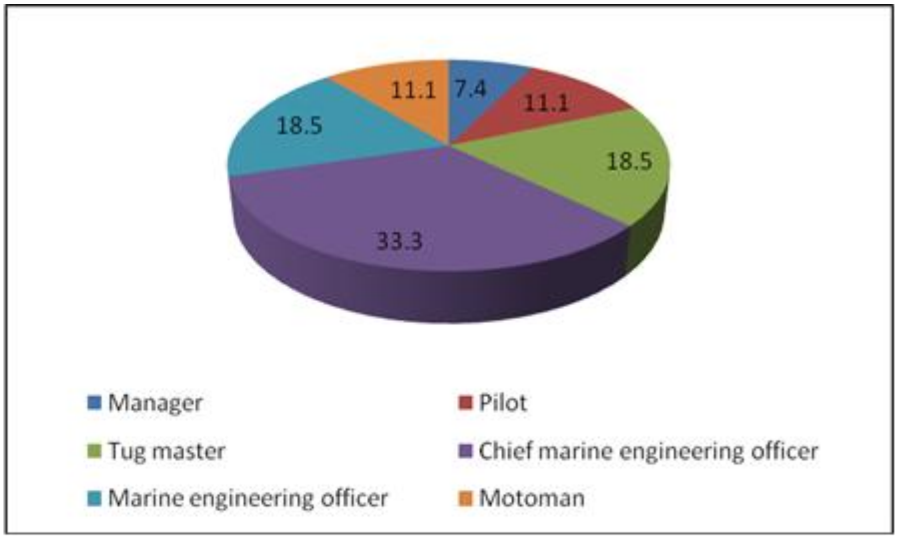
The accompanying pie chart in Figure 4.1 displays the percentage distribution of respondents according to their positions at work. The chief marine engineering officers (CMEOs), being the most technically knowledgeable, represent the highest percentage of 33.3 percent followed by tug masters and marine engineering officers (MEOs) at 18.5 percent each. The tug masters' contribution to the survey is valuable in that they drive the tugs and they are expected to be knowledgeable especially in efficiency and safety aspects. The MEOs are marine engineers at one level lower that the CMEOs and they have good knowledge of the different propulsion designs.

Table 4.1: Respondents by position

Position

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Manager	2	7.4	7.4	7.4
	Pilot	3	11.1	11.1	18.5
	Tug master	5	18.5	18.5	37.0
	Chief marine engineering officer	9	33.3	33.3	70.4
	Marine engineering officer	5	18.5	18.5	88.9
	Motorman	3	11.1	11.1	100.0
	Total	27	100.0	100.0	

Figure 4.1 Respondents by position



4.4.2 Respondents by time in position

The analysis results in Table 4.2 show that 40.7 percent of the respondents had less than five years in their positions. The majority, 59.3 percent of the respondents, had at least five years in their positions. This indicates that there could be good staff retention strategies in place in TNPA which keep the staff turnover low. On the other hand, the 59.3 percent of these respondents may be experiencing difficulties in obtaining jobs elsewhere. The situation can also reflect that the responses to the questionnaire can be relied upon since the majority of the respondents is experienced.

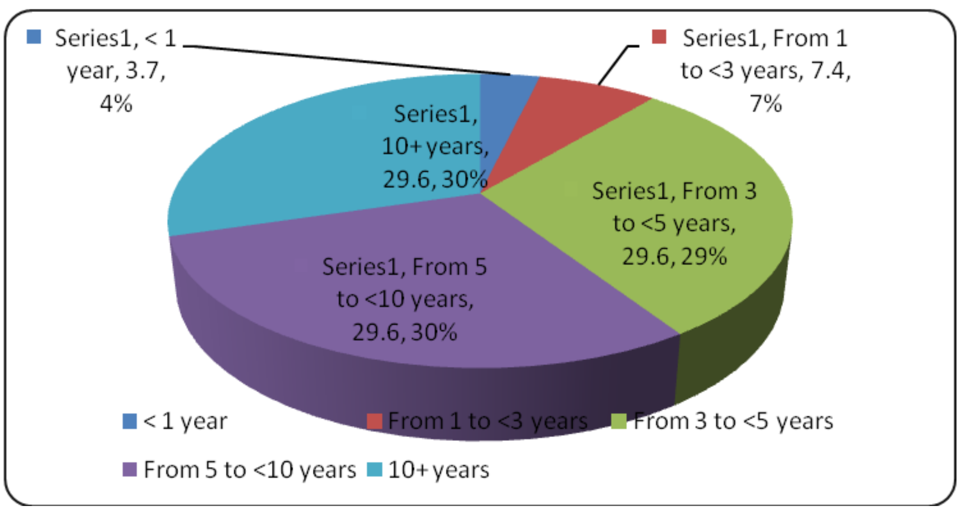
In the accompanying pie chart in Figure 4.2 the above fact is reinforced. The respondents who had been ten years and more in their positions represent 29.6 percent. Out of the 59.3 percent of the respondents who have at least five years in their positions, 29.6 percent had at least 10 years experience that will contribute to the reliability of the responses to the survey questionnaire.

Table 4.2: Respondents by time in position

Time in position

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	< 1 year	1	3.7	3.7	3.7
	From 1 to <3 years	2	7.4	7.4	11.1
	From 3 to <5 years	8	29.6	29.6	40.7
	From 5 to <10 years	8	29.6	29.6	70.4
	10+ years	8	29.6	29.6	100.0
	Total	27	100.0	100.0	

Figure 4.2 Respondents by time in the position



Source: Questionnaire Analysis Results.

4.4.3 Respondents by gender

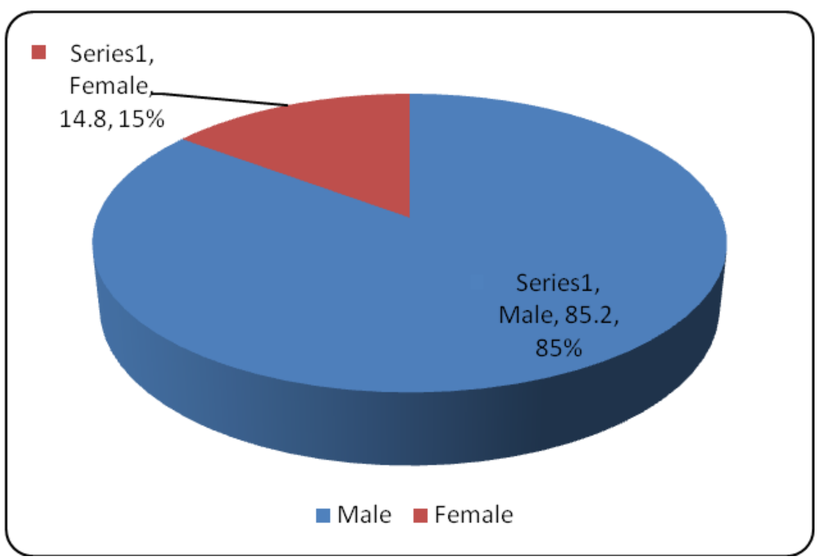
According to table 4.3, the male respondents represent 85.2 percent and 14.8 percent are females. The marine environment has generally been male dominated until only in recent years when there has been an increase in the number of females. The onus is left on the females to determine if they will be fit for the risky tasks such as climbing the pilot ladder and working in hot engine rooms, to name but a few.

Table 4.3: Respondents by gender

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	23	85.2	85.2	85.2
	Female	4	14.8	14.8	100.0
	Total	27	100.0	100.0	

Figure 4.3 Respondents by gender



4.4.3 Respondents by age

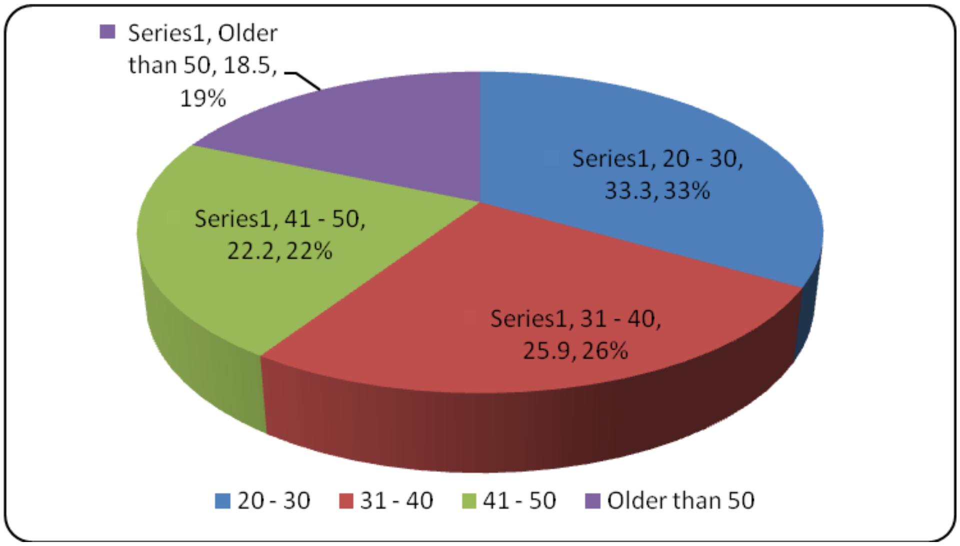
The illustrated age statistics on Table 4.4 show that 59.3 percent of respondents were aged between 20 and 40 years. The other 40.7 percent of respondents were older than 40 years. There were more employees that are part of a younger generation than those who are approaching the retirement age of 63 years. The same is also evident on the accompanying pie chart in Figure 4.3 where the respondents with the ages from 20 to 30 years are 33.3 percent of all the respondents. This can also be an indicator that as the organisation seeks to accomplish its growth related strategies, there has been a trend of employing younger people. The fact that there is only a difference of 18.6 percent between these age groups would mean there is a balanced mix of experiences.

Table 4.4: Respondents by age

Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	20 - 30	9	33.3	33.3	33.3
	31 - 40	7	25.9	25.9	59.3
	41 - 50	6	22.2	22.2	81.5
	Older than 50	5	18.5	18.5	100.0
	Total	27	100.0	100.0	

Figure 4.4 Respondents by age



4.5 RESULTS FROM SECOND SECTION OF THE QUESTIONNAIRE

Cronbach's Alpha

Cronbach's alpha is a measure of internal consistency. That is, how closely related is a set of items as a group. A "high" value of alpha is often used as evidence that the items measure an underlying (or latent) construct. In other words, the responses to the group of questions under the same theme must be about the same. However, a high alpha does not imply that the measure is uni-dimensional. If, in addition to measuring internal consistency, you wish to provide evidence that the scale in question is uni-dimensional, additional analyses can be performed. Technically speaking, Cronbach's alpha is not a statistical test - it is a coefficient of reliability (or consistency) (www.ats.ucla.edu/stat/spss/faq/alpha.html).

For items to be considered reliable and for one to be able to consider a group of questions as measuring one 'theme', Cronbach's alpha should be > 0.7. This measure was used to analyse the grouped questions.

4.5.1 Maintenance results - grouped

Questions are grouped per theme based on each of the objectives of the research. in this instance, the relevant objective deals with how the perceived maintenance factors will contribute to the minimisation of operational costs on the two propulsion systems. As shown in Table 4.5, the consistency for the maintenance questions is 0.787, which is greater than 0.7. This indicates that the respondents were in agreement with all the five items that are grouped together as a measure for maintenance. The mean of the questions ranges from 1.26 to 1.81 which is far from the uncertainty point, 3. Therefore the responses to maintenance questions are consistently in agreement.

Table 4.5: Reliability and item statistics – maintenance

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.766	.787	5

Item Statistics

	Mean	Std. Deviation	N
Maint - reduce costly breakdowns	1.26	.447	27
Maint - Increase tug reliability	1.30	.465	27
Maint - Implementing maintenance reduces costs	1.81	.622	27
Maint - cost effective procurement processes	1.56	.506	27
Maint - computerized maintenance planning tool	1.59	.747	27

4.5.2 Maintenance results – by question

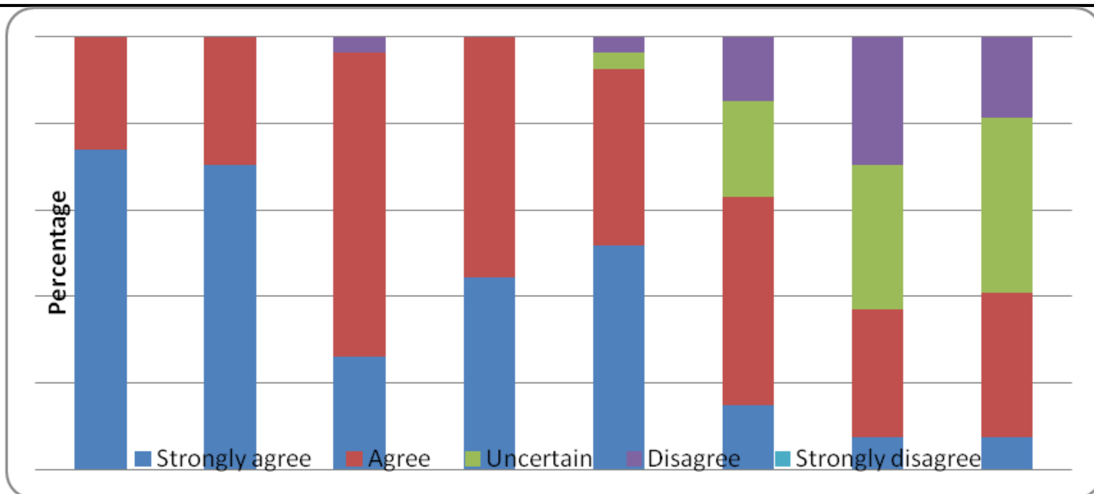
For each of the three sections, each question has been taken separately and the following was performed:

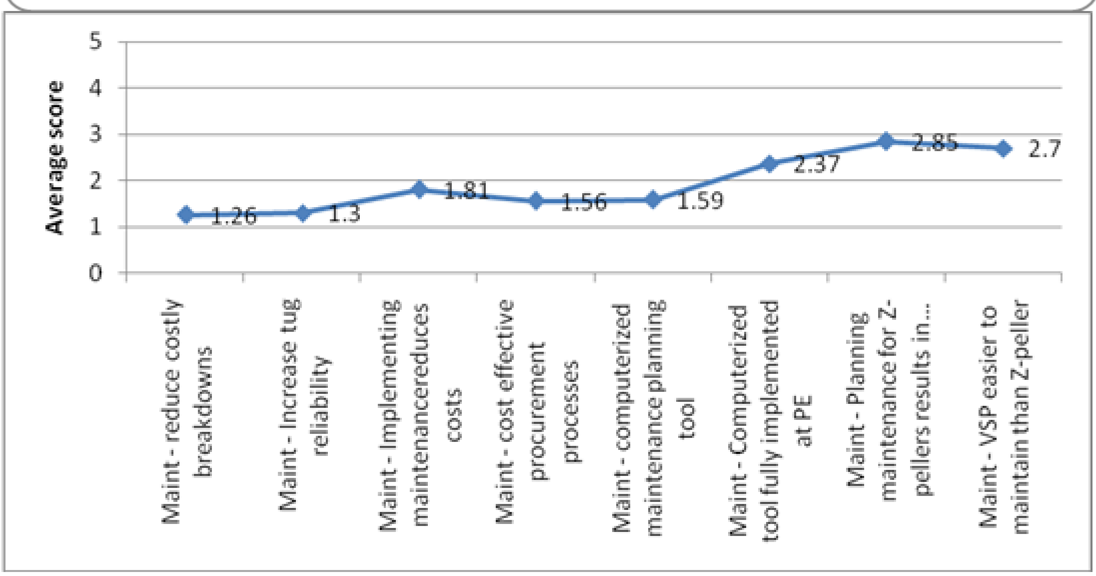
(a) Graph of the frequency responses for the questions

(b) T-test to test whether the average score for a question is significantly different from the neutral score of 3. If significant difference is found one can interpret there to be either significant agreement or disagreement with the statement. This should give similar results to the chi-square goodness-of-fit tests.

Table 4.6. Maintenance – each question

Frequencies	Maint - reduce costly breakdowns	Maint - Increase tug reliability	Maint - Implementing maintenance reduces costs	Maint - cost effective procurement processes	Maint - computerized maintenance planning tool	Maint - Computerized tool fully implemented at PE	Maint - Planning maintenance for Z-pellers results in more cost minimization than VSP system	Maint - VSP easier to maintain than Z-peller
Strongly agree	20	19	7	12	14	4	2	2
Agree	7	8	19	15	11	13	8	9
Uncertain	0	0	0	0	1	6	9	11
Disagree	0	0	1	0	1	4	8	5
Strongly disagree	0	0	0	0	0	0	0	0





The grouped results for maintenance questions indicated consistency in agreement. The analysis of each question shows that all respondents either strongly agreed or agreed on questions 1, 2 and 4. None of the respondents were uncertain or disagreed. This is shown in Table 4.6 and these questions are listed below:

Question 1: Planning maintenance of propulsion systems will result in reduced costly breakdowns, thereby minimising operational costs.

The agreement to Question 1 indicates that most employees appreciate planning their maintenance in order to avoid breakdowns which are more costly than doing planning maintenance.

Question 2: Planning maintenance of propulsion systems increases tug reliability thereby decreasing ship delays and penalties.

The agreement to Question 2 indicates that the employees are customer focused and they value keeping them satisfied by avoiding ship delays. Fixing breakdowns is costly and penalties that relate to ship delays are also high. The option of planning maintenance still remains the best option. The positive responses to question 4 highlights that the employees are aware of the fact that planned maintenance will enable procurement to plan for the needs of the department. Furthermore, procurement can even stock up maintenance related items for cost effective purchasing.

Question 4: A better managed maintenance function will result in cost effective procurement processes thereby minimising operational costs.

Questions 3 and 5 have only four percent respondents disagreeing and four percent uncertain in question 5. On question 6, sixty three percent of respondents either strongly agreed or agreed, 22 percent were uncertain and 15 percent disagreed. This would mean that most marine employees were aware of the relationship that exists between having a computerised tool to plan your maintenance and reducing costs. On the average score graph, that still leaves the average of all questions significantly different from the neutral point 3. In each case the average value is less than 3, indicating significant agreement with the statements.

According to Table 4.7, the cross-tabulation between positions and question 6 shows that 22 percent of the uncertain respondents, the 64 percent who agreed and the 14 percent who disagreed were tug staff. The indications are still stronger on agreement and the fact that the tug employees contribute most adds to the credibility of the results because they are closer to maintenance than office personnel. The researcher, therefore, deduces that existence of a computerised maintenance tool is realised by respondents as vital to successful maintenance planning. These questions are listed below:

Regarding Question 3, 5 and 6: There is noticeable minimisation of operational costs after implementing maintenance plans. Maintenance planning ensures that the repairs to equipment happens timely and avoids too close intervals between services, which may increase the costs. Maintenance planning also ensures that repairs are done before breakdowns. A computerised maintenance planning tool is vital for minimising operational costs. The running of the maintenance planning by a computerised program ensures that the plans are kept up-to-date easily. The responses to Question 6 indicate that this tool is in use in TNPA's Port Elizabeth harbour.

Average scores for question 7 and 8 are not significantly different from a neutral 3. Table 4.6 shows that 37 percent of respondents agreed that planning maintenance for Z-pellers results in reduced costs than for the VSP system; 33 percent of the respondents are uncertain and 30 percent of respondents disagreed. A common understanding among the employees does not exist with regard to this question. This may point to the fact that this port has had both propulsion systems for a couple of years and different employees became comfortable in working with either of the propulsion system, hence the lack of strong common agreement. The questions are shown below.

Question 7: planning for Z-pellers results in more cost minimisation than for VSP systems.

Question 8: Maintainability is better on VSPs and they are therefore more effective in minimising costs than Z-pellers.

Table 4.8 shows that 56 percent of the chief marine engineering officers disagreed with question 7, twenty two percent were uncertain and 22 percent agreed. The chief marine engineers are involved in ordering spares and carrying out maintenance on the tugs and the majority disagreement might really mean that they have not yet realised that the Z-peller system minimises costs better than the VSP system.

Based on the grouped maintenance results, there is consistency in agreement to the questions. The analysis of each maintenance question shows more values that are less than 3, which means agreement and a few highlights made using the cross-tabulations show that questions 7 and 8 had a lesser degree of agreement than the rest of the questions.

Table 4.7. Cross tabulation – position vs Question 6

Position * Maint - Computerized tool fully implemented at PE Crosstabulation

Count

		Maint - Computerized tool fully implemented at PE			Total
		Agreement	Uncertain	Disagreement	
Position	Manager	1	0	1	2
	Pilot	2	1	0	3
	Tug master	3	2	0	5
	Chief marine engineering officer	6	0	3	9
	Marine engineering officer	3	2	0	5
	Motorman	2	1	0	3
Total		17	6	4	27

Table 4.8. Cross tabulation – position vs Question 7

Position * Maint - Planning maintenance for Z-pellers results in more cost minimization than VSP system Crosstabulation

Count

		Maint - Planning maintenance for Z-pellers results in more cost minimization than VSP system			Total
		Agreement	Uncertain	Disagreement	
Position	Manager	1	0	1	2
	Pilot	1	2	0	3
	Tug master	1	3	1	5
	Chief marine engineering officer	2	2	5	9
	Marine engineering officer	3	1	1	5
	Motorman	2	1	0	3
Total		10	9	8	27

4.5.3 Efficiency results - grouped

The alpha value of 0.224 is very low and so the items under the objective of efficiency can not be grouped and treated as one measure. See Table 4.6. The means for each question range from 1.63 to 1.93. Especially the value of 1.93 indicates that some of the respondents are either uncertain or even disagree. The researcher's view is that there is no common understanding of the subject of efficiency among employees.

This low consistency illustrates the fact that this section needs the respondents to be more technically knowledgeable which will lead to more detailed analysis and possibly consistent responses.

Table 4.9: Reliability and item statistics – efficiency

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.224	.069	4

Item Statistics

	Mean	Std. Deviation	N
Eff - low fuel consumption	1.67	.832	27
Eff - good propulsion design	1.70	.724	27
Eff - more compact and lighter tug	1.93	.675	27
Eff - well maintained system	1.63	.492	27

Source: Questionnaire Analysis Results.

4.5.4 Efficiency results – each question

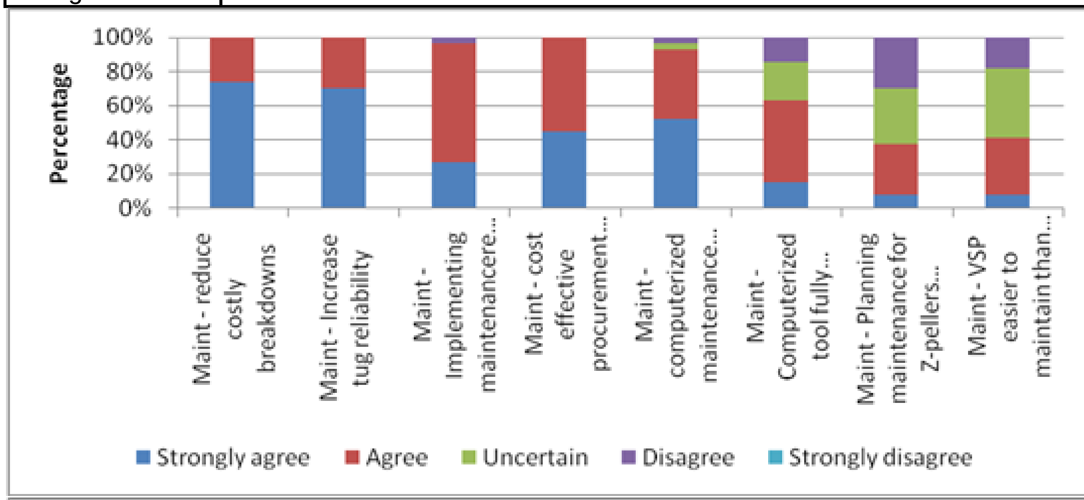
According to the frequencies in Table 4.10, the respondents that strongly agreed or agreed with question 9 amount to 85 percent, 11 percent are uncertain and four percent disagree. The average score as shown on the graph is 1.67 which is significantly lower the uncertainty point 3. This reveals that the employees mostly agreed that propulsion efficiency reduces fuel consumption and as a result, costs. The cross-tabulation on Table 4.11 shows that none of the marine engineers and motormen were uncertain. Only 6 percent disagreed against 94 percent that agreed to question 9.

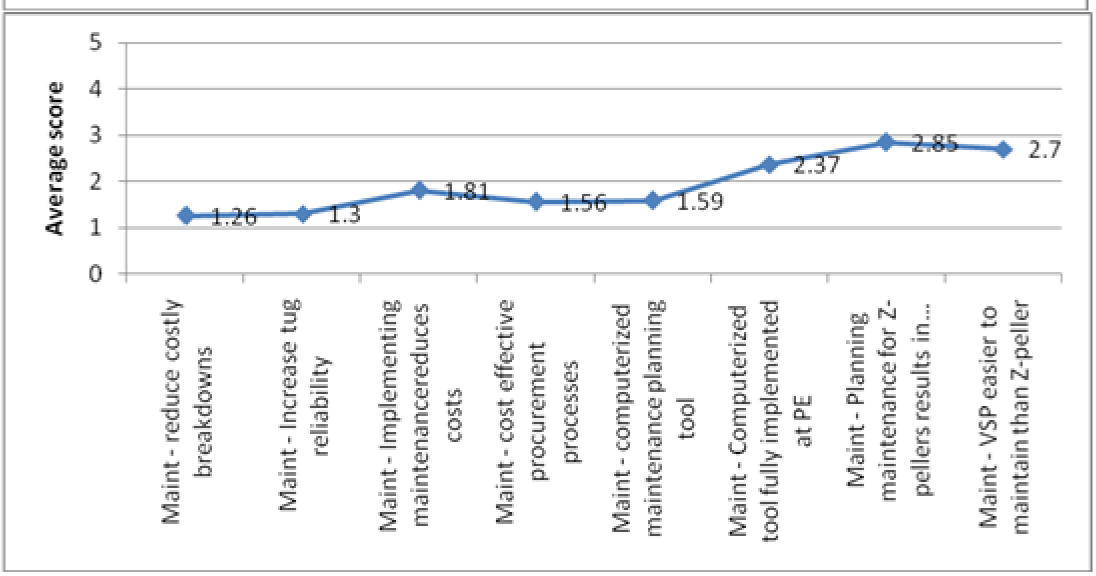
One sample t-tests show that average scores for questions 9 - 12 are significantly different from a neutral 3. In each case the average value is less than 3, indicating significant agreement with the statements.

Average scores for questions 13 and 14 are not significantly different from a neutral 3. In Table 4.10 the respondents that agreed are 41 percent on question 13, 41 percent were uncertain and 18 percent disagreed. On question 14, 52 percent of respondents agreed with question 14, 19 percent are uncertain and 29 percent disagreed. Seemingly, the pattern on these two questions is that a number of employees disagreed. What separates these questions from the rest is that these questions also seek to compare between the Z-peller and the VSP systems. The researcher appreciates the fact that when comparing two pieces of equipment the element of subjectivity may creep in and affect the responses.

Table 4.10 Efficiency – each question
Efficiency

Frequencies	Eff - low fuel consumption	Eff - good propulsion design	Eff - more compact and lighter tug	Eff - well maintained system	Eff - Z-pellers more efficient than VSP	Eff - VSP manoeuvrability uses more fuel than Z-peller
Strongly agree	14	11	6	10	3	1
Agree	9	14	18	17	8	13
Uncertain	3	1	2	0	11	5
Disagree	1	1	1	0	4	7
Strongly disagree	0	0	0	0	1	1





Source: Questionnaire Analysis Results.

Table 4.11 Efficiency – by question

Position * Eff - low fuel consumption Crosstabulation

Count

		Eff - low fuel consumption			Total
		Agreement	Uncertain	Disagreement	
Position	Manager	2	0	0	2
	Pilot	2	1	0	3
	Tug master	3	2	0	5
	Chief marine engineering officer	8	0	1	9
	Marine engineering officer	5	0	0	5
	Motorman	3	0	0	3
Total		23	3	1	27

Source: Questionnaire Analysis Results

4.5.5 Safety results - grouped

In the section that relates to safety in the questionnaire, there is consistency among the responses as proven by the Cronbach's Alpha that is greater than 0.7 as shown in Table 4.7. Judging by this condition, it can be deduced that the respondents shared the same understanding on the impact that safety has on operational cost reduction. The safety awareness among the employees was such that they can act judiciously where the safety of an asset or people, is at stake.

On the question of redundancy factors the mean of 1.89 shows that the responses are closer to the point of uncertainty than in the rest of the questions. The researcher assumes this is caused by the respondents' unfamiliarity with the term 'redundancy' although it does not affect all the respondents.

Table 4.12: Reliability and item statistics – safety

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.756	.766	5

Item Statistics

	Mean	Std. Deviation	N
Safety - reducing damages	1.33	.480	27
Safety - curb incidents that lead to injuries	1.85	.662	27
Safety - redundancy factors prevent accidents	1.89	.506	27
Safety - prevention of failure of propulsion system	1.59	.501	27
Safety - well maintained propulsion system is safer	1.41	.501	27

Source: Questionnaire Analysis Results.

4.5.6 Safety results – Each question

The following discussion touches on Questions 15, 16, 17, 18, 19, 20, and 21 on the questionnaire:

Average scores for each question are graphed in Table 4.13 below. One sample t-tests show that average scores for questions 15 to 20 are significantly different from a neutral 3. In each case the average value is less than 3, indicating significant agreement with the statements. This means that the respondents shared the same understanding in the matters of safety and the relationship with cost reduction.

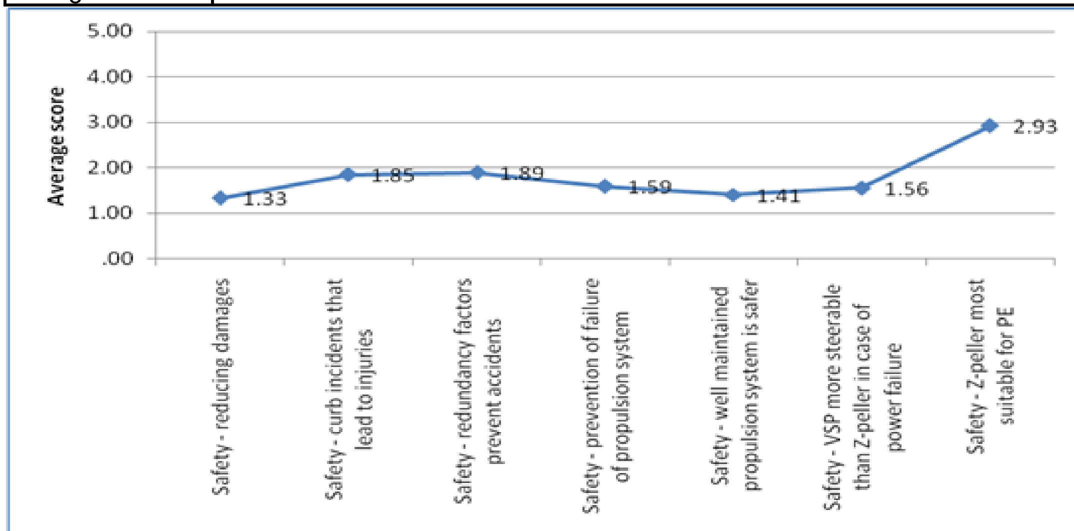
Average scores for question 21 are not much different from a neutral 3. As can be seen from the frequency graph below, 41 percent of the respondents agreed that the Z-peller propulsion system is most suitable for the Port

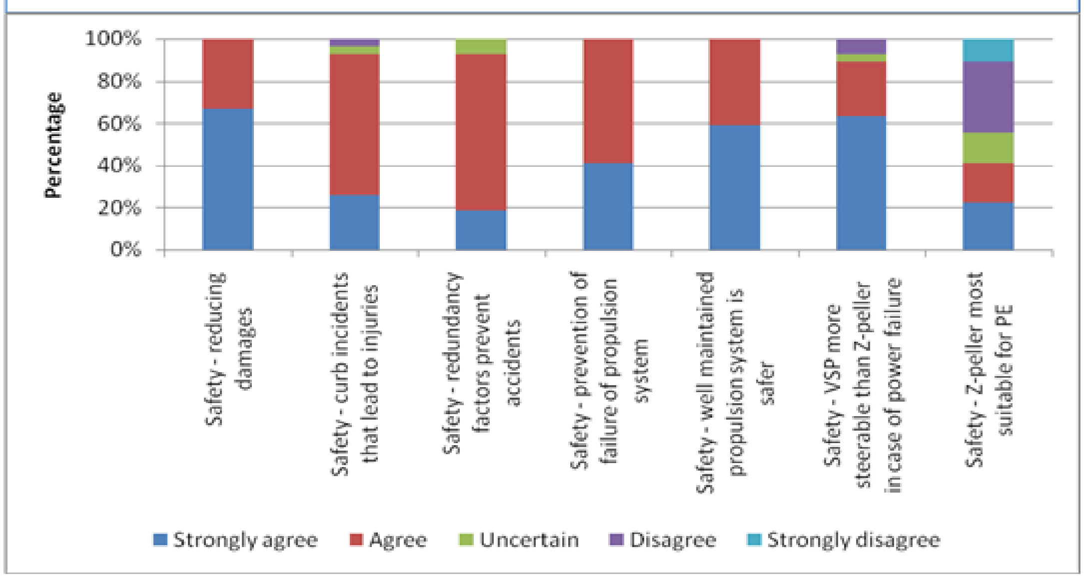
Elizabeth harbour. 15 percent of respondents are uncertain and 44 percent disagree. Clearly, there are more respondents who disagree than those that do not.

Question 21 asks the respondents to compare the two propulsion systems. The view of the researcher is that not all the respondents were able to critically compare as they responded according to their personal experience with the system they were more familiar with. The safety questions are listed below:

Table 4.13: Safety – each question*Safety*

Frequencies	Safety - reducing damages	Safety - curb incidents that lead to injuries	Safety - redundancy factors prevent accidents	Safety - prevention of failure of propulsion system	Safety - well maintained propulsion system is safer	Safety - VSP more steerable than Z-peller in case of power failure	Safety - Z-peller most suitable for PE
Strongly agree	18	7	5	11	16	17	6
Agree	9	18	20	16	11	7	5
Uncertain	0	1	2	0	0	1	4
Disagree	0	1	0	0	0	2	9
Strongly disagree	0	0	0	0	0	0	3





4.6 SUMMARY

This chapter presented the results of the study. Some indicators of the employees' perceptions on maintenance management, equipment efficiency and safety in Port Elizabeth marine operations were identified.

The researcher merged the findings and related them to each sub-problem under the research topic and also highlighted the reasons for possible challenges to the reliability of the responses. The analysis links the three factors of maintenance management, equipment efficiency and equipment safety, to the minimisation of operational costs as perceived by the tug personnel, the pilots and the marine managers.

There was strong agreement among the respondents on the theme of maintenance. The people using the tugs do realise that planning maintenance brings benefits to the business by avoiding the occurrence of costly breakdowns. There is still some room for improvement on the awareness of how maintenance reduces operational costs. Some respondents were not sure of how the Voith Schneider and the Z-peller propulsion systems compare in the issue of maintenance.

There is a possibility that the business unit realises that costs are reduced as a result of planned maintenance but the information is not shared with the people on the tugs. The reports that pertain to the correlation between implemented maintenance planning and scheduling and the resulting minimisation of costs can be incorporated in the employee information sessions that are part of the culture of Transnet National Ports Authority. In this manner the tug personnel can become aware of the impact of what they do on the cost of maintenance.

A divergence of thoughts on the theme of equipment efficiency was noticed. This area needs to be addressed by training and information sharing because efficiency is a vital factor when acquiring and running tugs. The theory side revealed that there is a link between efficiency and safety because an efficient tug would use less space for her manoeuvres and this relates to reduced chances of collisions. Another link is between efficiency and maintenance based on the fact that the designed capability of a tug's propulsion system will not be compromised by equipment deterioration which follows neglect and lack of maintenance.

On questions that relate to safety, there was strong agreement among respondents and the response pointed towards the fact that safety awareness is strongly embedded in tug personnel. A deduction was made, based on the analysis of results, that the respondents shared the same understanding of the impact that safety has on operational cost reduction. Interestingly, when comparing the safety handling of the two systems, respondents seemed to have more trust in the system that they were familiar with. The managers will have to look at the issues of the versatility of tug masters so that they are familiar with both systems. The suggestion is made so that there should be equal levels of safety awareness and equipment familiarity for both tug propulsion types.

The conclusions, remarks and recommendations drawn from this data analysis are presented in Chapter 5.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents a summary of the results of the research conducted at Transnet National Ports Authority Marine Operations. As was stated in Chapter 1, the purpose of the research was to analyse two propulsion systems used by tugs in the Port Elizabeth Harbour. The results of the research were discussed drawing from the literature and the unanalysed survey data. This chapter will be structured according to these topics:

- Summary of research
- Limitations of the study
- Value of the study
- Recommendations and concluding remarks
- Opportunities for further research

5.2 SUMMARY OF RESEARCH

The synopsis of this research study is presented in alignment with the sub problems of the research. The sub problems were aimed at addressing the main problem which was:

To analyse the two propulsion systems used by the tugs at Port Elizabeth harbour in order to minimize operational costs.

Outlined below are the sub problems that were identified for the purpose of developing a research strategy to solve the problem.

- How will the perceived maintenance factors contribute to the minimisation of operational costs on the two propulsion systems?

- How will the perceived efficiency factors assist in the minimisation of operational costs on various propulsion systems?

- How are safety factors perceived to contribute to minimising operational costs on the two propulsion systems?

The sub problems above were investigated by using the topics that were outlined in Chapter 2 are as follows:

- maintenance management
- equipment efficiency
- equipment safety

This flow of thought and argument is continued throughout this chapter and the conclusions will be made by linking the survey research results to the sub problems. This will establish whether the hypothesis set for this research holds or not.

5.3 CONCLUSIONS AND RECOMMENDATIONS

5.3.1 Maintenance management

Literature

The literature review in Chapter 2 revealed that maintenance is a process that is triggered by equipment failure or planned repair. Coupled to this is the function of managing the maintenance by planning, scheduling and controlling. Coetzee Jasper (1998:22) states the following with regard to the need for maintenance:

> As all equipment is prone to breakdown, there must be some function in existence to replace or repair such unit(s) so that the production can be rescued. This function is called maintenance.

Throughout Chapter 2 the relationship between maintenance and costs has been expressed and the literature showed that careful considerations need be taken to ensure that there is balance between the amount of maintenance and cost savings or minimisation. This thought is based on that planned maintenance costs money while failures due to breakdowns also cost money. As the maintenance gets planned such that repairs are done before failures, breakdowns are eliminated.

Survey

Questions were first grouped per theme based on each of the objectives of the research and the consistency for the maintenance questions was 0.787, which is greater than 0.7. This indicates that the respondents were in agreement with all the five items that were grouped together as a measure for maintenance. The mean of the questions ranges from 1.26 to 1.81 which is far from the uncertainty point, 3. Therefore the responses to maintenance questions were consistently in agreement. The researcher deduces that the mindset of planning and executing maintenance is embedded among the tug staff.

Average scores for questions 7 and 8 are not significantly different from a neutral 3. Table 4.6 shows that 37 percent of respondents agreed that planning maintenance for Z-pellers resulted in more cost minimisation than VSP system, 33 percent of the respondents were uncertain and 30 percent of respondents disagreed. Common understanding among the employees did not strongly exist with regard to this question. This may point to the fact that this port has had both propulsion systems for a couple of years and different employees became comfortable in dealing with either of the propulsion systems, hence the lack of a strong in agreement.

Hypothesis

The hypothesis that was set to correspond with maintenance sub problem is:

- The choices for particular tug propulsion systems are based on the perceived maintenance effects to minimise operational costs.

There was strong agreement among employees concerning all the statements that relate to planning maintenance having a positive effect on minimisation of operational costs. The hypothesis is therefore aligned to the sub problem that deals with maintenance factors. This reveals that the current and the future tugs would be built or purchased with due consideration being taken with regard to maintenance costs of the tug.

Conclusions and recommendations

Base on above findings and the rest of the results from Chapter 4, the employees of TNPAs marine services perceived the existence of maintenance management. They realised the minimisation of operational costs and the culture of a planned maintenance system would be perpetuated.

The researcher recommends that there should be a more focussed analysis and reporting on maintenance expenditure in alignment with maintenance plans. The fact that the respondents differed in their responses to the comparison between Z-peller and VSP systems may indicate that the financial reports are not communicated to the staff. The personnel involved in planning maintenance should generate regular reports on planned and breakdown maintenance and compare from the financial reports as to which system cost less to maintain. This will help in establishing whether the planning of maintenance reduces the amount of break downs.

5.3.2 Equipment Efficiency

Literature

Based on the theory from the literature study, the choice of propulsion systems when designing or purchasing tugs is mainly based on the categories of ports, environmental conditions, the ships to bee manoeuvred, services required in and around the harbour, the ship assisting methods in use, available experience and safety requirements, to mention but a few.

The basic principles of a variety of propeller designs were briefly discussed by Hensen (1997:22) pointing out different designs of propellers and how the configurations affect the efficiency of equipment. The stages of design would be expected to be the right time for ensuring the best possible propulsion efficiency.

The literature also discussed overall equipment efficiency, which is a combination of the uptime or availability of the equipment, cycle time efficiency or production efficiency, and quality output of the equipment. The uptime or availability of equipment is the proportion of time the equipment is actually available out of the time it should be available.

Survey

Because the means for each question were close to uncertainty, they could not be grouped and treated as one measure. That indicates that some of the respondents were either uncertain or even disagreed with the relationship between efficiency and the minimisation of operation costs. The researcher's view is that there is no common understanding of the subject of efficiency among employees and this topic needs to be studied theoretically and experientially by the tug masters and the engineers.

Hypothesis

The following hypothesis was formulated with regard to equipment efficiency:

- The tug propulsion choices are based on perceived efficiency effects on minimisation of operational costs.

The agreement on the survey questions, although not strong, does exist.

Conclusions and recommendations

This low consistency highlights the fact that this section needs the respondents to be more technically knowledgeable, which will lead to more detailed analysis and consistent responses. The employees need to study the subject of efficiency concerning tug operations so that it becomes a stronger factor in keeping or even building new tugs.

The tug masters will have to look into efficiency with regard to manoeuvres and the tug's ability to survive in tight situations, meaning that the tug has prompt responses. The marine engineers need to focus on the designed efficiency and the overall equipment efficiency as discussed in Chapter 2. All the tug personnel must realise the relationship between maintenance and efficiency because lack of maintenance will lead to eventual loss of designed efficiency.

5.3.3 Equipment safety

Literature

While the harbour tugs are utilised to assist the docking and the undocking of ships, all facets of safety have to be ensured. The safety referred to includes that of humans and assets in the form of machinery, among other things. Bloch (1988:316) has the following to say about safety:

> This is the number one consideration in maintenance and operation, as in any other field of endeavour. General guidelines to safety must be developed, issued, and discussed with all operating and maintenance personnel.

Survey

There was strong and consistent agreement with the survey question under the theme of safety. In the section that relates to safety there is consistency among the responses. Judging by this condition, the researcher deduced that the respondents shared the same understanding of the impact that safety has on minimisation of operational costs. The safety awareness among the employees was such that they could act judiciously where the safety of an asset or of people was at stake. They would also be able to assess different propulsion designs in order to inform the decisions where tugs are to be kept, disposed of or acquired.

Average scores for questions 15 to 20 are significantly different from a neutral 3. In each case the average value is less than 3, indicating significant agreement with the statements. This means that the respondents shared the same understanding in the matters of safety and its relationship with cost minimisation. The tug staff also showed uniform understanding on maintenance factors. The good about this fact is that safety features are restored or kept in their original state if maintained.

Hypothesis

The hypothesis that was formulated for the theme of safety is the following:

- The safety factors in relation to minimisation of operational costs form part of the choice for tug propulsion.

The relationship between the safety factor and the minimisation of operational costs, based on the perceptions of the employees exists quite strongly. The new tug builds will be safer as the information will be shared about the safety features of the current tugs.

Conclusions and recommendations

Safety as a theme can always be reinforced especially in an environment where there will always be new recruits coming up as marine personnel. The tug employees have to record and report all incidents and their causes. In cases where the incidents could have been prevented with a different propulsion system, this must be highlighted so that the facts can inform the decisions in acquiring new tugs.

Opportunities for further studies

The researcher presents the following suggestions for possible future studies.

- Maintenance management with a special focus on tug acquisition, tug life cycle and tug midlife projects. The proposed future study will help in ensuring best value for money when building new tugs, determining the right time to dispose of tugs and deciding the right time for the midlife refit project and its value in adding usable life.
- Marine craft corrosion prevention and marine coatings. The marine environment is highly corrosive and keeping corrosion at bay is both cumbersome and expensive. A study will have to focus on marine specific approaches to dealing with corrosion and the application of coatings and paints that are chemically structured for highly corrosive environments.
- The training of marine engineers focusing on new technological trends. The researcher's view is that the advancement of technology is at a rapid rate and the proposed study will possibly craft a path for catching up by reviewing the training of marine engineers.

5.4 SUMMARY

The research conclusions indicated that the management of maintenance does exist in the Port Elizabeth harbour. The research also established that the employees are aware of the positive impact that maintenance, efficiency and safety factors can have on different propulsion systems. The employees could also relate these three themes to the reduction of operational costs. As employees were asked questions that compared the VSP and the Z-peller propulsion systems, their responses differed.

On all three themes that are related to sub problems disagreement was noticeable. There is room for improvement on all three aspects that affect minimisation of operational costs. The researcher is of the opinion that reports for maintenance, efficiency and safety need to be analysed with the view of comparing the two propulsion systems. The researcher is also of the opinion that the size of the sample can be increased by conducting research combining a cluster of ports that use similar tug propulsion systems. In that manner there will be an increased accumulation of ideas and the research results will not be easily affected by a few responses that are far off.

The chapter concluded by outlining opportunities for further research. The proposed studies will hopefully lead to intensive discussion forums and consultations, all to the benefit of the maritime industry as a whole.

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ANNEXURE 1 - LETTER REQUESTING PERMISSION TO CONDUCT SURVEY WITHIN TRANSNET NATIONAL PORTS AUTHORITY.

20 May 2010

The Manager Human Resources
Transnet National Ports Authority
Corporate Office
Braamfontein

Dear Sir

REQUEST TO CONDUCT RESEARCH ANALYSIS OF TWO TUG PROPULSION SYSTEMS IN THE PORT ELIZABETH HARBOUR.

This letter serves to request consent to conduct research within the company regarding the topic above. I am currently enrolled for the Master's degree in Business Administration at the Nelson Mandela Metropolitan University (NMMU). In partial fulfilment of the requirements for the Master's degree, it is expected from the student to engage in a research project.

The researcher will report the findings in a complete and honest fashion, without misrepresentation of what have been done or intentionally misleading others about the nature of the findings. The participants used in the study will remain anonymous. The name of the company will appear in the research report, and other further publications that might emanate from the research, and be accepted for publication in a professional journal.

Thanking you for your co-operation.

Yours faithfully,

____

Dumsani A Dlamini

The Researcher

ANNEXTURE B - RESEARCH QUESTIONNAIRE

The purpose of this survey is to establish your perceived views regarding the VSP and the Z-peller propulsion systems on the Port Elizabeth tugs.

The questionnaire seeks to establish the correlation between maintenance management, equipment efficiency, equipment safety and the minimisation of operational costs.

Please indicate the extent to which you agree with each statement by marking an **X** in the appropriate box.

1. What is your position?

Manager	
Pilot	
Tug Master	
Chief Marine Engineering Officer	
Marine Engineering Officer	
Motorman	
Other	

2. How long have you been in this position at Transnet National Ports Authority?

less than 1 year	
1 – less than 3 years	
3 – less than 5 years	
5 – less than 10 years	
10 years or more	

3. What is your gender?

Male	
Female	

4. What is your age (years)?

20 – 30	
31 – 40	
41 – 50	
older than 50	

In view of the Voith Schneider Propulsions (VSP) and Z-pellers, please indicate the extent to which you agree with each statement by marking an **X** in the appropriate box.

	How will the perceived maintenance factors contribute to the minimisation of operational costs on the two propulsion systems?	**Strongly agree**	**Agree**	**Uncertain**	**Disagree**	**Strongly disagree**
1	Planning maintenance of propulsion systems will result in reduced costly breakdowns, thereby minimising operational costs.					
2	Planning maintenance of propulsion systems increases tug reliability thereby decreasing ship delays and penalties.					
3	There is noticeable minimisation of operational costs after implementing maintenance plans.					
4	A better managed maintenance function will result in cost effective procurement processes thereby minimising operational costs.					
5	A computerised maintenance planning tool is vital for minimising operational costs.					
6	A computerised maintenance planning tool is fully implemented in our port and minimisation of operational costs is realised.					
7	Planning maintenance for Z-pellers results in more cost minimisation than for VSP systems.					
8	Maintainability is better on VSP’s and they are therefore more effective in minimising costs than Z-pellers.					
	How will the perceived efficiency factors assist in the minimisation of operational costs on various propulsion systems?	**Strongly agree**	**Agree**	**Uncertain**	**Disagree**	**Strongly disagree**
9	Propulsion efficiency minimises operational					

	costs because it results in low fuel consumption.					
10	Propulsion design affects its efficiency, thereby resulting to low fuel consumption, minimising operational costs.					
11	A more compact and lighter tug design leads to propulsion efficiency thereby minimising on operational costs.					
12	A well maintained propulsion system will be efficient, resulting in minimisation of operational costs.					
13	Z-pellers are more effective in minimising operational costs than VSP's by virtue of their better propulsion efficiency.					
14	VSP's manoeuvrability leads to higher fuel consumption thereby leaving the Z-peller as the better system for operational costs minimisation.					
	How are safety factors perceived to contribute to minimising costs on the two propulsion systems?	**Strongly agree**	**Agree**	**Uncertain**	**Disagree**	**Strongly disagree**
15	A safer propulsion system design will minimise operational costs by reducing damages to the tug and the client's ships.					
16	A safer propulsion system will curb incidents that lead to injuries and IOD's therefore minimising operational costs.					
17	Redundancy factors built into a propulsion design prevent accidents to minimise operational costs.					
18	Prevention of failure of propulsion systems will eradicate costly accidents and thereby minimising operational costs.					
19	Well maintained propulsion systems are safer and that contributes to minimising operational costs.					
20	VSP tug will remain more steerable than the Z-peller in case of power failure, thereby preventing accidental damages and contributing to minimisation of operational costs					
21	All in all, a Z-peller propulsion design is most suitable for the Port of PE because there is more operational cost minimisation realised from it.					

Thank you for your participation. I really appreciate it.