

Chapter 1

Introduction

1.0.Introduction:

“It is not possible to manage what you cannot control and you cannot control what you cannot measure!” (Unknown author)

Petroleum companies invest large amount of resources to build and run production and product exporting facilities. To make the best of these facilities along their life span, it is essential to adopt effective management practices. There must be away to learn these essential practices, the research is trying to explain what to look for and how to achieve it.

1.1. Statement of the problem

The company needs to maintain its valuable assets. The maintenance body should find a way to adopt world best practices in maintenance in order to reach excellent level of maintenance performance.

In the first place it is essential to know what these best practices are. How far the current situation of maintenance from these best practices? What to do to reduce the gap between the current performance and the excellent one.

1.2. Background review

The research is going to give a general understanding of maintenance, its definitions, objective, types, and evolution. Then adding profound discussion on the importance of maintenance to business, maintenance Challenges, and to know why improvement is needed in maintenance.

The study will give a broad clarification of maintenance excellence exploring some of the recent practical strategies in maintenance excellence like Total Productive Maintenance (TPM), Reliability -Centered Maintenance (RCM), Business -Centered Maintenance (BCM), and Terotechnology, in addition to Computerized Maintenance Management System (CMMS) as one of the important best practice. After that the paper shows the best-in-class company characteristics so as to be targeted, as well as the lower performance company characteristics to be avoided in the other hand.

The main source for the information is the valuable PHD thesis of WEI-CHUNG LIU, Development of a Strategically Driven Production Facilities Management (PFM) Framework.

1.3. Personal Research Motivation:

I'm a maintenance team leader in Greater Nile Petroleum Operation Company-(GNPOC), a pioneer oil operating company in Sudan. My position is a field based and at the lowest level of management or supervision. We face (me and my team) a lot of problems and difficulties at work to complete our assigned jobs.

I used to lay the blame on my direct supervisors and upper level managers but since I joined the MSC program in managing quality excellence in the University of Sudan, I could get some knowledge that enable me to see things behind the scene. I could see the causes of problems and difficulties from the quality perspective; I could see obviously some of the bad practices such as:

- There are a lot of managers, supervisors, administrators but no leaders.
- Each department working only for itself.
- Management trying to control people through systems.
- Cheap price is a first choice when buying materials.
- Doing things with high cost.
- Firefighting, reactive behavior in dealing with work problems.
- The "It's not my problem" attitude.

I learnt that system is causing more than 90% of the problems of the work, not the people. In order to reduce the amount of difficulties facing the bottom level of maintenance management and to go further steps into the future with sustain improvement in performance I think it is essential to concentrate on system improvement rather than correcting the results or symptoms.

1.4. Research Motivation

In the path to improve maintenance system performance it is needed to adopt world class best practices to get the desired outcome. If the company uses a maintenance excellence model, it will know where it was, where it is now, and where it can go.

Since maintenance performance is not measured in a way that can make a relevant comparison neither with best in class excellent companies or for internal use. The best-in-class company characteristics to be targeted are:

- Significantly improved asset reliability.
- Greater asset uptime and availability.

- Lower costs of servicing assets.
- Fewer unexpected downtimes and outages.
- A higher return in invested capital.

The researcher think by following the excellence model there will be a shared vision and a common language which will lead to unified objectives and targets that may stimulate challenge spirit among the people in all levels.

Managing effectiveness is achieved by integrating strategies, actions, and measures; that means evolution and learning can and must occur on all three dimensions. As strategic objectives are achieved, new ones are formulated; new actions are required to achieve the objectives, and new measures are needed to encourage and monitor those strategic actions. The driving force for improvement often comes from strategies. That is, measures can lead to both an evolution in actions and a change in strategy.

1.5. Research significance:

This study can be used in maintenance sections and departments in public or private sector with some modification in criteria to suit organization activities. The research can help in facilitating, promoting, and advancing the use of performance-based management concepts in maintenance management from a learning perspective.

The information of this research can be used as a base to drive improvement, benchmarking, reengineering and process improvement from operational management perspectives.

1.6. Objective

- To make a brief understanding of maintenance.
- To develop a better understanding of maintenance excellence.
- To explain how to get sustain maintenance performance improvement by using a maintenance excellence model.

1.7. Approach

The researcher follows the four steps to quality according to Feigenbaum (Juran, 1998):

1. Set quality standards.
2. Appraise conformances to standards.
3. Act when standards are not met.
4. Plan to make improvements.

1.7.1. Research Time Plan:

Table -1-1: Tentative Research Time plan

<i>Tasks</i>	<i>1st Month</i>				<i>2nd Month</i>				<i>3rd Month</i>			
<i>Weeks</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>
Generate potential topics												
Literature review												
Finalise topic												
Design study												
Prepare materials												
Gather data												
Analyse data												
Write-up												
Revise and edit												
Submit dissertation												

1.7.2. Conventional approach

In descriptive studies the target is to gather facts about the object of study. A case study is a story about how something exists within a real world context that is created by carefully examining an instance. It recounts real life situations that present individuals with a dilemma or uncertain outcome. The case describes the scenario in the context of the events, people and factors that influence it and enables students to identify closely with those involved. When multiple cases are examined then it is called a comparative case study. **(Susan Soy, 1997)**

1.7.3. Proposed approach

In normative study models used for describing the existing problems and defining the improvements to the object of study. If an existing descriptive model of the object was made in an earlier study, it can be transformed into a normative model by adding an evaluative dimension to it. For example, the model of industrial production on the right can be made normative by adding the dimension of profitability and a target for it. Once the target for development has been defined with the help of a normative model, the project often continues as planning the practical operations, perhaps also realizing them and measuring the results. Sometimes the same model can be used as a basis of all these operations, but usually you will have to refine a model successively several times in the process of transforming a definition of goals into a plan of action or into a design of a product. Optimally a normative research project proceeds through successive stages:

1. Evaluation of the initial state and defining the need for improvements
2. Analysis of relationships and possibilities to change things
3. Synthesis: proposal for improvement
4. Evaluation of the final state.

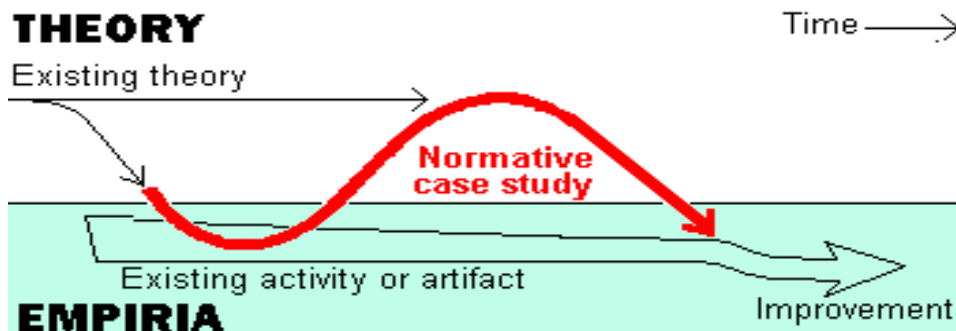


Figure -1-1: Normative Case Study

This research is a normative case study. Normative case study (fig -1-1) purports to find out methods to ameliorate physically the object. Normative research aims at improvements, which means including evaluation of the present state of things and the direction of future development. (Pentti Routio, 2007)

1.7.4. How the proposed approach different from conventional approach:

Normative research aims at improvements, which means including evaluation of the present state of things and the direction of future development.

Normative research differs from descriptive studies because the target is not only to gather facts but also to point out in which respects the object of study can be improved.

1.8. Limitations of the Research

- This research is conducted in the maintenance section in Pipeline division of GNPOC-Sudan. The data used is from the year 2011 and prior.
- The assessment is conducted by one person from operational level of management as a monograph.
- This research is based on the Tompkins Excellence Model in year 2011.

1.9. Roadmap, how to read this the thesis:

The first chapter is the introduction which identifies the research problem and states the overall objectives of the research.

Chapter two is the literature review which explains maintenance, maintenance excellence, performance measurement, and how to use performance measures to drive improvement.

Chapter three explains research models and case study researches then describes the research approach and methodology selected and used in this paper.

Chapter four applies the strengths of the theories and methodologies to develop a conceptual implementation of excellence model to improve maintenance performance

Chapter five is the data analysis and results.

Chapter six is containing the discussion and interpretation of the results.

Chapter seven composed of the conclusions and recommendations of the research.

Chapter 2

Literature Review

2.0.Literature review:

In this chapter the research is going to give a general understanding of maintenance, then provides a broad clarification of maintenance excellence, and exploring how to measure performance, and at last the research discuss how to use measurement information to drive improvement.

2.1. Maintenance.

Through this section a brief definition of maintenance and a selection of articles extracted from some MSC and PHD thesis explaining the evolution of maintenance types of maintenance, purpose of maintenance, the importance of maintenance for business , maintenance cost and its affect in business profitability, maintenance challenges , and the need for improvement in maintenance.

2.1.1. What is maintenance?

- The European standard on maintenance terminology (EN 13306:2001), defines maintenance as “Combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function”. (Henry Muyingo, 2009)
- A generic definition of maintenance is thus defined as the engineering decisions and associated actions necessary and sufficient for the optimization of specified capabilities. Capability is the ability to perform a specific action within a range of performance levels (Richard Doc Palmer,2006)
- " Activities necessary to restore equipment to, or keep it in, a specified operating condition" (Pintelon, et al, 1992)

2.1.2. Purpose of maintenance:

The purpose of maintenance is to produce reliable plant capacity; it is not simply providing repairing services (Richard D. Palmer, 2006).

2.1.3. Evolution of maintenance

Maintenance evolution started from the early days of machinery, when repairs were carried out only when the machines ceased to work. Then the era of preventive maintenance came, where parts were replaced to avoid breaks occurrence. Present day strategies have advanced to the stages of Reliability Centered Maintenance (RCM) and Total Productive Maintenance (TPM) in a search for optimization of existing assets.

a. First Generation:

The First Generation covers the period up to the Second World War (WWII), when industry was not highly mechanized and downtime did not matter much. Prevention of equipment failure was not a very high priority and most equipment was simple and overdesigned. This made it reliable and easy to repair. There was no need for systematic maintenance beyond simple cleaning, servicing and lubrication routines. **(John Moubray, 1999)**

b. The Second Generation

Dramatic changes occurred during (WWII) which led to increased mechanization. By the 1950s machines of all types were more numerous and more complex, and industry was beginning to depend on them with sharper focus on downtime. This led in the 1960s to preventive maintenance which consisted mainly of equipment overhauls done at fixed intervals. Cost of maintenance started to rise sharply and led to the growth of maintenance planning and control systems. People started to seek ways to maximize the life of assets as the amount of capital tied up in asset together with the cost of capital rose sharply. **(John Moubray, 1999)**

c. The Third Generation

Since the mid-seventies, the process of change in industry has gathered even greater momentum; Major concern with downtime and its negative effects on output, quality, operating costs, and customer service. This was aggravated further with the move to JIT. Growth of mechanization and automation has meant that reliability and availability are now becoming major issues in sectors other than manufacturing (e.g., health care, telecommunications, building management, etc.). More and more failures have serious safety or environmental consequences. Costs to own and operate assets, as well as the cost of maintenance continue to rise sharply. Return on assets becomes a major concern. **(John Moubray, 1999)**

2.1.4. Types of maintenance

a. Maintenance work performed during maintenance custody (shutdowns):

- Preventive Maintenance (PM): Can be planned far in advance of the shutdown and should be the most efficient effort by the maintenance department.
- Corrective Maintenance: Work performed to replace worn parts, adjust loose equipment, prevent a major failure, etc. As with PM, this work can be planned in advance.
- Emergency Repair: Occasional and unavoidable shutdown of equipment because of unforeseen circumstances requiring unplanned repairs.

b. Maintenance work performed during production custody:

- Prefabrication: Prefab work includes rebuilding equipment in the shop, setting up equipment prior to a planned shutdown, etc.
- Preventive maintenance: Preventive periodic and prescribed maintenance (time-based) adjustments, lubrication, tests, inspections, and calibrations performed on equipment while it's running.
- Predictive maintenance (PDM): Predictive maintenance based on equipment condition (condition-based). This includes nondestructive tests performed on the equipment to determine its condition.
- Corrective maintenance: Corrective run-to-failure or breakdown maintenance (unplanned).

2.1.5. Why maintenance is important for business:

Plant capacity is the lifeblood of a company. Plant capacity must be reliable for the company to produce a product to stay in business. Reliable plant capacity connected with revenue streams. Reliable plant capacity is by definition an investment in maintenance. In real life, capacity must be maintained. Capacity is not reliable by itself. Poor maintenance equals poor revenue streams. Maintenance provides a competitive edge in many companies. If the capacity were not available, the plant could certainly not produce products for sales. The significance of higher availability extends even beyond the daily increase of sales and reduction of production interruption. If maintenance can achieve continued superior availability, then a company can defer construction of new capacity even as annual sales grow. The ability to defer capital construction as a company grows leads to lower company capital cost, a financial blessing. Today's money invested in

proper maintenance ensures high capacity and guards against premature future construction. Proper maintenance makes a company cost competitive. (Richard D. Palmer, 2006)

2.1.6. The Impact of Maintenance in Production

The importance of reliability and maintenance has long been understood by aircraft operators and by the military in general. However, it is only relatively recently that the reduction of life cycle costs through maintenance has received close attention from managers. In a benchmarking study of Scandinavian and US manufacturers, many manufacturing organizations now realized the critical need for effective maintenance of production facilities. There are two major trends identified in maintenance management:

- The emergence of advanced maintenance technologies and methods, such as expert systems and condition monitoring.
- The linking of maintenance to quality improvement strategies and the use of maintenance as a competitive strategy.

(WEI-CHUNG LIU, 2000).

2.1.7. Maintenance, Company Vision and The 1-10-100 Rule

The company vision for producing a profitable product should understand that effective maintenance provides reliable plant capacity. Some of the most important maintenance decisions are made before a company even builds a plant.

Gifford Brown of Ford Motor Company explains the 1-10-100 Rule. This rule means that every \$1 spent up front during engineering to reduce maintenance eliminates a later \$10 cost to maintain equipment properly or \$100 in breakdown maintenance. In this sense, Brown says, “The company vision should be how to prevent maintenance, not how to do it efficiently.” Companies should spend more effort purchasing machines that need a minimum of attention. This is preferred first over being efficient at either performing work to keep machines from failing or reacting to repair failed machines. Any company would prefer machines that run constantly without any attention.

Phillip Young of DuPont says industry typically does not involve maintenance intellect up front, a serious fault. By far, the greatest maintenance opportunities exist before the company installs equipment.

Therefore, the first step in dealing with maintenance effectiveness involves working actively with engineering and construction departments before installing equipment. Nevertheless, some maintenance attention will be required after a company installs equipment. Once equipment is installed and operating, the second step in dealing with maintenance effectiveness is to be proactive. Proactive maintenance means to act before breakdowns occur. It acts through preventive maintenance, predictive maintenance, corrective maintenance, and project work. Proactive maintenance recognizes and addresses situations to prevent them from ever becoming urgent problems or breakdowns. Urgent maintenance performed under schedule pressure is rarely cost efficient. Breakdowns interrupt revenue producing capacity and destroy components. Maintenance does not want to recover plant capacity by repairing broken components. Proactive maintenance programs stay involved with the equipment to prevent decline or loss of capacity. In this sense, maintenance produces a product which is capacity; maintenance does not just provide a repair service. (Richard D. Palmer, 2006)

2.1.8. Maintenance Contribution to Profitability

An important criterion for investment in a company is the financial return on its fixed assets (ROFA). Asset management focuses on achieving the lowest total life-cycle cost to produce the required product or provide a sought-after service. The goal is to achieve a higher (ROFA) than other competitors in order to be the lower-cost producer of a product or service. The maintenance management impacts on the (ROFA) because maintenance costs are a significant contributor to manufacturing costs. If the maintenance cost as a percentage of manufacturing cost fluctuates, then the effectiveness of maintenance should be examined to find the cause of the variation. Downtime increases the industry's financial expenditure because of the costs of:

- Idle production/operations personnel.
- Late deliveries.
- Overtime payment to make up for lost production in order to meet promised deliveries on time.
- Lost sales as a result of products not being made on time.

However Japanese studies relating to Total Productive Maintenance (TPM) have concluded that “inefficiency” losses tend to exceed downtime losses. (M.C. ETI, et al, 2006)

In Sudanese industries, the researcher could not find a clear study to deny that most inefficiency losses have never been measured and reported. Moreover, many chronic problems, that have a dramatic impact on equipment effectiveness, have never even been

comprehended. If only accurate maintenance records kept very well then these **problems** can be realized.

Utilizing the maintenance data, combined with pertinent financial data, a worthwhile estimate of the resulting costs can be achieved. As maintenance is regarded as an expense, any maintenance saving will contribute directly to the profit achieved. As the effectiveness of maintenance improves and downtime is reduced, there is less need for investment in standby (but otherwise) redundant plant. This will contribute to an overall rise in the (ROFA) for any organization. (M.C. ETI, et al, 2006)

2.1.9. Maintenance Cost

Within many large-scale plant-based industries, maintenance costs can account as much as 40% of the operational budget, and therefore improving maintenance effectiveness is a potential source for making financial savings. Today's competitive environment requires that industries try to sustain full production capabilities, while minimizing capital investment. From the maintenances perspective, this involves maximizing equipment reliability (i.e. uptime) including prolonging the equipment's life. Wise operation and careful maintenance should together deliver cost-effective production reliability and this should be the basis for shrewd management decision-making. Overall, the goal for an organization is to increase profitability. The maintenance and asset-management function can increase profits in two main ways, i.e. by decreasing running costs and increasing capability. If the annual maintenance cost exceeds 5 percent of the asset value, the organization is probably in financial difficulties. The total maintenance cost depends on the quality of the equipment, the way it is used, the maintenance policy and the business strategy. The wise business owner buys equipment that will subsequently need little maintenance, i.e. is highly unlikely to fail.

To increase the equipment's uptime, at least cost, is the aim. A proactive profit-focused approach is needed to narrow the gap between actual costs and ideal costs. Downtime seriously bedevils the productive capability of industries, so reducing average rate of output, increasing operating costs and interfering with customer service.

Downtime can easily increase as a result of the ineffective implementation of just-in time (JIT) and lean total-quality management (TQM) procedures. Hence, the applications of total productive maintenance (TPM) and reliability-centered maintenance (RCM) as company-wide improvement processes are highly desirable. (TPM) requires operators and maintainers to work together as a team in order to reduce waste, minimize downtime, enhance product-quality, and improve equipment effectiveness. (RCM) involves determining what must be done to ensure that any physical component continues to perform in the way that its user wants it to do. Two objectives must be met:

- Determine the maintenance requirements.
- Ensure that they are met as cheaply as possible.

(M.C. ETI, et al, 2006)

•Example of Maintenance Cost

In the chemical industry, the world's best-performance maintenance processes annually cost 1.8 to 2.0 percent of the current replacement value of the plant. In poorly-managed operations, maintenance costs per year exceed 5% of asset-replacement value, i.e. a wastage of \$30,000 yearly is typical for every M\$ 1 of asset value. The effect of compounding the maintenance cost, taken as \$ 30,000 annually, over a twenty-year life at the business average annual rate of 12 percent for the sake of calculation, then the lost opportunity cost would be \$2,162,000 because of

- (i) Poorly designed-or-built equipment.
- (ii) Ineffective operating and maintenance practices.

In the example cited, for each 1 percent of replacement asset value spent annually on maintenance over a 20-year period, \$ 75,000 of every \$1M of the original capital invested will not lead to any financial return. The lost-opportunity cost will then be assessed. Wiser planning and scheduling of maintenance activities could significantly improve. The objectives should be to:

- Increase the effectiveness/efficiencies of plant/equipment.
- Boost the profit achieved.
- Reduce maintenance and operating costs.
- Improve availability and reliability.
- Raise the financial return on asset investment.
- Introduce an inspiring corporate culture amongst maintenance personnel.
- Implement a continual-improvement paradigm.

The overall aim is to maximize the value achieved by maintenance investments, i.e. profit optimization with maintenance excellence reducing the cost of preventive maintenance (PM) through adopting a proactive reliability-focused culture.

(M.C. ETL, et al, 2006).

2.1.10. Maintenance Challenges

A major change in maintenance function is witnessed. It is moving from an equipment repair service to a business process for increasing equipment reliability and ensuring plant capacity. Its practitioners are trading their reactive cost center mentality for a proactive equipment asset management philosophy.

The maintenance function is now expected to offer higher plant availability and reliability, greater safety, better product quality, longer equipment life, greater cost effectiveness and no damage to the environment. This argues that the new maintenance plan should be linked with strategic concerns.

The efficiency and effectiveness of existing facilities rely on the integration of a specified business and maintenance policy, disciplined workforce, and constant collection of historic operation data. Traditionally, maintenance activities were based on reactive, fire-fighting, corrective maintenance approaches, or on Planned Maintenance (PM) practices that mainly take the form of equipment overhaul or item repair, item replacement at fixed intervals. The trends away from the labour-intensive to the computer-controlled intensive production and from manufacturing for stock to Just-In-Time manufacturing have made efficient maintenance a key function. Maintenance is a competitive weapon for manufacturing. It also concluded that reduction of production downtime is a strategic business issue which has a major impact on the bottom line. Lack of understanding of the real cost of production downtime and failure to adequately address the problem led to poor line efficiency. Since the 1980s, more and more researchers reported that due to the huge increase in the number and variety of physical assets (plant, equipment, and buildings), maintenance people are having to adopt completely new ways of thinking and acting, as engineers and as managers. Maintenance is responding to changing expectations. These include a rapidly growing awareness that the maintenance objective should be compatible with the corporate and production objectives such as safety, product quality, plant availability, cost, etc. Effective strategies deliver plant reliability and good maintenance emphasizes the need to consider plant reliability within a wider context of corporate and production objectives.

Business leaders increasingly realize the strategic importance of the maintenance function for organizations, which have significant investments in physical assets, and so is a necessary expense in the operating budget. In other words, reliability has become a critical issue in capital-intensive operations.

Unfortunately, in many industries, effective maintenance is usually not a high priority and the consequent cost of failures, as a percentage of the total cost, keeps rising. Businesses today need innovation, to break the inherent molds of perception and redundant patterns of behavior. Organizations should be changing from a repair focused to reliability-focused culture. Hence the set goals must provide “something in it for us” for all within the organization, thereby “building-in” commitment. So the leader should formulate these goals with reference to the needs of those working within the organization, and use the goal to shape the future of that organization individual rewards must be aligned with the achievement of the company’s strategic goals. These rewards can be both financial and non-financial: the most successful change-initiatives incorporate a blend of the two. The leader must create opportunities for teamwork and organizational learning. The challenge facing maintenance managers today is not solely to find the appropriate methodologies to apply, but in understanding how they fit together. It also lies in making sure that the application of this approach is not regarded as the latest fad or “flavor of the month”, but is fully adopted and internalized within the organization and simply becomes “the way we do things around here”. If wise leadership emanates from the top of the organization, then the

speed of cultural change will be much greater and far wider ranging. A vision statement should describe what the organization aspires to, whereas the resulting mission statement should explain how the vision is to be achieved. The vision statement for maintenance should be governed by current best-practice (CBP) as the benchmark.

Preventive Maintenance (PM) is usually based on an old-fashioned premise, namely fixed-time maintenance (FTM) overhaul or even replacement of components. This approach is seldom justifiable, because less than 20% of all components fail within the usually prescribed periods, and hence the relatively high costs incurred as a result of implementing (PM). Thus, if adopted, (PM) activities should be primarily individual component-condition based, and implemented via a more wisely-scheduled corrective maintenance procedure (M.C. ETI, et al, 2006).

2.1.11. Why Improvement Is Needed in Maintenance

Effective maintenance reduces overall company cost because production capacity is available when needed. The company makes a product with this capacity to sell at a profit. This explains the reliability–cost relationship; focus on overall cost reduction and reliability gets worse, but focus on reliability improvement and overall cost goes down. Nevertheless, examining the cost of the maintenance operation cannot be dismissed as unimportant. After maintenance effectiveness, maintenance efficiency must be considered. What if the same or better maintenance could be provided for less cost? What if the company could grow by adding new production capacity and maintain it without increasing the current maintenance cost?

Keeping the purpose of maintenance in mind, one may focus on the cost of the maintenance operation. Understanding the details of one’s maintenance system provides the information on how it may be improved. Many companies trying to become more competitive change their maintenance budget without any understanding of how their maintenance system works. They may increase the budget to add maintenance personnel when making capital plant additions. They may reduce their budget for an existing plant. They may not increase the budget when making capital plant additions. They may hope that budget pressure will cause the maintenance force to “work harder” or “do what it takes.” Nonetheless, to make improvements to the efficiency of a maintenance operation, one must understand the details of the system.

What are the details in the maintenance system? The following case shows a pertinent example of the details involved in a maintenance system. In the 12 months resulting in

93% availability, the previously mentioned power station spent over \$9 million in maintenance. This amount included more than \$5 million in wages and benefits for the mechanical, electrical, and instrument and control (I&C) crafts. A study revealed that productivity of maintenance personnel was about 35%. That is, on the average, a typical maintenance person on a 10-hour shift was making productive job progress for only 3 1/2 hours. The other 6 1/2 hours were spent on “nonproductive” activities such as necessary break time or undesirable job delays to get parts, instructions, or tools. The study only included persons who were available for the entire shift so training time and vacation time were not even included. For example, if mechanic Joe Stark had a pump job and a valve job for a 10-hour day, typically he would have physically performed maintenance on the equipment for only 3 1/2 hours. The rest of the time Joe might have done something very necessary for completing the job. He may have stopped to get a gasket or a special wrench, but when he stopped, the job did not progress. If the job did not progress when it otherwise might have, the company lost an opportunity not only to regain plant capacity, but also to have Joe perform another job that day. If Joe had not had to stop, the work would have proceeded much faster. Overall, only 35% or \$1,750,000 of the \$5 million paid to the employees was for productive maintenance. The company paid 65% or \$3,250,000 for unproductive maintenance. Considering that training time and vacation time were included in the \$5 million would make the actual amount paid for productive maintenance even lower. The company was surprised to learn that 35% productivity was typical of good traditional-type maintenance organizations. However, the company realized that the average of 6 1/2 hours of nonproductive time per person accompanying the significant cost of maintenance was an opportunity to improve maintenance efficiency. Understanding the details in the maintenance system leads to improvement opportunities. Understanding what is happening allows selection of maintenance strategies for the specific opportunities to improve. **(Richard D Palmer, 2006).**

2.2. Maintenance Excellence

In this section the research will give a broad clarification of maintenance excellence and concentrate on the recent practical strategies in maintenance excellence, and showing the characteristics of both the best in class and the lower grade companies. The main source for the information is the valuable PHD thesis of WEI-CHUNG LIU, Development of a Strategically Driven Production Facilities Management (PFM) Framework.

2.2.1 Best-in-class company characteristics to be targeted:

- Significantly improved asset reliability.
- Greater asset uptime and availability.
- Lower costs of servicing assets.
- Fewer unexpected downtimes and outages.
- A higher return in invested capital.

2.2.2 Lower performance company characteristics to be avoided:

- Insufficient data available on asset performance and service history,
- Management does not see maintenance as a top priority, and
- Disjointed, nonstandard maintenance processes prevail.

2.2.3 Maintenance Excellence Management Strategies and Best Practices:

Experience gained in leading manufacturing companies has shown that formulating a maintenance strategy is a difficult process with many problems. It often suffers from the lack of a systematic and consistent methodology, and satisfying all the many different interested parties - while at the same time achieving the objectives of the company - becomes an almost impossible task. As a result, maintenance strategies are formulated in an iterative way, involving different decision makers and multiple objectives; such as achieving high productivity, availability, and quality - subject to availability of spares, manpower and skills and to meeting the constraints of the production plan. The general procedures for formulating strategy have not been widely used by maintenance practitioners. Some manufacturing strategy formulation proposals have not included maintenance processes as well.

Continuing operation depends on designers of the equipment, as well as its constructors and its operators, i.e. not just the maintainers. Developing and executing a maintenance strategy consist of three steps:

- Formulate a plan of what needs to be done for each component.(i.e. work identification);

- Acquire the resources (skilled personnel, spares and tools) needed to executive the proposed procedure effectively
- Implement the strategy (i.e. acquire and deploy the systems needed to manage the resources effectively).

The following are some maintenance strategies and best practices adopted by excellent companies:

- a. Total Productive Maintenance (TPM).
- b. Reliability-Centered Maintenance (RCM).
- c. Business-Centered Maintenance (BCM).
- d. Terotechnology.
- e. Computerized Maintenance Management System (CMMS).

The research is giving an overview for each of the fore-mentioned strategies and best practices.

a. Total Productive Maintenance (TPM):

Total Productive Maintenance (TPM) is one of the methodologies for the management of existing facilities which was first introduced to Japanese Industry in 1971 by “Seiichi Nakajima”. Nowadays, (TPM) has become one of the main streams in maintenance management methodologies. When equipment has a history of breakdowns and defective operation, a plant must input excess work-in-process and prepare excess inventory for the unpredictable accident. When minor stoppages eat into the production schedule, extra labour hours are required for catching up. Ideally, (TPM) covers most aspects of manufacturing operations on the shop floor, including:

- Simple 'good housekeeping' activities (5Ss) - Roughly seiri (organization), seiton (tidiness), seiso (purity), seiketsu (cleanliness), and shitsuke (discipline).
- Operator or 'first line' maintenance - Autonomous maintenance by operators.
- Continuous improvement groups - total participation for TPM implementation
- Measuring equipment effectiveness and improving effectiveness (Measuring and eliminating the six big losses) - equipment loss (such as breakdown of equipment), set-up and adjustment losses (such as die change), idling and minor stoppage losses (such as abnormal operation of sensors), start-up and shutdown losses (due to unstable conditions during start-up), reduced speed or capacity losses (deviation between designed speed and actual operation speed), and quality defects or rework losses (scraps and rework of defective products).

- Maintenance systems and techniques - for preventive maintenance.
- Specify new machinery - equipment redesign for easy maintenance implementation.

TPM is not only a maintenance initiative or improvement program but a strategic operational strategy. In implementing (TPM), continuous monitoring of equipment performance and selection of appropriate monitoring measures are the key activities and the measure for this monitoring purpose is useful. The basic conditions related to the performance of the equipment of the future are development, reliability, economics, availability and maintainability. Collection and analysis of historic maintenance data related to these requirements is necessary for the improvement of facilities management. **(WEI-CHUNG LIU, 2000)**

b. Reliability -Centered Maintenance (RCM):

Reliability-Centered Maintenance (RCM) is a process used to determine the maintenance requirements of any physical asset in its operating context. (RCM) consists of structured processes to determine the equipment maintenance strategies required for any physical asset to ensure it continues to fulfill its intended function(s) in present operating conditions.

The goal of RCM is to determine what the critical components in any process are and, based on this information, design a customized preventive/predictive maintenance strategy.

(RCM) is another methodology for the management of existing facilities which was started with the publication of the United Airlines report by Nowlan and Heap in 1978. (figure-2-1) shows their observation results. The graph shows the conditional probability of failure against the operating age for a variety of electrical and mechanical items. (RCM) has been proven to be useful primarily in the aviation industry in the beginning to determine scheduled maintenance policies for civil aircraft. Briefly, it is a structured methodology and a unique process, formulated via a structured framework of analysis aimed at ensuring the attainment of a system's inherent reliability, i.e. the reliability that it was designed to attain. This kind of analysis has since been adapted for the production and process industry as an evolutionary approach to equipment reliability as well. Also, the structured framework can be utilized to develop optimum equipment maintenance plans and strategies. The RCM process has three key features:

- It recognizes that the inherent reliability of any item (including any facility) is governed by its design and how it is made, and that no form of maintenance can

yield reliability beyond that inherent in the design. An (RCM) analysis starts by defining the desired performance of each plant in its operating context and ascertains whether the inherent reliability is such that maintenance can deliver that performance. If it cannot, it highlights the problems which are beyond the scope of maintenance and need further action such as redesign, modification, change in operating procedures or raw material change.

- RCM recognizes that the consequences of failure are far more important than their technical characteristics.
- RCM incorporates the latest research on equipment failure patterns into a sophisticated decision algorithm for the selection of preventive maintenance tasks.

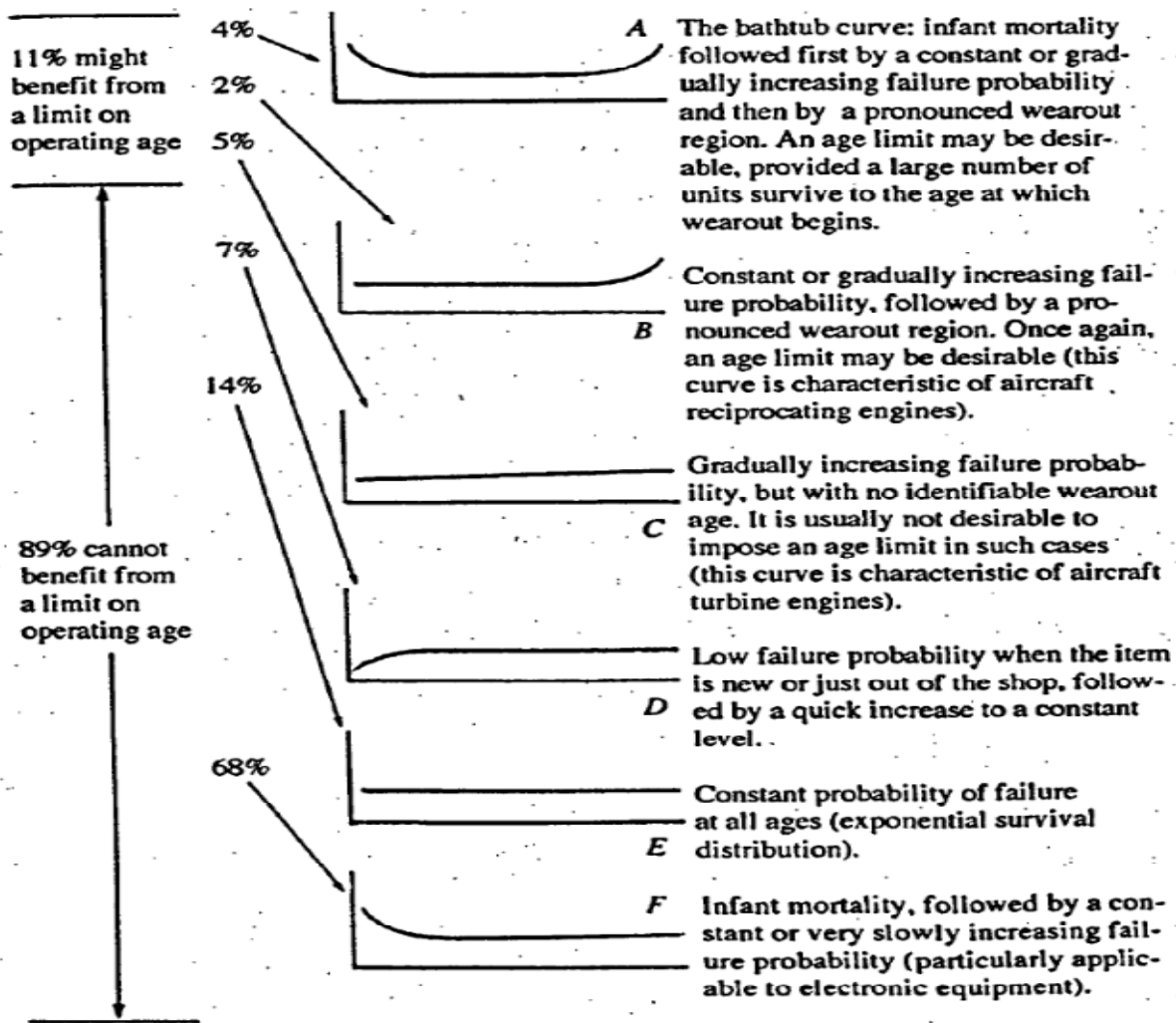


Figure-2-1: Age-reliability Patterns

The strength of RCM is that it recognizes that the reason for doing any kind of proactive maintenance is not to avoid failures but to reduce the consequences of failures. The driving element in all maintenance decisions is the consequence of the failure for the equipment as a whole. The purpose of (RCM) is to preserve a system's function. Therefore, (RCM) is focused on the needs of the asset, not the shape of the organization. The implementation of the (RCM) approach is based on the principle that no preventive maintenance task will be performed unless it can be justified. The (RCM) process consists of inspecting the way equipment fails, and choosing the correct maintenance action to ensure that the desired overall level of plant performance (i. e. availability, reliability) is met. The advantages of RCM are to identify the failure modes and prioritize the maintenance tasks. (WEI-CHUNG LIU, 2000)

Nowadays, (RCM) is one of the main streams of maintenance management methodologies, a large number of interpretation and variations of (RCM) analysis, decision logic, and processes have been developed, such as Smith's seven steps, Knowles's seven steps, Moubray's eight steps and Kelly's six step structure of (RCM).

With the focus on the aim of reliability, (RCM) has been successfully achieved in the aviation industry. However, (RCM) is not so popularly accepted by industries other than aviation. Unsuccessful implementation of (RCM) in companies is a result of the following barriers:

- The implementation of (RCM) will need much greater resources of time and manpower for data collection and analysis work than had been anticipated.
- Insufficient equipment failure data.
- Poor results in Preventive Maintenance (PM) and Predictive Maintenance (PdM) efforts.
- Poor training in the RCM methodology.
- Lack of organizational buy-in.
- Insufficient staffing for the problem.
- Reactive or instant RCM results.
- Short-term equipment focus.
- Poor organizational discipline.

Nevertheless, the contribution of (RCM) to maintenance knowledge is that it incorporates several basic techniques of reliability engineering with the development of techniques in

failure mode analysis which has proved to be useful. In comparison with (TPM), (RCM) better addresses the technical characteristics of a production system and (TPM) aims to more effectively manage the human aspects. Therefore, production companies should adopt a maintenance strategy that integrates both (RCM) and (TPM). (WEI-CHUNG LIU, 2000)

c. Business -Centered Maintenance (BCM)

BCM was coined by Kelly in 1998 whose aim was to research a methodology or guidelines for deciding maintenance objectives, formulating equipment life plans and plant maintenance schedules, designing the maintenance organization and setting up appropriate systems of documentation and control, The optimal maintenance strategy for industrial plants is driven throughout by the identification of primary business objectives and their translation into maintenance objectives, and the organizational design, the maintenance and production departments being inseparable, therefore it is termed. The methodology for developing maintenance strategy in BCM is outlined in (figure-2-2)

The concept of BCM is that the best time to influence maintenance and unavailability costs is before the plant comes into use, and is hence within the strategic decision making field. In implementing BCM, a control system is needed to ensure that the maintenance effort is achieving its objectives and to provide corrective action if it is not. The functions of the control system are:

- Control of the overall maintenance effort: Ensuring that the budgeted levels of maintenance effort are being sustained and that required plant output is achieved.
- Control of maintenance effectiveness: Ensuring that life plans are effective in controlling plant reliability.
- Control of maintenance organizational efficiency: Monitoring utilization of workforce, material and tools.

Purchase of new or replacement plants should be based on a present-value life-cycle analysis of costs which should consider both maintenance and unavailability costs, these being estimated from documented experience. The company should set up a system to record and analyze plant failures and identify areas of high maintenance cost. Within the organization, a facilities management system should be defined and established. This should transcend traditional functional boundaries for decision making and will require commitment from the senior management. This highlights the necessities that maintenance

strategy should be strategically driven and a well-structured performance measurement system is required in achieving maintenance work. (WEI-CHUNG LIU, 2000)

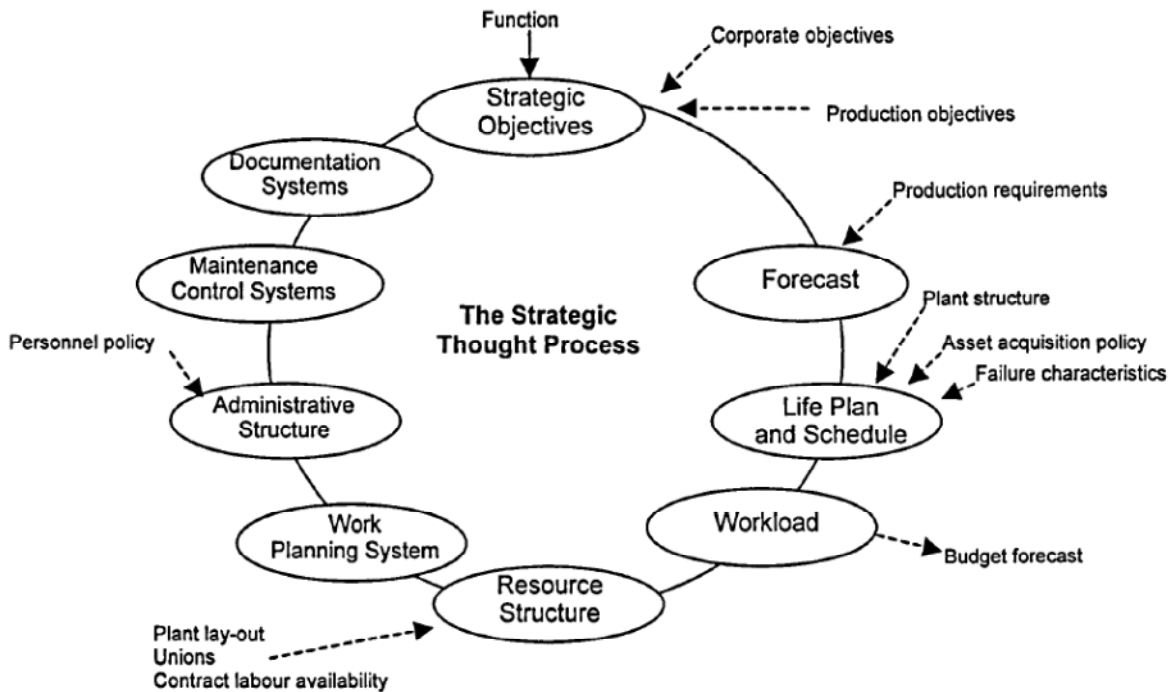


Figure-2-2: Business-Centered Maintenance Model

d. Terotechnology

"Terotechnology" was coined in the U. K. in 1970. The British Standards Institution defined it as: "A combination of management, financial, engineering, and other practices applied to physical assets in pursuit of economic Life Cycle Costs (LCC). More recently, Nakajima (1988) stated "Its practice is concerned with the specification and design for reliability and maintainability of plant machinery, equipment, buildings, and structures, modification, and replacement, and with feedback of information on design, performance, and cost. " The fact that "Terotechnology" is virtually unknown in manufacturing today is testimony to the failure of this DTI initiative. However, the initiative of Terotechnology is creative whilst it needs more research on the implementation of the integration of these separate practices applied to asset management. Its goal of integration of management, financial, engineering, and other practices applied to physical assets in pursuit of economic Life Cycle Cost (LCC) might be workable once the appropriate CMMS and MIS (Management Information System) are applied. Also, it highlights the importance of linkage between strategic

requirements (management level) and maintenance and LCC control of the operational level. **(WEI-CHUNG LIU, 2000)**

e. Computerized Maintenance Management System (CMMS)

In facilities management, it is imperative to handle historic operational data from different facilities locations simultaneously. The bigger the organization, the more complicated it is to collect and analyze useful information from them. With powerful and cheaper processing power, the Computerized Maintenance Management System (CMMS) has been available from the late 1970s and is now common in the manufacturing industry. The CMMS is, in reality, a computerized version of a maintenance information system. In theory, the CMMS should make maintenance faster, make it easier to collect data and then manipulate it into a meaningful report format. In reality, the need for appropriate maintenance software is growing rapidly as well. "The maintenance management market will exceed £918M by the year 2001 and currently totals £437M, according to estimates by International Data Corporation (IDC) and Automation Research Corporation. Its growth is out pacing that of the overall software market. In dealing with the key elements of a CMMS, (figure-1-4) highlights the basic components of it.

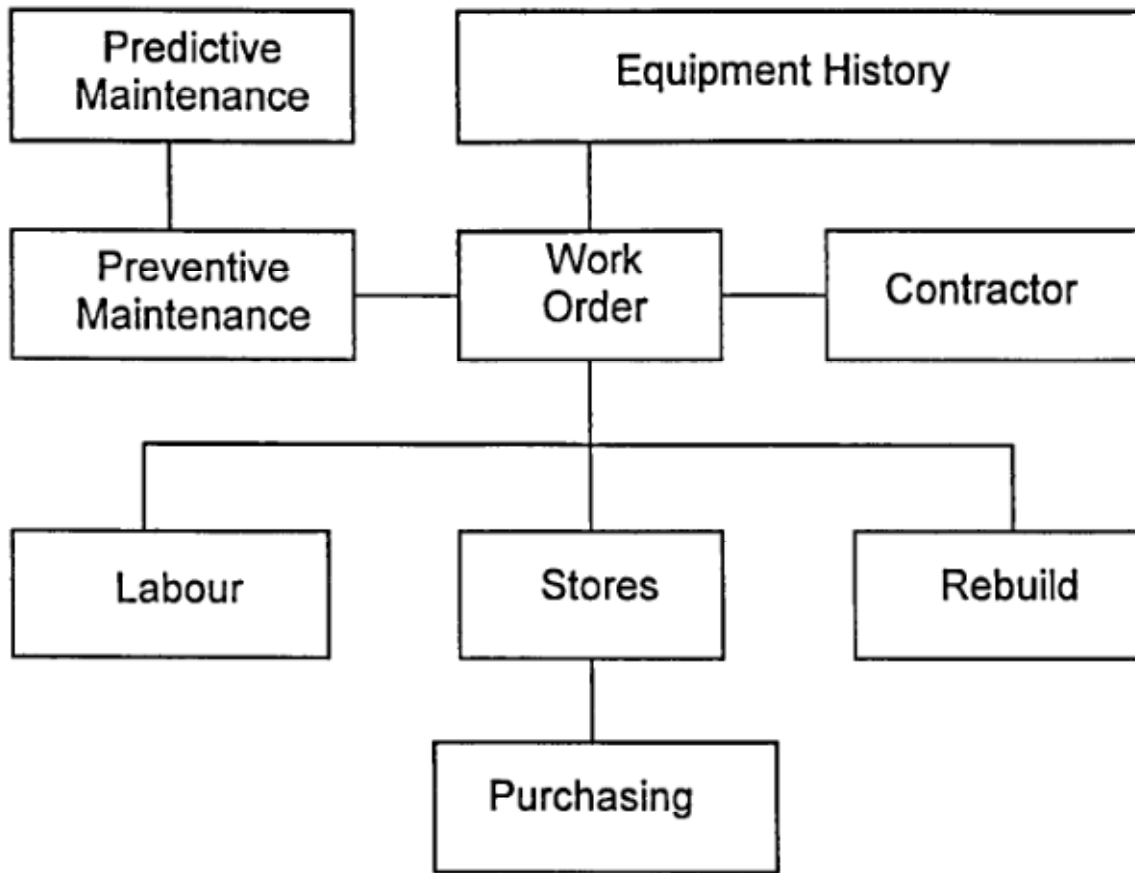


Figure-2-3: Basic Components of a CMMS

The work order is the key feature of the system. It collects all the labour data, material data, contractor data, and preventive maintenance data that is written against a piece of equipment. The information collected is then stored in a database called the equipment history, where all of the data is drawn to produce all of the reports needed by the organization to manage the equipment or assets). The CMMS software is developed to solve some obvious and pragmatic issues:

- To reduce downtime, by accurately identifying why, when and where problems are occurring.
- To reduce costs, by identifying where resources are being used.
- To increase safety, by maintaining on a regular controlled basis.
- Quality system compliance. Giving the ability to show where and when maintenance work has been carried out.

- Control. A hidden benefit of CMMS is that the manager will become much more aware of both production requirements and resources. This awareness helps to create a more professional "switched-on" feeling amongst both management and workers.

Therefore, a CMMS can help production facilities management in three main ways:

- Information resources- holding easily accessible data on plant, facilities and their work performance.
- Work processing and control- keeping track of what work needs to be done, what work is in progress and what work has taken place.
- Reporting and analysis - using information recorded in the system to help report the performance and make decisions, for example when to replace a piece of equipment rather than maintain it.

However, there is evidence that such systems have often failed to deliver the expected benefits. In an analysis of 725 maintenance management audits carried out on behalf of the DTI in the U. K. over 60% of companies were not satisfied with their MMIS (Maintenance Management Information System). The common reasons are:

- CMMS is designed by people with insufficient experience of maintenance management.
- Absence of clear maintenance strategy - In the aforementioned analysis, 85% of the companies audited did not have a clear maintenance strategy. This result shows if there were such a strategy, it would be supported by the CMMS used.
- Lack of sufficient and effective training and a failure to address the fear of using computers.

In the application of CMMS, the part of "resource planning and control" is very much a background activity but can have a major impact when things go wrong. It is a complicated activity which considers many more parameters than can be handled simultaneously by any means of human intervention. To any software developer, this part is always left to the user to make timely decisions based on hard facts rather than supposition. From the viewpoint of consistency, the decision-making of these parameters should match the strategic objectives of the company. In implementing PFM work, the consistency of the strategic requirements from the corporate level down to the operational level is always one of the key factors to be concerned **(WEI-CHUNG LIU, 2000)**.

2.3.Maintenance Performance Measurement.

In this portion the research will discuss some of important tools and techniques used by quality practioner to know the current level of maintenance performance. The first is Performance Measurement System (PMS) followed by benchmarking techniques and Self-Assessment Excellence Models.

2.3.1. Performance Measurement Systems :

A Performance Measurement System (PMS) is a management tool composed of a set of performance measures to assist the assessment of how well the activities within a process or the outputs of a process achieve a specific goal. In implementation, PMS consist of two key elements, the identification of Performance Measures (PM)/ Performance Indicators (PI) and the benchmarking process (WEI-CHUNG LIU, 2000).

The Performance Measurement System (PMS) is a monitoring tool which provides the linkage of the interface to translate the strategic requirement into the facilities management requirement. Properly utilized, performance indicators should highlight opportunities for improvement within companies today (Wireman, 1998).

Whether the performance measurement system implementation will succeed or not depends a lot upon the development of an effective and efficient performance measurement system. Performance measures link the mission, strategy, goals, and processes of the organization. (WEI-CHUNG LIU, 2000).

- **The Why, What, Where and How of Performance Measurement**

In implementing PMS, workers and managers should work together to get the benefit of a proper performance measurement because of the operation gap it can reflect and improve. A PMS is required due to the following reasons:

A company cannot manage what a company cannot measure – Performance measures are the media of management because without them no target can be made.

To determine what to pay attention to and improve - Resources in any organization are limited and scarce. Performance measures provide the company the opportunity to make the right allocation of resources and to set the right priorities for improvement.

Performance measures provide a "scorecard" for people to monitor their own performance levels - People like to know how well they are doing and where they should next focus for improvement.

Performance measures show the standard for establishing comparisons - Quality is an aggregate name for a journey without a destination. If organizations want to be competitive, they must first set high internal standards which reflect their strength to enable them to carry out comparisons with their key competitors and to be the best in their class.

Performance measures must comply with the strategic objectives - Effective strategy deployment can only be achieved if there are proper measurement systems in place. The company needs to measure all the time to ensure that their goals are being achieved.

In the current business climate, to be competitive, a company requires measures that can accurately reflect the company's performance in the future. These measures allow the organization to focus on priority items and not waste resources on non-value added initiatives or programs (WEI-CHUNG LIU, 2000).

•The Evolution of Performance Measurement Systems:

Traditionally, the majority of performance measures of manufacturing business organizations are usually based on the cost and management accounting aspects which still remain largely unchanged. These efforts place an emphasis on cost, price, and profit. On the other hand, the production management technology and processes have had numerous changes and these cannot be shown from these aspects. Why the traditional measures are not suited to the current situation:

- The measures produced irrelevant or misleading information, or worse, provoked behavior that undermined the achievement of strategic objectives.
- Measures that tracked each dimension of performance in isolation were distorting management's understanding of how effectively the organization as a whole was implementing the company's strategy.
- Traditional performance measures did not take into accounts the requirements and perspective of customers, both internal and external.
- Bottom-line financial measures coming too late (monthly) for mid-course corrections and actions.

- Cost-based measures are inconsistent with the new emphasis on quality, just-in-time.
- Traditional management accounting is no longer relevant or useful to a company moving toward a world class manufacturing environment.
- Customers are requiring higher standards of quality, performance and flexibility.
- Management techniques used in production plants are changing significantly.
- A comparison between traditional and non-traditional performance measures as shown in (table-2-1). The comparison table not only presents the changing of performance measures requirements but also provides a new direction for the design of a new PMS (WEI-CHUNG LIU, 2000).

• **The new required performance measurement:**

Measurement approaches must support ever-increasing excellence; all employees should be involved in the drive to implement new ideas more quickly; the objective is total and continual organizational learning, managers need to spend more time taking actions and less time reporting actions, and improvement actions must be integrated across functions and across company borders.

Managing effectiveness is achieved by integrating strategies, actions, and measures; that means evolution and learning can and must occur on all three dimensions. As strategic objectives are achieved, new ones are formulated; new actions are required to achieve the objectives, and new measures are needed to encourage and monitor those strategic actions. Moreover, obsolete measures must be discarded.

The driving force for improvement often comes from strategies, but it can and should also come from actions and from measures. That is, new measures can lead to both an evolution in actions and a change in strategy.

Table-2-1: Comparison Table of Traditional and Non-traditional Performance Measures

Characteristic	Traditional Performance Measures	Non-traditional performance measures
Basis of system	Accounting standards	Company strategy
Types of measure	Financial	Operational and financial
Audience	Middle and top management	All employees
Frequency	Lagging (weekly or monthly)	Real-time (hourly or daily)
Linkage with "reality"	Indirect, misleading	Simple, accurate, direct
Shop floor relevance	Ignored	Used
Format	Fixed	Flexible / variable
Effect on continuous improvement	Impedes	Support
Local-Global relevance	Static, non-varying	Dynamic, situation structure dependant
Stability	Static, non-changing	Dynamic, situation timing dependant
Purpose	Monitoring	Improvement
Support for new improvement approaches (JIT, TQM, CIM, FMS, etc.)	Hard to adapt	Applicable
Effect on continuous improvement	Impedes	Support

The design of any performance measurement system should reflect the basic operating assumption of the organization it supports so in creating process performance measures four steps are suggested:

- Defining what kinds of factors, such as time, cost, quality and product performance, are critical to satisfying customers
- Mapping the cross-functional process used to deliver results
- Identifying the critical tasks and capabilities required to complete the process successfully
- Designing measures that track those tasks and capabilities.

(WEI-CHUNG LIU, 2000).

- **Measuring the operational performance for world-class competition:**

To measure the operational performance for world-class competition, what companies need is a process by which they can continually realign their strategies, actions, and measures, not just a new cost accounting system. Competitive environments vary widely between industries, within industries, and even within companies. Although what is considered to be valuable will differ in detail and the scope is based on the actual products and services wanted, today's customer demands on products are Quality, Price, Delivery, Products and Service. The transformation of traditional financially-based measures into the operation related measures suggested that basic customer requirements are: Quality, Delivery Lead Time, Delivery Reliability, Design Flexibility, Volume Flexibility, as well as Cost/Price.

Therefore, Performance measurements and systems also differ from plant to plant, depending on the focus, technology, and goals of each plant. Hence, performance measurements should not be applied across the board but should change as customer's requirements change, a new performance system should include at least some of the following characteristics:

They are directly related to the strategy.

- They primarily use non-financial measures.
- They may vary between locations.
- They change over time as needs change.
- They are simple and easy to use.
- Timely provide fast feedback to operators and managers.
- They are intended to foster improvement rather than just monitor.

(WEI-CHUNG LIU, 2000).

- **Equipment Management Performance Measurements:**

- Mean Time Between Failure (MTBF),
- Mean Time Between Repair (MTBR),
- Mean Time To Failure (MTTF),
- Mean Time To Repair (MTTR)

See (figure -2-4)

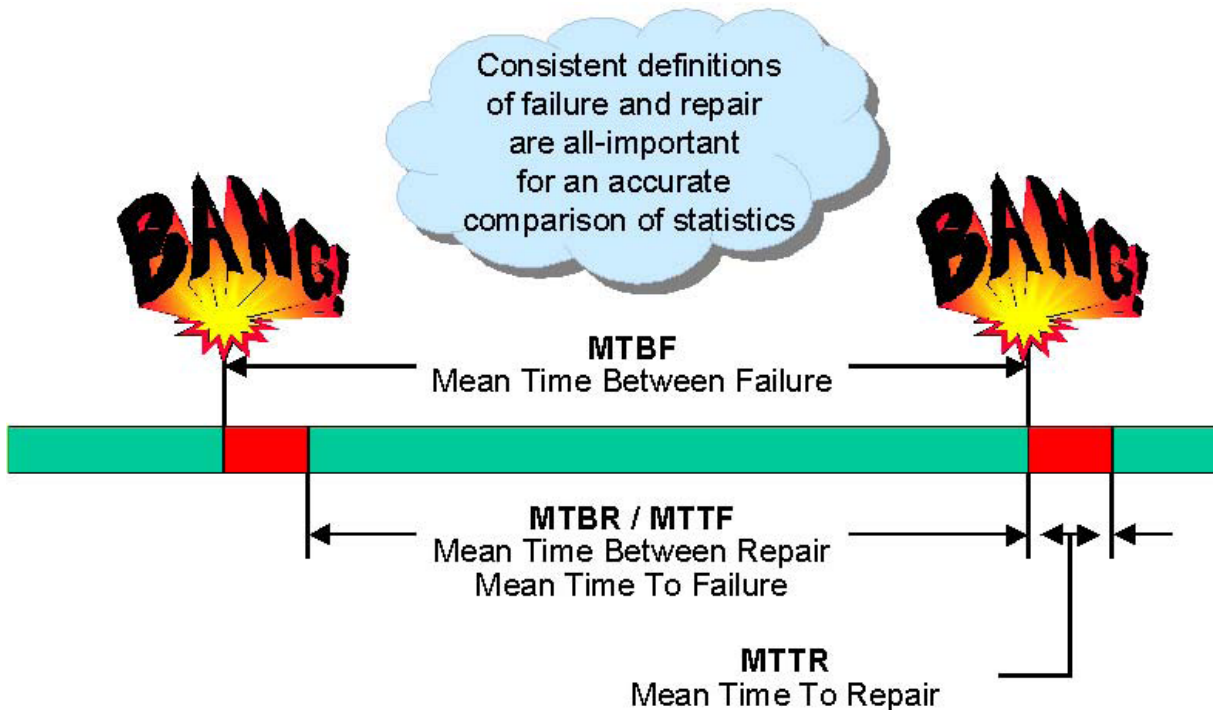


Figure-2-4: The relationship between equipment performance metrics.

2.3.2. Benchmarking, Benchmark Frameworks and Techniques

Benchmarking is the implementation of comparing the strategic requirements with pragmatic implemented results. Benchmarking is "the search for the best practices that will lead to extreme performance through the implementation of these practices" Also, benchmarking can be used as a goal-setting process, an aid in setting performance objectives to achieve performance improvements. The benchmarking process involves the systematic analysis and continuous efforts to compare the performance of an organization against the performance of the leaders in that field. With the comparison between the company and world class manufacturing companies or world-wide industrial standards, the strategy to win the business and implementation policies can be decided sequentially. The key to successful benchmarking always depends on what is to be benchmarked, and with whom it will be benchmarked. The decision on what to benchmark must be made with reference to what impact is made upon customer satisfaction and what functions are keys to the business strategy (WEI-CHUNG LIU, 2000).

- **Basic Benchmarking Process**

There are two types of benchmarking:

- Product benchmarking involves the process of reverse engineering whereby a firm acquires a superior product from another firm and breaks it down into its various components.
- Process benchmarking is an external, directed focus on an internal activity or operation in order to achieve continuous improvement.

The application of benchmarking in maintenance performance is close to process benchmarking, i. e. to select proper measures to be monitored and to analyze the gap between the practical performances with the strategic requirement. While there are two types of benchmarking, there are four ways of identifying process benchmarking partners:

- Benchmarking internal operations: To find the best-performing unit within own company.
- Benchmarking the competitors: This is rather difficult, because the competitor will not expose key information; however, the company can collect them from marketing information for reference.
- Best-in-class benchmarking: Learning how to improve certain activities by benchmarking processes of companies, i. e. to analyze the competitors the best they can with their own company.
- Strategic benchmarking: Identifying how a company should position its product in relation to its competitors, as well as suggesting what needs to be done to the processes or functions to support those competitive advantages. It is started with two additional stages: situation analysis and product feature analysis.

By identifying how superior companies organize their processes, a company can seek to adopt and adapt their practices. Benchmarking can be an effective tool for planning and implementing change processes that lead to organizational improvement when the knowledge gained is converted into a detailed action plan to improve the competitive advantage.

Benchmarking is used as a goal-setting process, an aid in setting performance objectives to achieve performance improvements. Companies who over-estimate their

competitiveness may become complacent, and thus delay adopting improvement programs and be overtaken by competitors whilst companies who are realistic will increase their chances of identifying the improvement areas which can have the most competitive leverage, and thus be able to compete on a more level playing-field (WEI-CHUNG LIU, 2000).

- **Benchmark Frameworks and Techniques**

Pioneered by Xerox, benchmarking has been widely adopted by companies as an improvement initiative. In an attempt to identify those areas where competitors had gained an advantage over themselves, Rank Xerox set out a ten steps benchmarking process, department by department, to compare their performance against their competitors. This comparative analysis extended from a comparison of technical features of equipment and cost data, through to a detailed examination of customer perceptions of quality and service. Some other models may be applied such as the Spendolini five-step process. In discussing the benchmarking failure, experienced benchmarkers most often blame poor selection of the process to benchmark. Determining which function to benchmark is the crucial stage in the beginning of benchmarking two stages and seven steps benchmarking model is proposed. Some of the current benchmark practices are introduced below.

- a. Balanced Scorecard Technique
- b. The SWOT analysis
- c. Gap Analysis and Polar Diagram Application

(WEI-CHUNG LIU, 2000).

- a. Balanced Scorecard Technique:**

The complexity of managing an organization today requires that managers be able to view performance in several areas simultaneously. The aim of a balanced scorecard is translating vision and strategy from four perspectives which allows managers to look at the business performance comprehensively they are:

- Having a customer perspective: How do customers see us? All businesses exist to satisfy customer requirements. In order to compete successfully, there is a need to start with the customer first. In addition, measurement has to be externally focused using external data such as service, quality, and cost.

- Having an internal and business perspective: What must we excel at? Building capability internally is essential to becoming competitive."
- Having an innovation and learning perspective: Can we continue to improve and create value? Modern competitiveness is based on fulfilling customer requirements through creativity and innovation. The consideration of people as the main asset is crucial and measurement of employee satisfaction and employee attitude is crucial. The challenge is to compete on a set of competencies which are capable of delivering future strategies.
- Having a financial perspective: How can we look to shareholders? Shareholders are another set of stakeholders and value added to shareholders has to be continuously monitored and measured.

(WEI-CHUNG LIU, 2000).

b. The SWOT analysis:

The aim of a SWOT analysis is to identify the extent to which the current strategy of an organization and its more specific strengths and weaknesses are relevant to, and capable of dealing with, the changes taking place in the business environment. Although what follows is somewhat crude as an analytical device, it has proved in practical applications to be a helpful means of achieving these aims. The procedure can be undertaken in typical steps as follows:

1. Identifying the current strategy or strategies that the company is following. This should be the realized strategy of the organization. This might be problematic due to management maybe not doing what the current strategy recommends but this assessment should be based on the true situation. The debate between the real situation and specific requirements is very important.
2. Identifying the key changes in the company's environment. While there is no fixed number which should be agreed upon, it is helpful to control the items on the list not to exceed seven or eight points (Johnson & Scholes, 1993).
3. Identifying the key capability (strengths) and key limitation (weaknesses) of the company.

The SWOT analysis is a simple generic analytical tool that examines the following aspects of the organization and manufacturing function (Hull, 1998):

- Strength: activities, systems, technologies, procedures, etc., which the manufacturing function performs well.
- Weaknesses: activities, systems, technologies, procedures, etc. which the manufacturing function does not perform to an accepted standard.
- Opportunities: activities, systems, technologies, procedures, events, potential events, etc., which the manufacturing function could exploit.
- Threats: activities, systems, technologies, procedures, events, potential events, etc., which may prevent the manufacturing function achieving its aims. The application of SWOT analysis in PFM provides a basis for the improvement of the current situation. A SWOT analysis provides a mechanism for systematically thinking through the extent to which the organization can cope with its environment. The key point is that the analysis requires an understanding of both the environment and the resource capabilities of the company.

(WEI-CHUNG LIU, 2000).

c. Gap Analysis and Polar Diagram Application

The Gap Analysis is one of the typical benchmark techniques and it becomes clearer with the combination of Polar Diagram application. A typical Polar Diagram is shown in (Figure-2-5).

The two types of benchmarking processes that Gap Analysis can be applied to are:

- Internal benchmarking: This compares the performance of an organization's internal activities (system's performance profile) and processes with the strategic objective (company requirement profile) to establish standards within the organization.
- External benchmarking (Competitive benchmarking): This involves the investigation of competitors (benchmarking profile), with the aim of identifying a company's current position (company requirement profile) compared to market or industry standards. The purpose of carrying out such a practice is to enable a company to compare their performance with the performance of competitors' in the same field.

The most important benefit of Gap Analysis is that it allows a company to see beyond its existing performance. As the company benchmarks other organizations, it will greatly improve the ability of seeing the solutions of the future to fit the problems of the

present. Gap Analysis combined with the application of Polar Diagram gives a clear deviation for the company to improve (WEI-CHUNG LIU, 2000).

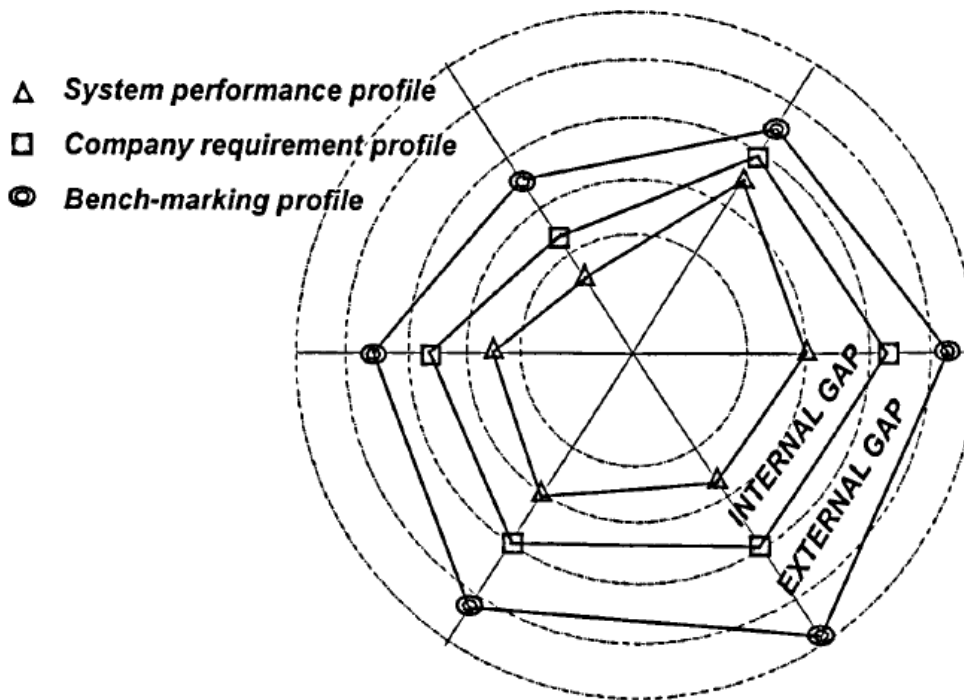


Figure-2-5: Polar Diagram for Gap Analysis

2.3.3. Self-Assessment Excellence Models.

Increasing global competition has resulted in firms knowing that quality improvement will result in a reasonable return on investment. This situation forces many firms to seek guidelines to implementing a continuous quality improvement program. Meanwhile, several national and regional quality self-assessment models have been developed so as to benchmark the performance of the implementation. Most of them are based on the concepts of Total Quality Management (TQM). The more popular ones amongst them are:

- a. The Deming Application Prize:
The Deming Prize is the oldest self-assessment framework and was developed in Japan in 1951. There are ten criteria used for assessing the Deming Prize application.
- b. The Malcolm Baldrige National Quality Award:

In 1987, the Malcolm Baldrige National Quality Award (MBNQA) was instituted in the United State.

c. European Quality Award (EQA).

The EQA was developed and introduced by the European Foundation for Quality Management (EFQM) in 1991.

(WEI-CHUNG LIU, 2000).

2.3.4. Maintenance Excellence frameworks:

The following are some of maintenance excellence models:

- d. Tompkins Scoreboard for Maintenance Excellence, see (Appendix-B)
- e. Army Award for Maintenance Excellence
- f. The Australian Maintenance Excellence Awards.
- g. Craig Roseneder Award for Technical & Maintenance Excellence in the Workshop.
- h. The North American Maintenance Excellence.

a. Tompkins Scoreboard for Maintenance Excellence

This is the chosen framework to make the self-assessment for the company under study. The most important thing in comparing with other models is that it contains detailed best practice and it is easy to measure and transform the collected qualitative data into numerical quantitative figures, besides its flexibility to suit different types of organizations.

To evaluate the company maintenance performance level and determine opportunities for improvement through developing a strategic maintenance plan based on a strategy of continuous improvement.

The Tompkins model is simply a monograph of a two-part, working document that includes:

1. The Maintenance Evaluation Guide evaluates 18 major functional areas in maintenance from A to R, provides evaluation criteria for assessing 200 improvement areas, and the total evaluation of maintenance operation provides the baseline for establishing priorities for action.
2. The Scoreboard for Maintenance Excellence provides the base for strategic maintenance plan. It serves as a means to highlight priorities, assign responsibilities, develop

schedules, monitor progress, and measure results. It can also be tailored by adding specific goals for each type of maintenance operation.

The model has a scale of 2000 points and divided into 5 levels according to the total number of points achieved as a result of the evaluation process.(Excellent, very Good, Good, Average, and below Average)

(See appendix-B)

2.4. Using Performance Information to Drive Improvement:

The following are some of the quality excellence tools which can be used to drive maintenance continuous improvement. These tools are explained in The Performance-Based Management Handbook by Diana Gee et al (Diana Gee, et al 2001)

2.4.1 Brainstorming:

Brainstorming is a technique for generating ideas. Ideas are thrown out, igniting more ideas. As thoughts begin to come together, innovative solutions are born. This tool is suggested to be used when investigating the problems that lead to an area for improvement.

Here are the steps to brainstorming:

- Assemble a group of five to seven people.
- Identify a problem to solve or a desired goal.
- Throw out as many ideas as possible relating to your purpose. Encourage a freewheeling, relaxed atmosphere. Consider all ideas; don't be judgmental.
- Record the team's progress on a flipchart, overhead, or whiteboard.
- When all thoughts have been exhausted, begin grouping similar ideas.

(Diana Gee, et al 2001)

2.4.2 Cause and Effect Diagram:

This diagram is described in The Performance-Based Management Handbook A cause and effect diagram (also called a fishbone diagram or Ishikawa diagram after the man who championed its use), is a brainstorming tool that guides in to organizing thoughts. The cause and effect diagram takes a consequence (the effect), and explores all possible causes. The diagram is a visual aid in helping flesh out ideas through branching, (figure-2-6).

Here are the steps to creating a cause and effect diagram:

- Determine the effect that the team is addressing. This effect could be either a problem you are trying to solve, or a goal you are trying to achieve.
- Put the effect in a box to the right-hand side of the paper, drawing an arrow from left to right pointing to the effect.
- Decide upon major categories around which to group your ideas. Typically, these categories include: people, materials, methods, equipment, and environment.
- Put the major categories in boxes and direct a branch arrow from each box to the main arrow. Brainstorm causes under each category, branching out from each idea. Categories of large clusters indicate problem areas.
- Remember that the goal is to cure the causes, not the symptoms. (Diana Gee, et al 2001)

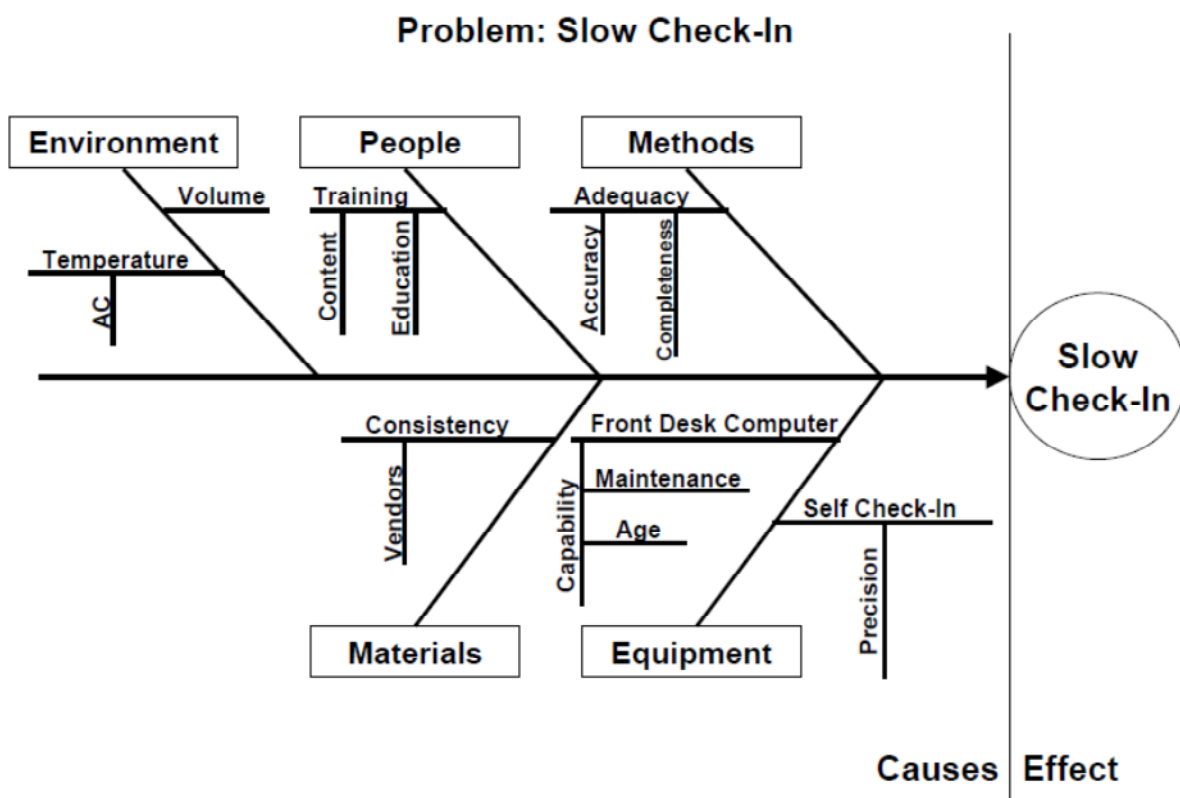


Figure-2-6: Cause and Effect diagram

2.4.3 Root Cause Analysis:

Root cause analysis breaks down a problem into component causes. The causes are evaluated as problems themselves to ensure that the root cause has been identified. Once the root cause is corrected, the problem shouldn't reoccur again.

Here are the steps to performing a root cause analysis:

- Clearly define the problem to be solved.

- Using either brainstorming or a cause and effect diagram, identify a list of possible causes.
- For each cause you have identified, ask, why is this a problem?” Continue to explore the causes until you get to the root. A general guideline is to ask, Why?” at least five times.
- Collect data to verify that you have identified the root cause.
- After implementing a solution, check back periodically to ensure that you stopped the problem at its root.

(Diana Gee, et al 2001)

2.4.4 PDCA Cycle:

The PDCA cycle is known as the Deming cycle, although it was developed by Dr. Shewhart. The cycle is about learning and on-going improvement, learning what works and what does not in a systematic way; and the cycle repeats; after one cycle is complete, another is started, (figure-1-7)

(Diana Gee, et al 2001)

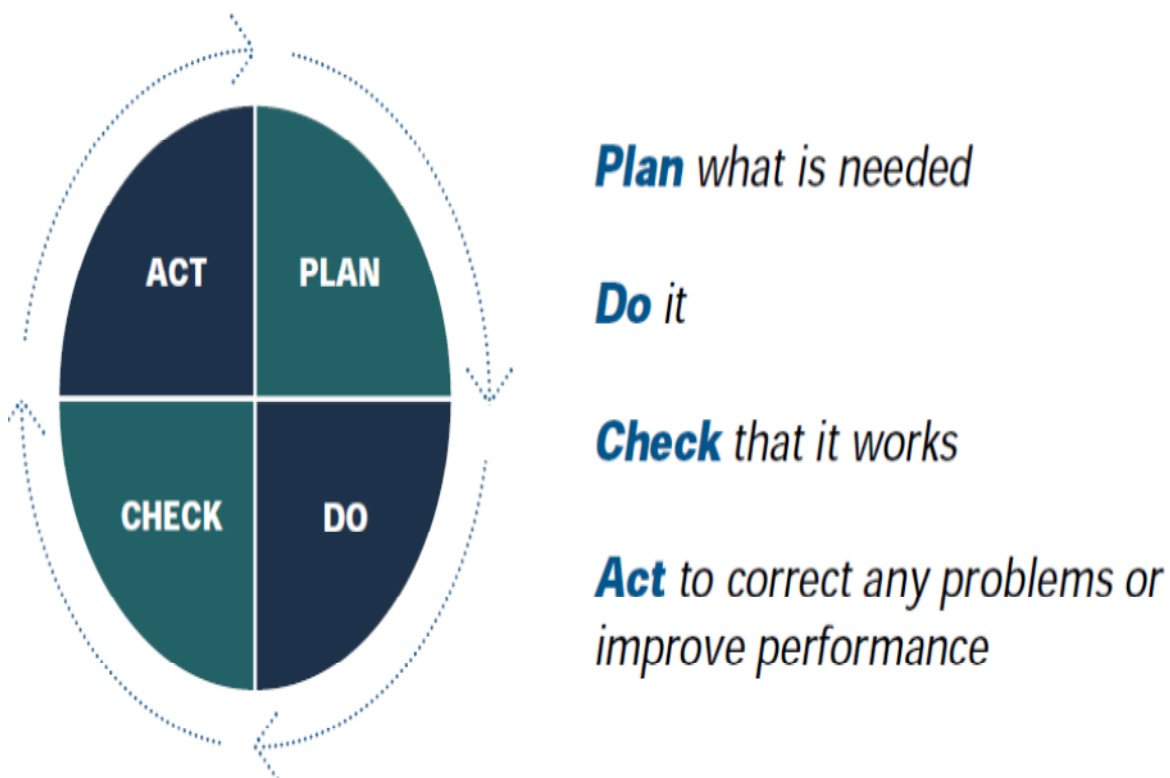


Figure-2.7: PDCA Cycle

2.4.5 DMAIC:

DMAIC is used for projects aimed at improving an existing business process, (figure-2-8). DMAIC has five phases:

- Define the problem, the voice of the customer, and the project goals, specifically.
- Measure key aspects of the current process and collect relevant data.
- Analyze the data to investigate and verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered. Seek out root cause of the defect under investigation.
- Improve or optimize the current process based upon data analysis using techniques such as design of experiments, Poka-Yoke or mistake proofing, and standard work to create a new, future state process. Set up pilot runs to establish process capability.
- Control the future state process to ensure that any deviations from target are corrected before they result in defects. Implement control systems such as statistical process control, production boards, visual workplaces, and continuously monitor the process.

(Diana Gee, et al 2001)

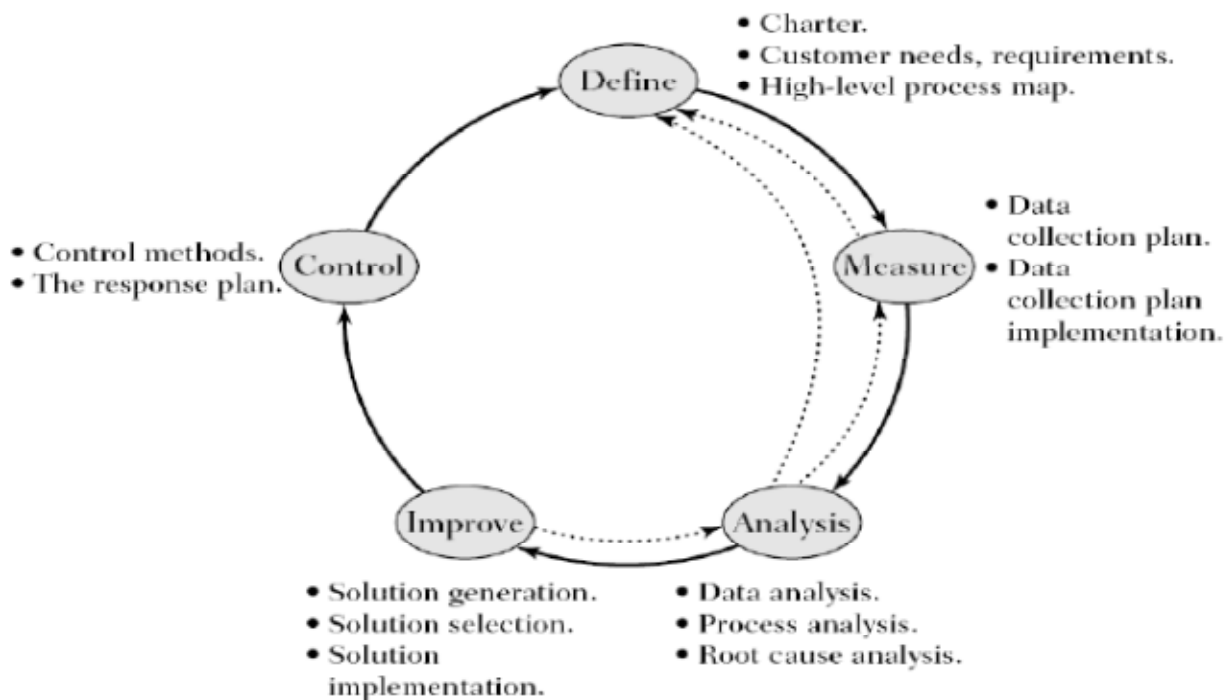


Figure-2-8: Basic DMAIC improvement methodology

Chapter 3 Materials and Methods

3. Research Methodology:

In this chapter the research is explaining research models and normative analysis besides characteristics of case study researches. The researcher depends on the work of Pentti Routio in his web page Arteology, the science of products and professions (**Pentti Routio, 2007**).

3.1. Research Models

3.1.1. The Scientific Models

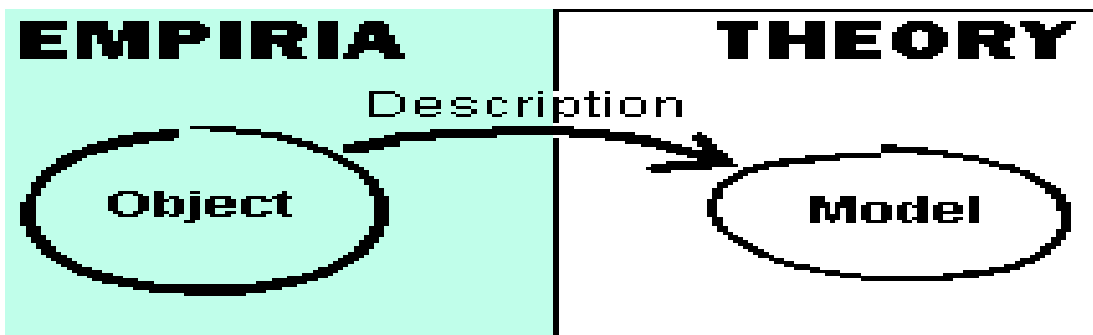


Figure-3-1: Research Model

The object of empirical study exists in the tangible world, or in empiria, as researchers call it. One of the first goals of most research projects is to create a theoretical picture of the empirical object of study into the conceptual world of thinking and theory. Scientists often use the name of model of this picture of the object of study, as can be seen in (Figure-3-1). In the initial phases of a research project, the model often exists only as an idea in the researcher's mind, but quite soon he will want to put it on paper or computer, too.

In a research project, two types of theoretical models are used: those that depict one empirical object (or other case of study), and those models that describe a population of more or less similar cases.

The first alternative, a case study focuses on only one object or occurrence, and the model is made to depict this object or phenomenon. As a contrast, in all other types of study there are quite a number of study objects that are more or less similar, and in this case the model should describe what is common to all (or at least to most) of the cases or objects in the population. The model is in this case said to be general.

The last mentioned goal of empirical study - constructing a single generalizable model on the basis of a number of empirical observations - can be difficult or impossible to attain completely. Today most scientists agree that it is not only practically but also logically impossible to write an absolutely reliable model on the basis of a class of empirical observations. It would almost never be possible to know all relevant cases that should be measured, or approach them; sometimes the number of cases would be so great that you can afford to study only a sample of them, and this sample can be biased; and finally all empirical observations can contain errors. In a word, it would never be possible to exclude totally the possibility that at least one case remains unnoticed that invalidates the general model and prevents calling it categorically "true".

While scientists thus today accept the fact that general models never can be absolutely reliable, these models are all the time being constructed and used in nearly all research projects. The reason is that even as imperfect they belong to the most indispensable tools of research. Besides, they are invaluable for transmitting the results of research to practical applications.

In a research project, a general model helps analyzing data obtained from the object and finding the answer to the researcher's problem. A scientific model need not enumerate all the properties of every object that is being studied. On the contrary, you will normally want to take into account only the "interesting" properties, i.e. those that are related to the purpose of your study. Restricting your view to just the essential measurements, attributes and properties of the object will help you to manage a large material and unearth the answers to your questions.

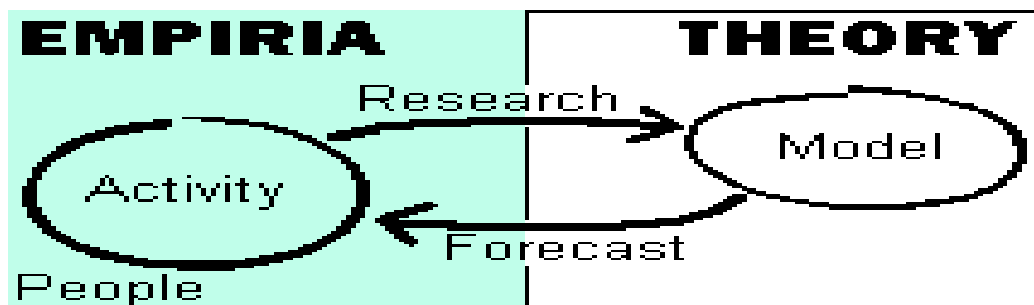


Figure-3-2: Research Model

Those patterns or characteristics which are common to several or all cases in the material of study - in other words, which are invariable from case to case - are often called invariances. As was already said above, there is no certainty that these patterns are true in other cases than those that have been studied. Nevertheless such a generalization has to be done always when

somebody wants to apply the findings of research into practice, for example for predicting the future development of the studied phenomenon (figure-3-2), or for the development of new products below, (figure-3-3). This is why almost all researchers are all the time boldly generalizing their empirical findings into general models.

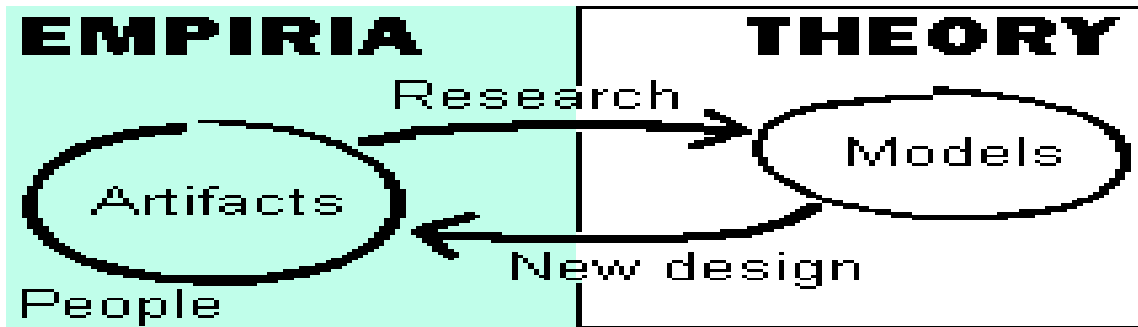


Figure-3-3: Research Model

The method of audacious generalizing works often quite well in practice, because as long as the present high activity of research persists, invalid generalizations will always be discovered and rectified sooner or later. Findings of descriptive (or "disinterested") research are today quite effectively tested, first in the internal peer critique in a field of research, and a second time when other researchers are using them as a basis of their own work. For the results and proposals of normative (or "applied") research, the final test arrives at once when somebody tries to apply them into practice. Results of this current practice of scientific self-correction have been commented by Popper as follows:

"Science does not rest upon rock-bottom. The bold structure of its theories rises, as it were, above a swamp. It is like a building erected on piles. The piles are driven down from above into the swamp, but not down to any natural or 'given' base; and when we cease our attempts to drive our piles into a deeper layer, it is not because we have reached firm ground. We simply stop when we are satisfied that they are firm enough to carry the structure, at least for the time being".

Because a model is made to be an image of the object of study, its indispensable material will be observations and measurements from the object of study. Sometimes - but not very often - no other material is available to help the researcher in constructing a model because very little or nothing is known about the object in advance. In such a situation of exploratory research one has to collect all the substance for the model by meticulously examining the objects. Often it will be laborious, because much material will have to be collected and in the beginning you do not quite well know which data are important and which are not.

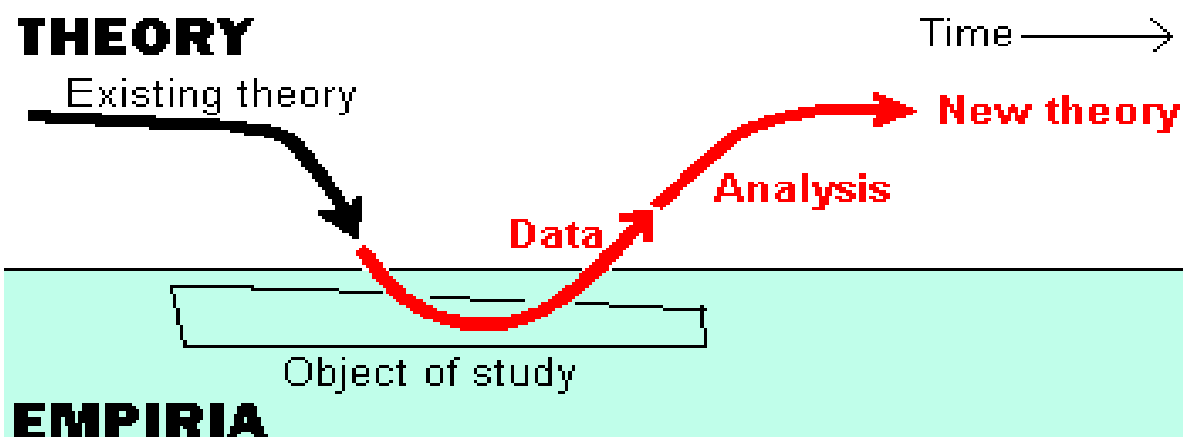


Figure-3-4: Research Model

Fortunately, today the normal situation at the outset of a novel research project is that one already know quite a lot about his object, and in the best case there are already published research reports where researcher can find models that have been used successfully by earlier researchers in the field. At least one will find vocabulary and instruments - such as concepts, definitions, and methods of measurement - for building a new variant of model that serves his purposes (figure-3-4)

(Pentti Routio, 2007)

3.1.2.Case Study:

Case study, sometimes called monograph, means studying only one event, process, person, organization unit or object. Such an approach would not seem to promote the general target of research - to unearth generally valid knowledge - but it can be motivated for various reasons, typically the following:

- The case is singular: only one such case exists, and it is important and worth studying. Typical such objects or phenomena are pivotal historical events, prominent men and women such as statesmen, great thinkers and artists, political and religious organizations, renowned works of art or of engineering. The purpose often is to document the case before information on it gets lost.
- The case is complicated, typically a person and her activity, and you want to study it thoroughly.
- The case belongs to a class of practically identical cases, such as industrial products of a given type and model. It would be useless to study more than one case, because all the findings from it can be generalized.

- Sometimes you would like to study a class of cases, but only one case is available for study. This can happen in archaeological study, when only one case of many has survived to our day. Similarly, many internal mechanisms of the brain have been discovered from unique cases where the brain of a patient has been injured in an accident.



Figure-3-5: Research Model

- Among the alternatives above, only C and D are able to produce generally valid knowledge. Types A and B only aim at describing a case, and they do not search universally valid knowledge. Nevertheless, it is always possible that some findings of a case study can also later be applicable to other cases which have not been studied, though this is usually difficult or impossible to assess in the framework of a single case study. In any case, anybody later reading the report of a case study can himself evaluate which findings he perhaps can apply to his own problems (figure-3-5).

What kind of knowledge you can expect to find with a case study? In the diagram above, the findings are characterized as 'description', but also other types of knowledge can be obtained with case studies. Usual targets in case studies are: **Describing** the object or phenomenon - not only its external appearance but also its internal structure, and perhaps also its earlier phases of development.

1. Explaining the reasons why the object is as it is, or its earlier development.
2. Predicting the future of the object.
3. Planning improvements to the object or to other similar objects, or gathering opinions about it, in other words a normative approach.

(Pentti Routio, 2007)

3.1.3. Normative Analysis:

Normative approach aims at finding out not only how things are, but above all how they should be, which means that it will be necessary to define the subjective point of view that shall be used, in other words to select the people who shall evaluate the proposals which aim at improving the object of study.

For the task of defining how the present state of things should be improved, there are several possible logical chains of reasoning that can be used. Three of them are delineated in (figure-3-6). Each of them uses a different starting point:

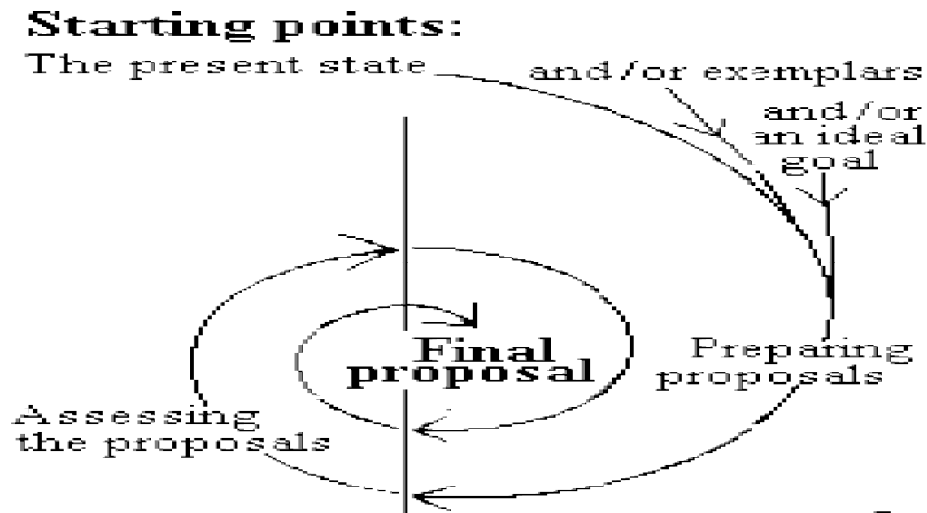


Figure-3-6: Research Model

- When the starting point is the present state of things, the process of analysis consists of describing it objectively and evaluating subjectively the need for developing it, which two things can often be made simultaneously. Finally, a proposal is made about how the existing problems or weaknesses can be corrected. If you use this approach, you can conserve the useful parts of the present state of things and replace only those parts that are unusable. This approach is often used when developing an activity of people, and also in product development when an existing product is available as a point of departure.
- It often happens that the sought-after state of things already exists elsewhere, at least partially, and your target will be to make it true in your local object of study by replicating its strong points in your own object. This could mean either modifying your original object of study, or creating a new, comparable but better object or process. In both cases it is possible to take this existing superior case, or **exemplar**, as a starting point in the normative analysis. This method is usual when developing a new product, where the

exemplars are often selected among the keenest competitors of your existing product. When developing a service or another existing activity, the exemplar could be taken from a known, skillfully arranged activity elsewhere. In this approach, the logical procedure does not much differ from the alternative "A", mentioned above. It is also possible to take more than one exemplar as starting points, and in this case the target becomes combining their best properties.

- A third often used alternative is to start the analysis from a description of an **ideal state** of things, which could perhaps be constructed on the basis of the subjective preferences of the interest groups. Starting points also include the known restrictions and goals for the activity, such as ecology or economy. This approach can be used, either when there is neither usable existing model nor exemplar on which you could base your proposals, or as a complement to the approaches "A" and "B". An example of this approach is the specification method of product development.

Any two or all three approaches can also be used in parallel in order to give a more reliable basis for the proposal.

In any case, the final stage of the normative process usually consists of an alternation of preparing detailed tentative proposals (often by professional designers or researchers) and evaluating these proposals, preferably by people from the interest groups or at least by simulating their points of view.

For the entire process of normative analysis nobody has yet found a reliable and generally applicable model, but quite often one or more of the following logical procedures are used in the process:

- Analyzing requirements
- Creating the proposal with the techniques of innovation, planning and design.
- Evaluating Normative Proposals.

(Pentti Routio, 2007)

3.2. Case Study Approaches

A case study is a story about how something exists within a real world context that is created by carefully examining an instance. It recounts real life situations that present individuals with a dilemma or uncertain outcome. The case describes the scenario in the context of the events, people and factors that influence it and enables students to identify closely with those involved. When multiple cases are examined then it is called a comparative case study.

A case study as a general approach to understanding phenomena can involve many specific methodologies such as interviews and direct observation. The art and science of creating case studies is known as the case method. Thus the case method is a set of specialized research and writing techniques designed to create rigorous case studies. It also refers to ways of teaching with case studies.

The case study method has long been accepted as an important method for training managers and administrators. It is a method of learning based on active participation and cooperative or democratic discussion of a situation faced by a group. The method of discussion also replicates the manner in which most decisions are taken in practice. It also involves replicating discussions with supervisors, peers or subordinates. If properly used, it has the power to improve the acquisition of knowledge, skills and attitudes.

Case study research excels at bringing us to an understanding of a complex issue or object and can extend experience or add strength to what is already known through previous research. Case studies emphasize detailed contextual analysis of a limited number of events or conditions and their relationships. Researchers have used the case study research method for many years across a variety of disciplines. Social scientists, in particular, have made wide use of this qualitative research method to examine contemporary real-life situations and provide the basis for the application of ideas and extension of methods. Researcher Robert K. Yin defines the case study research method as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used.

Critics of the case study method believe that the study of a small number of cases can offer no grounds for establishing reliability or generality of findings. Others feel that the intense exposure to study of the case biases the findings. Some dismiss case study research as useful only as an exploratory tool. Yet researchers continue to use the case study research method with success in carefully planned and crafted studies of real-life situations, issues, and problems. Reports on case studies from many disciplines are widely available in the literature.

Many well-known case study researchers such as Robert E. Stake, Helen Simons, and Robert K. Yin have written about case study research and suggested techniques for organizing and conducting the research successfully. This introduction to case study research draws upon their work and proposes six steps that should be used:

1. Determine and define the research questions

2. Select the cases and determine data gathering and analysis techniques
3. Prepare to collect the data
4. Collect data in the field
5. Evaluate and analyze the data
6. Prepare the report

(Susan Soy, 1997)

In normative study models used for describing the existing problems and defining the improvements to the object of study. If you can find an existing descriptive model of the object, made in an earlier study, you can often transform it into a normative model by adding an evaluative dimension to it. For example, the model of industrial production can be made normative by adding the dimension of profitability and a target for it.

Once the target for development has been defined with the help of a normative model, the project often continues as planning the practical operations, perhaps also realizing them and measuring the results. Sometimes the same model can be used as a basis of all these operations, but usually you will have to refine a model successively several times in the process of transforming a definition of goals into a plan of action or into a design of a product. The latter process, for example, can include such phrases as product concept, various drafts of design, a series of prototypes and finally a detailed proposal for the product. Optimally a normative research project proceeds through successive stages:

5. Evaluation of the initial state and defining the need for improvements
6. Analysis of relationships and possibilities to change things
7. Synthesis: proposal for improvement
8. Evaluation of the final state.

It is quite usual that you will have to repeat the above sequence several times before you get an acceptable result. Normative projects often deal with complex practical problems, and when making a theoretical model of the problem, the researcher may wish to make the model more easily manageable by simplifying it, i.e. by leaving out factors that seem nonessential. However, in the final practical test or appraisal it may turn out that an excluded factor is

important after all, which makes it necessary to adjust the model and repeat the sequence once more. (Pentti Routio, 2007)

Below are four dominant approaches to case methods:

3.2.1. Traditional Approach

This approach attempts to understand a subject through systematic gathering of empirical data. Emphasis is on ensuring that the research evidence is accurate and unbiased. As a result much of the case study report is spent describing and justifying the specific methodological decisions made and elaborating on detailed findings. It involves accurate observation and rigorous collection of evidence. Variants of this approach include:

- Illustrative Case Study: is a descriptive account of the main characteristics of a real world example to clarify an idea or reinforce an argument.
- Exploratory Case Study: Attempts to understand what happened within a case by looking beyond descriptive features and studying surround context.
- Explanatory Case Study: Attempts to explain why certain behaviors occurred by determining causes and effects.

3.2.2. Business School Approach

It emphasizes analyzing decisions and actions of managers and their consequences through using real world examples to better prepare students for on the job challenges. Variants include:

- Field Case Study: Involves the gathering of original research by gathering data within the context being studied. Usually involves direct observation and interviews.
- Literature Case Study: Developed by looking exclusively at already existing/published materials.
- Armchair Case Study: Explains a management idea by presenting a hypothetical scenario.

3.2.3. Learning History Approach

This method involves collectively reflecting on experience in order to draw constructive lessons. It analyzes actions, events, and episodes from multiple points of view in order to gain insights.

3.2.4. Best Practice Approach

This method emphasizes analyzing the worthwhile and replicable practices likely to improve the way an organization operates i.e. analyzing factors likely to contribute to success or failure. The primary aim is to identify techniques that can be replicated elsewhere. Variants of this method include:

- Implementation Case Study: Focuses on the change management aspects of putting a practice into effect within the workplace. Here the scrutiny is placed on each major stage of the process, not necessarily the long-term outcome.
- Success Case Study: Looks at those practices that have proven successful in terms of outcomes. Involves isolating success factors and likely causes of failure.
- Failure Case Study: Looks at situation where things went wrong with the intention of generating ideas about the practices that could have been implemented to prevent problems from happening or make recommendations for recovery.

(Commonwealth Association for Public Administration and Management, 2010)

Table-3-1: Summary of Case Study Typologies

Business School Case Studies	Best Practice Case Studies
Field Case Study: Gathering of original research. Usually involves direct observation and interviews.	Implementation Case Study: Focuses on the change management aspects of putting a practice into effect within the workplace. Focus is on major stages of the process, not necessarily the long-term outcome.
Literature Case Study: Developed by looking exclusively at already existing/published materials.	Success Case Study: Looks at those practices that have proven successful in terms of outcomes. Suggests methodologies where similar practices can be used in other areas of Public Administration.
Armchair Case Study: Explains a management idea by presenting a hypothetical scenario.	Failure Case Study: Looks at situation where things went wrong with the intention of identifying lessons learned.

Chapter 4 The Model

4.0. Proposed Research Model and Approach

The type of this paper is a qualitative study. The approach followed in this research is a normative case study

4.1. Proposed Model

Normative research aims at improvements, which means including evaluation of the present state of things and the direction of future development.

Normative research differs from descriptive studies because the target is not only to gather facts but also to point out in which respects the object of study can be improved. There are two styles of normative research:

4.1.1. General normative research

Figure-4-1 below produces theory of practice for a professional activity, such as design, which can consist of recommendations, rules, standards, algorithms, advices or other tools for improving the object of study. It does not necessarily include any practical operations of development.

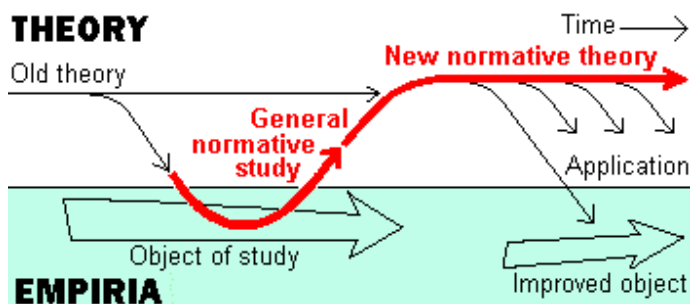


Figure 4-1: Research Model

4.1.2. Normative case study

Fig-4-2 below purports to find out methods to ameliorate physically the object, for example by reducing known human problems in the daily lives and work processes of people, by developing an activity or a new product.

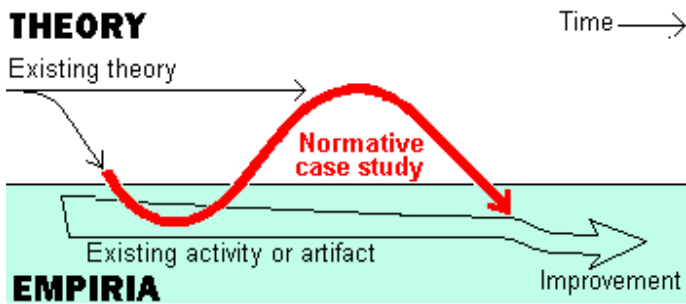


Figure 4-2: Research Model

4.2. Research Approach:

I will follow the four steps to quality according to Feigenbaum:

- Step 1 - Set quality standards.
- Step 2- Appraise conformances to standards.
- Step 3- Act when standards are not met.
- Step 4- Plan to make improvements

4.2.1. Self-Assessment:

The researcher will fill up the evaluation forms provided by the Maintenance Evaluation Guide from Tompkins Model (see Table-XX sample of evaluation form). To collect the necessary data about the company from the best practices perspectives. The data will be collected using the following methods:

- a. Making direct interviews with site operation and maintenance supervisors.
- b. Making phone calls with site operation and maintenance supervisors.
- c. Using the company (GNPOC) intranet and website and others.

4.2.2. Gap analysis:

The researcher will analyze this data to assess the gap between the company and the standard practices using the Maintenance Evaluation Guide and The Scoreboard for Maintenance Excellence. This will eventually show the current position of the company in terms of today's best maintenance practices, principles, and leadership philosophies. This will indicate the total points achieved out of 2000 points, and the correspondent performance level (Excellent, Very Good, Good, Average, and Below Average)

4.2.3. Improvement Implementation:

Then last steps are to use RADAR graph to show targeted develop priorities, to gain commitment to a strategic plan of action, and to begin the pursuit of maintenance excellence with a strategy of continuous maintenance improvement. Using a structured approach to implement improvements should help ensure the benefits are measured and used to assess the success of the project. The researcher suggests using the 5 steps of DMAIC Methodology:

- a. Define the improvement objective
- b. Measure the baseline position
- c. Analyze to identify the root cause and possible solutions
- d. Improve the process by implementing the identified solution
- e. Check the improvement has been effective

4.3. Company profile: Greater Nile Petroleum Operating Company (GNPOC)

In June 18, 1997, Greater Nile Petroleum Operating Company Limited (GNPOC) was incorporated to operate as a petroleum company in Sudan. GNPOC is a consortium comprising of CNPC of China (40%), PETRONAS of Malaysia (30%), Talisman of Canada-replaced later on by ONGC of India- (25%), and SUDAPET of Sudan (5%).

The company constructed a 28 inch 1500 km pipeline to transport the produced crude oil from the oil field at Heglig to the Marine Terminal at Portsudan (Maras Bashyer).

Geographically the company composed of Headquarter in “Khartoum”, Production fields at “Heglig” area in far south region, loading area at marine terminal “Bashyer” at the Red Sea, and the pipeline from “Heglig” to “Bashyer”.

The pipeline composed of six pumping stations and three metering stations. Each pump station plant composed of mainline pumps driven by diesel engines and electric power is provided from sets of diesel engines generators.

The pipeline offered transport of the crude oil produced from GNPOC fields and from two other companies and feeding two refineries El-Obied and Khartoum Refinery.

The maintenance section is divided into; mechanical and overhauls, electrical and instrumentation, SCADA, pipeline repair, and supporting equipment.

4.4. The Model implementation plan:

When processing the data and transform it into information using Excellence Scoreboard, this will provide a baseline of where the position of the company in terms of today's best maintenance practices.

Then setting the targeted level and developing priorities, to gain commitment to put a strategic plan of action, and to begin the pursuit of maintenance excellence with a strategy of continuous maintenance improvement.

The data collected by the researcher is from company local area intranet, phone calls, e-mails, and direct interview with company employees from both operation and maintenance sections.

1. Define the criteria to be measured. There are 18 different categories (criteria) proposed by Tompkins associate to measure performance see (table 4-1). These categories are divided into sections which is the questions to be answered as in the form in (table 4-1):

Table 4-1: Categories to be measured

Items	Category	Sections	Points
A.	Maintenance and Organization Culture	10	100
B.	Organization and Administration	12	120
C.	Work Authorization and Work Control	10	100
D.	Budget and Cost Control	11	110
E.	Maintenance Planning and Scheduling	12	120
F.	Maintenance Storeroom	16	160
G.	Preventive and Predictive Maintenance	22	220
H.	Lubrication Program	11	110
I.	Overall Equipment Effectiveness (OEE)	9	90
J.	Operator-Based Maintenance	8	80
K.	Engineering Support	9	90
L.	Safety, Housekeeping, and Regulatory Compliance	12	120
M.	Craft Skills Assessment	9	90
N.	Maintenance Performance Measurement	9	90
O.	Maintenance Supervision/Leadership	6	60
P.	Computerized Maintenance Management Systems (CMMS)	13	130
Q.	Maintenance Facilities, Equipment and Tools	7	70
R.	Continuous Maintenance Improvement	14	140
Total		200.00	2000.00

2. These categories are divided into sections which is the questions to be answered to get in term of percentage of degree of coverage as shown in the sample form in (table 4-2) for category (I) these applied in all of the 18 categories see Appendices-A:

Table 4-2: Sample of evaluation form

Goal Numb	Description of Maintenance Goal	Evaluation Criteria	Degree of Coverage (%)										Current Rating	
			No	10	20	30	40	50	60	70	80	90		100
I. OVERALL EQUIPMENT EFFECTIVENESS (OEE)														
1	Overall Equipment Effectiveness (OEE) ratings have been established for major equipment to provide a baseline measurement of equipment availability, performance, and quality.	OEE ratings are being established for what percentage of major equipment.	0	1	2	3	4	5	6	7	8	9	10	9
2	Priorities have been established with a plan of action for improving OEE.	YES –10, No-0	0	-	-	-	-	-	-	-	-	-	10	0
3	Equipment improvement teams have been established to focus on improving equipment effectiveness based on established priorities.	YES –10, No-0	0	-	-	-	-	-	-	-	-	-	10	0
4	Improvements in OEE are evaluated against base-line (OEE) measurements to determine progress.	YES –10, No-0	0	-	-	-	-	-	-	-	-	-	10	0
5	Documentation of all equipment conditions, factors, and settings that contribute to quality performance is available.	YES –10, No-0	0	-	-	-	-	-	-	-	-	-	10	0
6	Optimum machine speeds have been established and included in set-up procedures and operator training.	YES –10, No-0	0	-	-	-	-	-	-	-	-	-	10	10
7	All machine-related quality defects are aggressively evaluated and corrected.	Level of response and action to correct machine related defects: Excellent – 10, Very Good – 9, Good – 8, Average – 7, Below Average – 6, Poor – 5 or less.	0	1	2	3	4	5	6	7	8	9	10	8
8	Losses due to minor stoppages, idling, and minor equipment failures are addressed by operations and maintenance for corrections.	YES –10, No-0	0	-	-	-	-	-	-	-	-	-	10	10
9	Chronic equipment breakdowns and problems are aggressively investigated as to cause.	Level of response and action in determining the root cause of chronic breakdowns: Excellent – 10, Very Good – 9, Good – 8, Average – 7, Below Average – 6, Poor – 5 or less.	0	1	2	3	4	5	6	7	8	9	10	8
I. SUBTOTAL													45	

3. All of the 18 categories results are summed up to give a total number of points that indicate the coverage of the entire situation comparing to the model and answering the first research question where the company is and what is the level it should target to achieve the desired level.

4. Analyze the forms and get detailed lists of points of strength and areas for improvement for each of these 18 categories. This list is the starting points for improvement. Polar diagram or Radar graph used to show the gap.
5. Define the level to be targeted which is the level just above the current level as in the scale of general assessment see (table 4-3).

Table-4-3: General Assessment of Overall Current Rating

GENERAL ASSESSMENT OF OVERALL CURRENT RATING	
1800 to 2000 (90 - 100%)	Excellent: Practices and principles in place for achieving effective maintenance and world class performance based on actual results. Reconfirm overall maintenance performance measures. Maintain strategy of continuous maintenance improvement. Set higher standards for maintenance excellence and measure results.
1600 to 1799 (80 - 89%)	Very Good: Fine tune existing operation and current practices. Reassess progress on planned or ongoing improvement activities. Redefine priorities and renew commitment to continuous maintenance improvement.
1400 to 1599 (70 - 79%)	Good: Reassess priorities and reconfirm commitments at all levels to maintenance improvement. Evaluate maintenance practices and develop and implement plans for priority improvements. Ensure that measures to evaluate maintenance performance and results are in place. Initiate strategy of continuous maintenance improvement.
1200 to 1399 (60 - 69%)	Average: Conduct a complete assessment of the maintenance operation and current practices. Determine total costs/benefits of potential improvements. Develop and initiate strategy of continuous maintenance improvement.

<p>Less than 1200 (<60%)</p>	<p>Below Average: Same as for average, plus, depending on the level of the rating and major area that is below average, immediate attention may be needed to correct conditions having an adverse effect on life, health, safety, and regulatory compliance. Priority to key issues, major equipment or increasing costs that are having a direct impact on the immediate survival of the business.</p>
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6. Choose low performance categories for example those achieved lower than 60% of points for coverage.
7. List areas for improvement in in these lower performance level categories.
8. Make prioritizing of these categories to choose which one to start the improvement journey (Parito analysis can be used as a tool).
9. List area for improvement in order to transform them into point of strength.
10. Prioritize these lists to choose the first area for improvement (Parito analysis can be used as a tool).
11. Use brainstorming and cause and effect diagram to get the root cause of this low level of performance in this area.
12. Use DMAIC or PDCA Cycle for improving this area.
13. Report the area for improvement as a strength point.
14. Choose the next area for improvement in the same category and apply steps 10, 11, and 12 until completing the entire list in this category.
15. Choose the next category and apply steps from 7 to 14.
16. Make a new assessment by applying steps from 2 to 15.

Chapter 5 Results

5.0. Results:

- 1) Evaluation forms filled out and current rating is scored for each of the 18 sections as shown in Appendix-A, please see the sample form in (table 4-2).
- 2) The total points for each section is accumulated to give the total score point for the evaluated company in the scale. The company achieved 1045 points out of 2000 points which is 52.3% as in (table-5-1)
- 3) When compare the achieved total points with the scale in The General Assessment of Overall Current Rating (table-4-3), GNPOC falls in the below average level of the excellence practices , see (table 5-2) .
- 4) A polar diagram or Radar graph is provided to show the current situation to ease gap assessment and to make a reference point when measuring the improvement in the future, please see (figure-5-1).
- 5) A list of the 18 categories showing the main strength point and areas for improvement, please see (table 5-3).
- 6) A list of low grade categories- those achieved less than 60%- is shown in (table 5-4).
- 7) The next step is to prioritize these categories using Parito analysis or simply list them from lowest percentage category to higher as in (table 5-4), or by any other logical means.
- 8) Select the first category to start improvement journey in this case category (M).
- 9) Prioritize areas for improvement in this category using Parito analysis or simply list them as shown in (table 5-3).
- 10) Select the first area for improvement in selected category (M): There is no training needs assessment, no training plan and no skill development program for maintenance staff
- 11) Use brainstorming and cause and effect diagram to get the root cause of this low level of performance in this area.
- 12) Use DMAIC or PDCA Cycle for improving this area.
- 13) Report the area for improvement as a strength point and take it out from the list.
- 14) Choose the next area for improvement in the same category and apply the same steps until completing the entire list in this category.

15) Choose the next category which is category (N) and apply the same steps until completing the entire list of low performance level categories.

Make a new assessment to go to the next upper level of excellence.

Table-5-1: Evaluation Results of the Scoreboard for Maintenance Excellence Framework of (GNPOC):

SECTION	EVALUATION CATEGORY	EVALUATION ITEMS	CURRENT RATING POINTS BY SECTION	PERCENTAGE ACHIEVED FOR CATEGORY %	OVERALL PERCENTAGE ACHIEVED %
A.	Maintenance and Organization Culture	10	38	38.0	1.9
B.	Organization and Administration	12	79	65.8	4.0
C.	Work Authorization and Work Control	10	70	70.0	3.5
D.	Budget and Cost Control	11	61	55.5	3.1
E.	Maintenance Planning and Scheduling	12	86	71.7	4.3
F.	Maintenance Storeroom	16	121	75.6	6.1
G.	Preventive and Predictive Maintenance	22	77	35.0	3.9
H.	Lubrication Program	11	78	70.9	3.9
I.	Overall Equipment Effectiveness (OEE)	9	45	50.0	2.3
J.	Operator-Based Maintenance	8	39	48.8	2.0
K.	Engineering Support	9	49	54.4	2.5
L.	Safety, Housekeeping, and Regulatory Compliance	12	96	80.0	4.8
M.	Craft Skills Assessment	9	6	6.7	0.3
N.	Maintenance Performance Measurement	9	10	11.1	0.5
O.	Maintenance Supervision/Leadership	6	32	53.3	1.6
P.	Computerized Maintenance Management System	13	96	73.8	4.8
Q.	Maintenance Facilities, Equipment and Tools	7	46	65.7	2.3
R.	Continuous Maintenance Improvement	14	16	11.4	0.8
TOTAL EVALUATION POINTS			1045.00		52.3

Table-5-2: General Assessment of Overall Current Rating

GENERAL ASSESSMENT OF OVERALL CURRENT RATING	
1800 to 2000 (90 - 100%)	Excellent
1600 to 1799 (80 - 89%)	Very Good
1400 to 1599 (70 - 79%)	Good
1200 to 1399 (60 - 69%), This is the targeted level	Average
Less than 1200 (<60%), GNPOC: 1045 points= 52.3%	Below Average

Figure-5-1: RADAR graph or Polar diagram

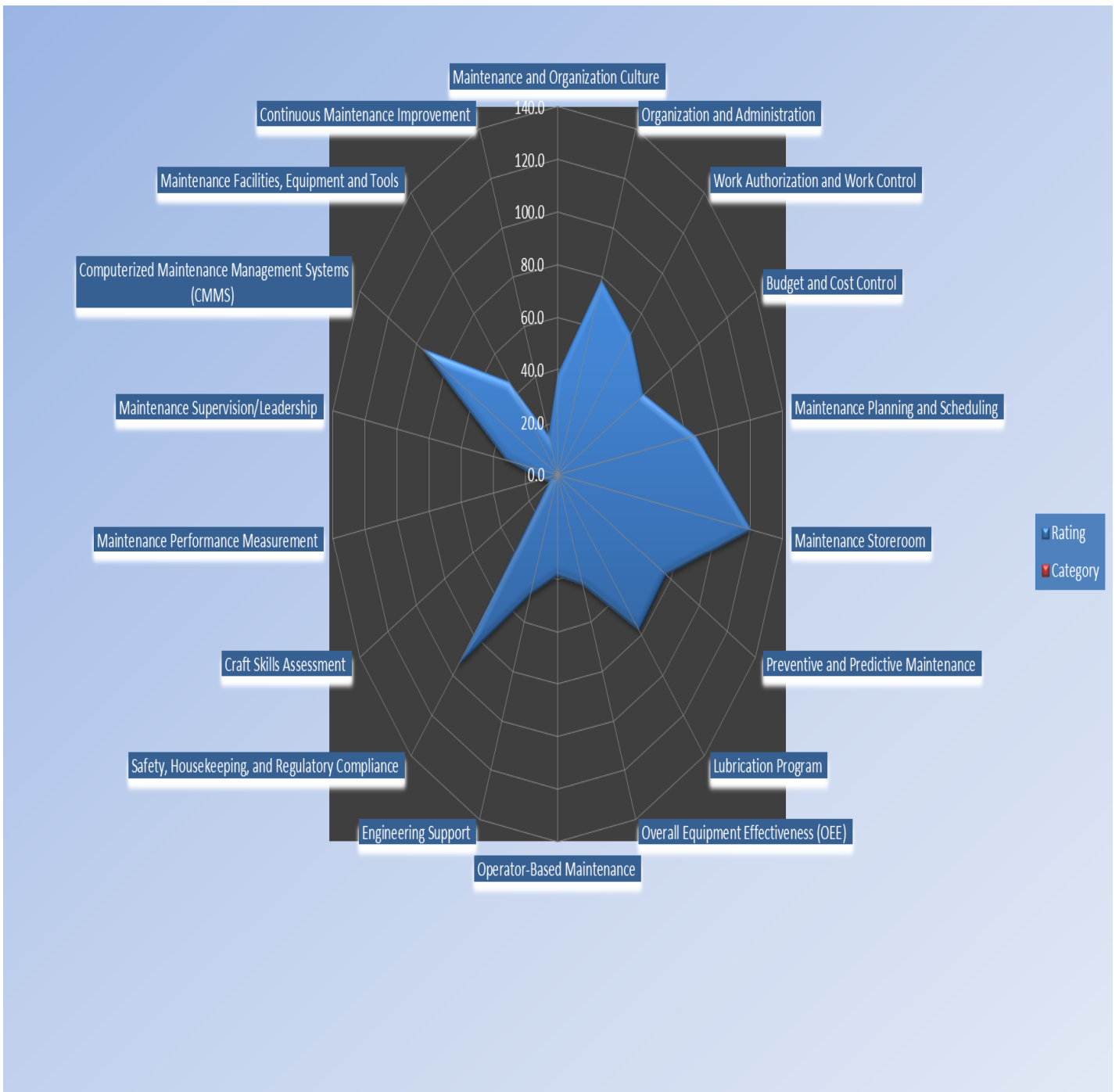


Table-5-3: Strength and area for improvement

Section	Strength	Area for Improvement
Maintenance and Organization Culture	Open communication facilities are available within maintenance and the overall organization to ensure inter-departmental cooperation, idea sharing and basic teamwork.	GNPOC does not include maintenance in its vision, mission, and requirements for success as a top priority and key goal.
		The company’s strategy is not known to all in maintenance and does not include a strategy for continuous improvement.
		No long-term commitments have been made to continuous maintenance improvement rather than short-term compromises
		Senior management has a limited contact with maintenance employees and not providing sufficient resources to support continuous maintenance improvement.
Organization and Administration	One single head of maintenance operations is supported by adequate clerical and technical staff. Daily, weekly, and monthly reports are available showing maintenance activities; corrective, preventive...	Maintenance section chart is incomplete and not revised periodically
		Employees are not provided with their job descriptions and not counseled periodically on job performance, job responsibilities, and skill

		development needs.
Work Authorization and Work Control	Work order forms, procedures, and responsibilities assignments are available	A formal maintenance planning function has been established and not staffed with qualified planners.
		The maintenance planner does not develop planning times for all work to be included on W.O. for each craft.
		Maintenance planner focuses on budget and cost control. Work planning carried out by supervisors
Budget and Cost Control	Maintenance expenditures are charged to work centers or operating departments and budget variances monitored to highlight problem areas.	The maintenance budget is based mainly on past budget levels rather than a realistic projection of actual needs.
		Labor and material costs are not estimated prior to the start of all repair work.
		The cost of downtime is not known for each piece of equipment to be used in determining priorities for repair.
		Major work order cost variances are not

		investigated and explained to person authorizing the work.
Maintenance Planning and Scheduling	<p>*A master plan for mainline engines overhaul is available indicating planned start date, duration, completion date, and type crafts required.</p> <p>*Planned repairs are completed in line with dates scheduled within ±15 percent.</p>	A formal maintenance planning function has been established and not staffed with qualified planners.
		The maintenance planner does not develop planning times for all work to be included on W.O. for each craft.
		Maintenance planner focuses on budget and cost control. Work planning carried out by supervisors
Maintenance Storeroom	An up-to-date storeroom catalogue is available and includes all stock items, storage locations, stock numbers, etc.	An operations assessment has not been conducted for the storeroom to provide overall evaluation of facilities, storage and handling equipment, staffing levels, inventory levels, systems, and procedures.
Preventive and Predictive Maintenance	Operations staff supports and agrees with the frequency and scope of the preventive maintenance (PM) program.	No routes for PM inspection no plan for PM inspection and no qualified inspectors.
		The PM program effectiveness is not measured.
		No plan developed for using current predictive maintenance (PdM) technology.

Lubrication Program	Allocated manpower carried out lubrication services at standard times according to equipment supplier guidelines.	Operators have not been trained to complete selected types of lubrication services as part of operator-based maintenance.
		There is no evaluation for compliance in meeting lubrication service schedules.
Overall Equipment Effectiveness (OEE)	Chronic equipment breakdowns and problems are aggressively investigated.	There is no Overall equipment effectiveness (OEE) improvement team or plan.
		Documentation and data are available but there is no analysis to improve OEE.
Operator-Based Maintenance	Operators have been trained to perform daily and periodic visual inspections on their equipment.	Operators have a limited maintenance skills and there is no intention or plan to implement operator-based maintenance
Engineering Support	Engineering coordinates material requisitioning with maintenance for project work, major overhauls, and machine building.	Engineering does not involve maintenance work during the design and specification stages to improve equipment reliability and maintainability.

		No obvious role for maintenance in purchasing new equipments or modification of existing ones.
Safety, Housekeeping, and Regulatory Compliance	Maintenance staff has a very good awareness of HSE and safe work practices.	There is no clear preventive maintenance program for lifting trucks and lifting tools.
Craft Skills Assessment	The company pay for training session and for trainees	There is no training needs assessment, no training plan and no skill development program for maintenance staff
		Craft skills types and levels required for an effective maintenance operation have not been identified.
Maintenance Performance Measurement	The company use Enterprise Resource Planning (ERP) to collect and process the data.	labor, equipment, performance and craft utilization are not measured although the availability of data
		The process for evaluating continuous maintenance improvements against past practice/ performance does not exist.
		There is no work sampling studies to evaluate maintenance performance
Maintenance Supervision/Leadership	Supervisor support safety and good housekeeping.	Lack of an effective supervisory development program to increase

		<p>leadership and technical skills.</p> <p>Supervisors have a limited support to creativity in their employees</p> <p>Supervisors consume much time in doing non-direct supervision activities.</p>
Computerized Maintenance Management Systems (CMMS)	Before purchasing the CMMS a study was carried out defining technical capabilities and financial justification.	<p>Selection of the CMMS and the supplier was not depended on clear criteria such as support service offered.</p> <p>The customization of the system for maintenance information system is just for store and work control.</p>
Maintenance Facilities, Equipment and Tools	The company provides maintenance with workshops equipped with tools and personal safety equipment.	<p>There is no clear procedure to control general and special tools</p> <p>Maintenance lack of awareness of new tools and equipment to improve methods and continually upgrades tools and equipment to increase craft safety and performance.</p>
Continuous Maintenance Improvement	The company has got the necessary resources to launch maintenance improvement program	The company failed to demonstrate any intention to apply maintenance improvement initiatives

Table-5-4: Lower grade sections:

SECTION	EVALUATION CATEGORY	EVALUATION ITEMS	CURRENT RATING POINTS BY SECTION	PERCENTAGE ACHIEVED FOR CATEGORY %	OVERALL PERCENTAGE ACHIEVED %
M.	Craft Skills Assessment	9	6	6.7	0.3
N.	Maintenance Performance Measurement	9	10	11.1	0.5
R.	Continuous Maintenance Improvement	14	16	11.4	0.8
G.	Preventive and Predictive Maintenance	22	77	35.0	3.9
A.	Maintenance and Organization Culture	10	38	38.0	1.9
J.	Operator-Based Maintenance	8	39	48.8	2.0
I.	Overall Equipment Effectiveness (OEE)	9	45	50.0	2.3
O.	Maintenance Supervision/Leadership	6	32	53.3	1.6
K.	Engineering Support	9	49	54.4	2.5
D.	Budget and Cost Control	11	61	55.5	3.1

Chapter 6

Discussions

6.0. Result Analysis:

- 1) The company achieved 1045 points out of 2000 points which is 52.3% that means GNOPC pipeline department maintenance level is BELOW AVERAGE.
- 2) The targeted near future improvement should be to raise the level in the scale to reach AVERAGE level (more than 60%), that is to achieve more than 1200 points as a target.
- 3) To reduce the gap between GNPOC current maintenance performance level and the targeted excellent level strength points should be reinforced and areas for improvement should be addressed agilely and seriously to sustain continuous improvement.
- 4) 10 out of the 18 sections achieved lower than 60% in their current rating in the scale. Eventually this will be the starting point for putting a strategic plan to reach maintenance excellence level.
- 5) In order to get the causes of weaknesses in aforementioned area for improvement, one or two of the following tools can be used: Brainstorming, Parito analysis, Cause and Effect Diagram, and Root Cause Analysis.
- 6) The last step is to deal with these causes by transforming them into points of strength. This can be achieved by using PDCA Cycle, or DMAIC methodology.

Chapter 7

Conclusions and Recommendations

7.0. Conclusion

- The future impact if maintenance in GNPOC continued to work in this below average level of performance is that plant reliability will decrease, downtime will increase, cost of maintenance will increase, equipment uptime will decrease, and eventually the unit transportation cost will increase leading to decrease in profitability of the business and lowering the financial return on asset investment
- The excellence way is the only way to lead Sudanese organizations to improve. Privilege of excellence culture among the leaders of the country and industrial sector can build strong strategies for sustainable progress.
- Top management commitment and understanding of the role of maintenance as a key success factor for their business is inevitable to increase profitability.
- The company should include maintenance continuous improvement in its strategies as a top priority.
- Maintenance data is available but the company needs to pay more attention to analyzed them and transforming them into knowledge to help decision maker to take decisions based on facts.
- Depending on performance measurement from one perspective cannot give the real performance level and accordingly this will be misleading and uncompleted facts.
- Due to the consortium structure of the company, top managers are in a continuous alteration according to their mother's company requirements. New-comer managers need awhile to understand the company and then to make initiatives for changes. But insufficient time to implement these initiatives will leads to immature execution or short term vision. The path to excellence and continuous improvement needs much time, high leader's commitment, and clear vision.
- The research shows that the gap is huge between maintenance practices and concepts in Sudan in general and the world around when taking into account that GNPOC as a pioneer oil company and one of leading companies in the country.
- The research is limited to maintenance section in the company but the results and improvement plan cannot take its desired effect unless management practices and activities in the company as whole are to be based on a common excellence culture.

7.1. Discussion against Research Objectives

- To make a brief understanding of maintenance.
- The research put a base for a broad understanding about maintenance; its definitions, importance to business, types, challenge, and new strategies.
- To develop a better understanding of maintenance excellence.
- The paper gradually built a coherent understanding about maintenance excellence from simple performance measurement indicator to generic management excellence models like Deming Prize and EFQM until reaching specialized excellence models for maintenance excellence.
- To explain how to get sustain maintenance performance improvement by using a maintenance excellence model.
- The research uses a simple approach to help the company to know its current maintenance performance level and then show the how to adopt world class best practices to reach excellent level in maintenance performance.

7.2. Strengths and Weaknesses of the Research

- The research could make a clear vision about the maintenance level in the company.
- The research lacks of the detailed financial outcome to draw the attention of part of stake holder but this can be a further study.
- The researcher uses simple quality tools.

7.3. Contribution to Knowledge

The research did not add something new but tried to link maintenance management practices to quality excellence. Besides gathering and arranging the available information to form an easy way to show how to do things like world class-companies do.

7.4. Limitations and constraints

- This research is conducted in the maintenance section in Pipeline division of GNPOC-Sudan. The data used is from the year 2011 and prior.
- Due to sanction against the country some valuable information resources could not be accessed as a result of country restricted or needs of electronic money.
- The assessment is conducted by one person from operational level of management.

- Although the language used by the model of excellence is simple and straight forward aiming the target, some managers found it difficult and full of terminology and need detailed explanation.
- There was an administrative difficulty in the process of research supervision and timing of defending the thesis that cause longer time for completion and as a result lots of changes happened in the ground for example there is a new version of Tompkins model and the Department of pipeline became a complete separated company called Petrolines.

7.5. Recommendations for future research.

- To implement this improvement model it should be held as a complete project and assigned a trained team to carry it out.
- To conduct detail improvement plans based on Lean six sigma methodology.
- To measure periodically the performance level after adoption of the maintenance excellence model to sustain improvement.
- To widen the contribution of the evaluation to include top and middle levels of management.
- The framework should include additional quality excellence sections to cover the relationship with partners, the process view of operations, nurturing creativity and innovation, and more about leadership roles.

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Appendices:

Appendix A: Assessment forms and results

**THE SCOREBOARD FOR MAINTENANCE EXCELLENCE
MAINTENANCE EVALUATION GUIDE**

Prepared by: Tompkins Associates

<http://www.tompkinsinc.com/>

Organization name: Greater Nile Petroleum Operating Company (GNPOC)

Evaluation Conducted By: *Issam Eldeen Adam Mohamed*

Date: From 1/9/2012 to 18/12/2012

Purpose: This maintenance evaluation guide is designed to support a total evaluation of your maintenance operation.

This guide will assist you in determining your “current rating” for each evaluation item on “The Scoreboard for Maintenance Excellence.”

Scope: A total of 18 major evaluation sections and 200 evaluation items are included.

They represent the key principles, best practices, and leadership philosophies that form the foundation for an effective maintenance operation.

Objective: To identify the current status of your maintenance operation and opportunities for improvement so that priorities can be established for a strategy of continuous maintenance improvement

Items	Category	Rating
A.	Maintenance and Organization Culture	
B.	Organization and Administration	
C.	Work Authorization and Work Control	
D.	Budget and Cost Control	
E.	Maintenance Planning and Scheduling	
F.	Maintenance Storeroom	
G.	Preventive and Predictive Maintenance	
H.	Lubrication Program	
I.	Overall Equipment Effectiveness (OEE)	
J.	Operator-Based Maintenance	
K.	Engineering Support	
L.	Safety, Housekeeping, and Regulatory Compliance	
M.	Craft Skills Assessment	
N.	Maintenance Performance Measurement	
O.	Maintenance Supervision/Leadership	
P.	Computerized Maintenance Management Systems (CMMS)	
Q.	Maintenance Facilities, Equipment and Tools	
R.	Continuous Maintenance Improvement	
Total		

THE SCOREBOARD FOR MAINTENANCE EXCELLENCE

