Benchmarking Maintenance Systems in Procter & Gamble

BY

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THESIS ABSTRACT

Name: Mohammad Akram Al-Zu'bi

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In this thesis, we have benchmarked maintenance practices and processes in Procter and Gamble plants in the region. This research has answered the question of how to improve maintenance practices and processes in a targeted plant via benchmarking. The thesis objectives have been achieved by benchmarking key maintenance factors, determined via using Analytic Hierarchy Process (AHP) methodology, out of standard maintenance factors that are available across the literature.

The study outcomes have focused on the results and improvements of an identified key maintenance factors, across benchmarked plants. This study also identifies key maintenance factors that need to be the focus of any effort, in order to improve the performance of the maintenance system.

We have concluded this research by identifying best plants, documenting key maintenance practices and processes and recommending key actions for each key maintenance factor, in order to improve maintenance systems.

This thesis has utilized benchmarking to come up with a set of recommendations to improve maintenance performance at the selected plant. Main recommendations were focusing on achieving best maintenance output measures through applying strong daily management system for planned maintenance, focus on productivity trainings as well as apply effective work process standards and incentive systems that were successfully applied in other benchmarked plants.

ملخّص الرسالة

الاسم: **مـحمـد أكـرم الزعـــبي**

عنوان الرسالة: **مقارنة أداء نظم الصيانة في بروكتر و غامبل**

التخصص: **هندسة النظم**

تاريخ التخّر ج: **مايو 2011**

قمنا في هذه الدراسة بمقارنة أداء أنظمة وتطبيقات الصيانة والعمليات في مصانع شركة بروكتر أند غامبل في المنطقة. لقد قام هذا البحث بدراسة كيفية تحسين وتطوير أنظمة وعمليات الصيانة في المصانع, من خلال مقارنة أداء مصانع شبيهة في المنطقة. منهجية هذه الدراسة كانت من خلال مقارنة أداء عوامل رئيسية للصيانة, حددت من خلال استخدام منهجية التسلسل الهرمي التحليلية, من عوامل الصيانة القياسية المتوافرة في الابحاث والرسائل العلمية المنشورة. كما قامت هذه الدراسة باختبار ما اذا كانت هذه العوامل قابلة للتطبيق أم لا, في المصانع التي أجري فيها هذا البحث.

ركزت نتائج هذه الدراسة على تحسين العوامل الرئيسية للصيانة التي سيتم تحديدها (مثل الصيانة المخططة وتخطيط الصيانة والمنظومة البشرية) ، في المصانع المختارة للمقارنة. هذه الدراسة تحدد أيضا أهم عوامل الصيانة التي يجب التركيز عليها, لتطوير أداء أنظمة الصيانة.

تم اختتام هذه الدراسة بتحديد أفضل المصانع, بالاضافة الى عمل توصيات لأهم الاجراءات التي يجب عملها في كل عناصر الصيانة المهمة, بهدف تطوير أنظمة الصيانة.

قامت هذه الدراسة باستخدام مقارنة الأداء لاستنتاج أهم الأقتراحات والتوصيات لتطوير أداء الصيانة في المصنع المختار. أهم التوصيات كانت مركزة على تحقيق أفضل نتائج مقاييس الصيانة من خلال تطبيق نظام عمل ادارة يومية للصيانة المخططة والتركيز على تدريبات تحسين الانتاجية بالاضافة إلى تطبيق مقاييس معيارية فعالة لطرق الأعمال و أنظمة الحوافز, التي طبقت بنجاح في المصانع التي أجري فيها هذا البحث.

CHAPTER 1

INTRODUCTION

In a very fast changing world, the importance of a solid and versatile maintenance management in the industrial world is becoming extremely important. More and more companies are realizing that to become best in class in this very competitive market: they need more than a reliable system to be in place. The responsiveness of such companies to global changes should be based on a very reliable, productive and effective system by having a very solid and rigorous maintenance program.

Procter and Gamble (P&G) is one of the oldest companies in manufacturing consumer products. Its diversity in many consumer based products has made its success through the years.

The benchmarking concept has been emerging in the last 40 years as a very important tool to educate the management and to improve their operations and product quality, market position and competitive advantage. Maintenance benchmarking is a need in Dammam P&G

plant, aiming to increase operations predictability to be able to cope with changing market trends and customers demand.

Although currently, Procter and Gamble (P&G) is one of the oldest companies in manufacturing consumer products, with plants distributed around the globe, yet, maintenance benchmarking was not systemically tackled to ensure that best maintenance practices can be easily applied leveraging the company scale.

This study used the tools of both benchmarking, as a standardized method for collecting and reporting data in a way that allows meaningful comparisons between different plants, and Analytic Hierarchy Process (AHP), which is a methodology to compare between different alternatives, to determine key maintenance factors.

The general objective of the thesis is to answer the question of how to improve maintenance systems in Procter and Gamble Dammam plant via benchmarking. This is achieved by accomplishing the following specific objectives: Identify five similar plants to benchmark with, select the maintenance factors to be benchmarked via using Analytic Hierarchy Process, complete the benchmarking study in the selected maintenance factors and finally identifying possible suggestions and improvements to the benchmarked plant.

The focus was kept to “internal Benchmarking” where an internal search for best practices look within the same organization is done. This research has thoroughly discussed benchmarking of maintenance systems; in terms of both maintenance processes and output measures across fabric and home care industry at Procter and Gamble.

This rest of the study is organized as follows; chapter 2 presents a brief background about maintenance systems and terminologies, as well as explaining benchmarking methodology. This is followed by a literature review of benchmarking and maintenance studies, as well as Analytical Hierarchy process (AHP) in chapter 3.

In chapter 4, AHP methodology was applied to identify key maintenance processes, among industry standard maintenance factors. This was followed by chapter 5 were the key processes were thoroughly discussed coupled with a comprehensive documentation of the best practices that was found across P&G, in those maintenance processes.

Plants review have followed in chapter 6, where key maintenance output measures among benchmarked plants have been gone through, coupled with observations that were collected during benchmarking visits. After that a survey was conducted, to identify key practices that were used by each plant in every maintenance factor, and included the outcomes in the benchmarking study results, in chapter 7.

This research was concluded by identifying best plants in each of the key maintenance factors, in addition to documenting key maintenance practices and processes among benchmarked plants in chapter 8, and finally, this was followed by the study conclusions in chapter 9.

CHAPTER 2

BACKGROUND

The main purpose of this chapter is to present a background about Procter and Gamble history and operations, maintenance, as well as thoroughly discussing benchmarking process and AHP methodology. This chapter flow will be as follows: in section 2.1, a background about Procter and Gamble operations will be presented; this will be followed by section 2.2 where maintenance definition will be discussed, philosophies and strategies and output measures. Section 2.3 will come next, where benchmarking definition is discussed, concepts and complete process documentation and finally in section 2.3, brief background about AHP and its methodology is presented.

2.1 Procter and Gamble Overview

Procter and Gamble is a multinational corporation that manufactures a wide range of consumer goods. As of 2008, P&G is the 6th largest corporation in the world by market capitalization and 14th largest US company by profit.

The company is divided into three global units: health and well being, beauty, and household care. Some of P&G's brands are billion-dollar sellers, including Fusion, Always/Whisper, Braun, Bounty, Charmin, Crest, Downy/Lenor, Gillette, Iams, Olay, Pampers, Pantene, Pringles, Tide, Ariel and Wella. Being the acquisitive type, with Clairol and Wella as notable conquests, P&G's biggest buy in company history was Gillette in late 2005.

The company history began when William Procter, a candle maker, and James Gamble, a soap maker, were immigrants from England and Ireland respectively, who had settled earlier in Cincinnati, formed the company initially. Their father-in law called a meeting in which he convinced his new sons-in-law to become business partners. In 1837, as a result of the suggestion, Procter and Gamble was born.

The company has started to manufacture brands and move into other countries, becoming an international corporation in 1930 after acquisition of Thomas Hedley Co. Numerous new products and brand names were introduced over time, and Procter and Gamble began branching out into new areas. The company introduced "Tide" laundry detergent in 1946. In 1955, Procter and Gamble began selling the first toothpaste to contain fluoride, known as

"Crest". Branching out once again in 1957, the company purchased Charmin Paper Mills and began manufacturing toilet paper and other paper products. Once again focusing on laundry, Procter and Gamble began making "Downy" fabric softener in 1960 , Ariel which was the first detergent introducing enzymes, in 1967 and "Bounce" fabric softener sheets in 1972. One of the most revolutionary products to come out on the market was the company's "Pampers", first test-marketed in 1961. Pampers simplified the diapering process.

Over the years, Procter and Gamble acquired a number of other companies that diversified its product line and increased profits significantly. These acquisitions included Folgers Coffee, Norwich Eaton Pharmaceuticals, Richardson-Vicks, Noxell, Shulton's Old Spice, Max Factor, and Iams Company, Clariol, Wella and Gillette.

2.2 Maintenance

In the below section, basic maintenance definition will be discussed, philosophies and strategies as defined and introduced by Duffuaa et al. [6]. The reason behind choosing this specific reference is that it is very much related to our research objective, provides applicable methodologies as well as it summarizes maintenance concepts that were discussed in the literature. The book defines maintenance as the combination of activities that is carried out on an asset or a machine in order to ensure that it continues to perform its designated functions. Maintenance consists of certain activities planned and implemented for achieving a pre-defined set of objectives and goals. The outcomes are wanted for further improvement actions and decisions.

The book also defines a maintenance system as “a collection of components that are working together to achieve a common objective”. Maintenance can be considerd as a system with set of activities carried out in parallel with production systems.

Production System primary objective is to maximize profits through converting inputs such as raw material and processes into products. An output is equipment failures or breakdowns which generates maintenance demand. This is an input for maintenance system, in addition to know how, labor and spare parts management, labor, tools, and equipment which forms maintenance system. From this, it can be seen that maintenance system role is to assist into achieving primary goals of production systems by minimizing breakdowns and downtime. In addition to that, it helps by improving finished product quality and improving productivity.

Output is the equipment which is reliable and available to achieve plant production demands. The activities needed to make this system running are planning, organizing and control. See figure 2.1 for a typical maintenance system – Duffuaa et al. [6].

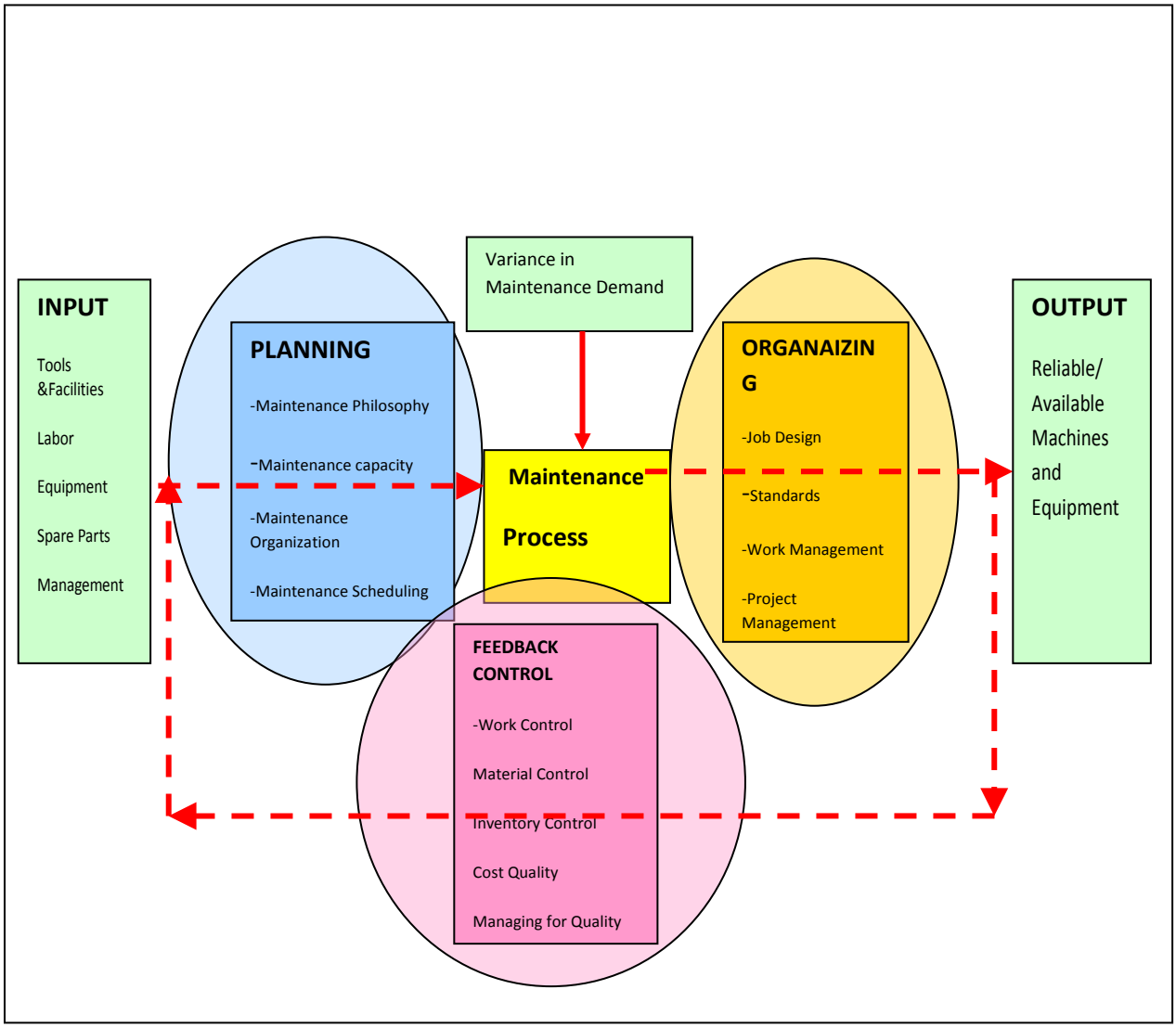

Figure 2. 1 **A Typical Maintenance System-** *Source: Duffuaa et al. [6]*

2.2.1 Maintenance Philosophies and Strategies

The maintenance philosophy of a plant is basically to maintain minimum level of maintenance staff that is consistent with production optimization and plant availability

without compromising safety. In order to achieve this, the maintenance program has the following basic maintenance strategies that can be applied:

Corrective or run to fail maintenance, preventive maintenance which can be divided into a- time based and b- condition based maintenance, opportunity Maintenance, fault Finding, design Modifications, Overhaul and finally Replacement maintenance

The run to fail strategy usually has the lowest investment yet the highest operating cost and the lowest availability. The predictive and proactive strategies generally require a large investment, have the lowest operating costs, and usually yield the highest equipment availability.

This section will include some definitions that are used in maintenance and will be used across our research. Maintenance in terms of practices and principles (such as Corrective Maintenance and Preventive Maintenance) will be briefly discussed, as well as this; benchmarking procedure will be introduced briefly showing its benefits.

2.2.2 Maintenance Practices and Terminologies:

Some of the most common maintenance practices used these days are:

Breakdown or corrective maintenance which is the type of maintenance only performed when the equipment is incapable of further operation. It is applied when other types of maintenance with extra cost cannot be justified. Sometimes, this is referred to as run to fail strategy, which is mostly used in electrical components.

Time –Use- Based Preventive Maintenance which is any planned maintenance performed to counteract any potential failures. This type of maintenance is performed on hours run or calendar basis. It needs high planning level in addition to knowing the specific job routines and frequency.

Condition Based preventive Maintenance which is a type of maintenance carried out on the basis of the known condition of the equipment. This condition is determined by monitoring key equipment parameters whose values are affected by equipment condition. This maintenance strategy is also known as predictive maintenance. CBM has the potential to greatly reduce costs by helping to avoid catastrophic and unpredicted failures as well as determining the intervals required for maintenance schedules.

One method for performing CBM is by using vibration analysis and measurements. The main objective is the detection of vibration characteristics which correspond to physical changes in the machine which indicate abnormal operation. An example of this is checking the vibration of a gear motor which could indicate failure. The primary challenge is to achieve a high degree of precision in classifying a machine's health given that its vibration characteristics will vary with many factors not all corresponding to defective components.

Opportunity Maintenance: carried out whenever opportunity arises. These opportunities could be used during shutdown periods, such as periods of no product demand (Holidays).

Fault Finding which is an act of inspection performed to assess failure level. An example of this is inspecting your equipment before running it.

Design Modification which is carried out to bring equipment to its desired acceptable conditions. It involves improvement and occasionally, manufacturing and expansion. Usually, this type of maintenance is carried out with involvement of engineering department within the organization.

Overhaul: a comprehensive examination and restoration of a piece of equipment or its major components to an acceptable condition.

Replacement; where replacing equipment is used instead of performing maintenance.

An important question that comes to mind: what is the difference between the above maintenance strategies and traditional maintenance?

The answer is that the above maintenance strategies have main differences from traditional maintenance programs, these differences are:

1-Extending equipment component life through redesign, re-specification, or improved maintenance practices,

2-Failure recurrence prevention,

3-Zero breakdowns,

4-Cost reduction through reducing mean time to repair activities,

5-Maintenance prevention on new equipment installations (maintenance free concepts),

6-Inventories based on equipment ranking, lead times for delivery of parts, planning process, and consolidation and standardization of parts,

7-Ranking equipment and components,

8-Driving daily maintenance to operating teams,

9-More integrated approach with storeroom, and finally

10- Efficiency improvement of maintenance systems.

2.2.3 Maintenance Measures

Now, certain measures that are used in maintenance are discussed. They are used as a tool to measure an organization performance in maintenance, each from its aspect. The measures are:

1. ***Availability*** for a system or equipment denotes the probability that the system or equipment can be used when needed. Alternatively, the term describes the fraction of the time that the service is available. The term unavailability is defined as the probability that a system or equipment is not available when needed, or as the fraction of the time service is not available.
2. ***Reliability*** is defined as the probability that the system or equipment will perform its intended function without failure over a given period of time.

Although the below reliability formula and measure is not a popular measure that would be found in the literature, the below formula has been used for the purpose of our benchmarking study; where the P&G uses this formula and measures its output across its plants.

$$\mathrm{R}eliability = \frac{\text{Net Production (units)}}{\text{Scheduled Time (min)} \times \text{Target Rate (units/min)}}$$

***Where**:*

-Net Production is the amount of product which will be sold. Net Production is the amount of product that is produced by the machine, excluding scrap and reworked/recycled product.

-Target Rate is the rate the line is scheduled to run on

-Scheduled Time includes all time the production system is scheduled, or running, or unable to run. Scheduled Time includes planned maintenance, changeovers, clean-ups, sanitization, start-up/shutdown, regulatory inspections, experimental orders or EOs (sellable production), training, meetings, lunches/breaks, utility outages, minor stops, breakdowns, process failures, blocked/starved conditions, natural disasters, lack of materials, and other losses. The "unable to run" condition excludes the line operating staff, so a line can be in Scheduled Time when it is unable to run, even though it is not staffed.

The above is a measure to understand how much product is manufactured and converted into sellable product (Net Production) during Scheduled Time at a set Target Rate.

To demonstrate calculation, consider a production line that is scheduled to run for 24 hours a day and produces 130000 units per day, with a target rate of 100 units/min. This line reliability calculation would be as follows:

$$Relaibity = \frac{130000\ units/day}{\left(60\frac{min}{hour} * 24\frac{hours}{day}\right) * 100\ units/min} = 0.903$$

This means that this line's reliability is 90.3%

3. **Mean *time between failures (MTBF)*** is the average expected time between failures.

This is the industry standard definition of MTBF which is also used in P&G.

$$MTBF_{Machine} = \frac{Total\ Machine\ Uptime}{Total\ Number\ of\ Failures}$$

4. ***Mean time to repair (MTTR)*** includes time required for failure detection, fault diagnosis, and actual repair.

$$MTTR_{Machine} = \frac{Total\ Machine\ Downtime}{Total\ Number\ of\ Failures}$$

As maintenance practices and measures have been introduced, this study will continue to introduce benchmarking, a term widely used by global and local institutes these days, not only in maintenance, but in any field.

2.3 Benchmarking

In this research, the approach of Andersen and Pettersen [1] is adopted for benchmarking maintenance best practices. This approach has been chosen as it is combines both

theoretical benchmarking steps mentioned in the literature, a hands on experience to benchmarking taken from actual examples as well as it is following a very common industry standard benchmarking steps of planning, searching, observing, analyzing and finally adapting.

Benchmarking can be simply defined as “the process of identifying, sharing and using the knowledge and best practices” [1] . Another definition for Benchmarking is “a performance measurement tool used in conjunction with improvement initiatives to measure comparative operating performance and identify Best Practice” [13].

Benchmarking benefits are: “Learn from who is better,” in terms of learning from an organization who had achieved excellence and cutting edge in what they do, “Identify priorities,” and “Improve performance” by finding new innovative ways for doing the same process in a different way.

Benchmarking was originally defined by the Xerox Corporation as “a management tool for monitoring and measuring its products, services, and practices against it competitors” in the late 1970s [18]. Since then, benchmarking has been widely adopted in many different industries, and a lot of publications have been issued in this area.

Benchmarking has been discussed thoroughly in the literature. A generic guideline for benchmarking was discussed by many researchers, such as Sole and Bist [12] and Terry Brueck and Riddle [2] .

Another definition for benchmarking is "A process of continuously measuring and comparing one's business process against comparable processes in leading organizations to obtain information that will help the organization identify and implement improvements" [18]

There are different types of benchmarking:[1]

Performance Benchmarking: Comparing performance measures for the purpose of how good one's own performance against others

Process Benchmarking: Comparison of methods and practices for performing business processes, for the purpose of learning from the best to improve one's own performance.

Strategic Benchmarking: Comparison of strategic choices made by other companies, for the purpose of collecting information to improve one's own strategic planning and positioning**.**

The comparison includes the following:

Internal: Studying a similar activity in a different location of the same organization.

Competitive or External: Studying a well-known competitor selling to the same product as your own. Competitive benchmarking shows you a different way of approaching the same operation.

Functional: Comparing processes and functions against non competitive companies within the same industry or technological area.

Generic: comparison of own processes against the best processes around, regardless of the industry.

Benchmarking Process:

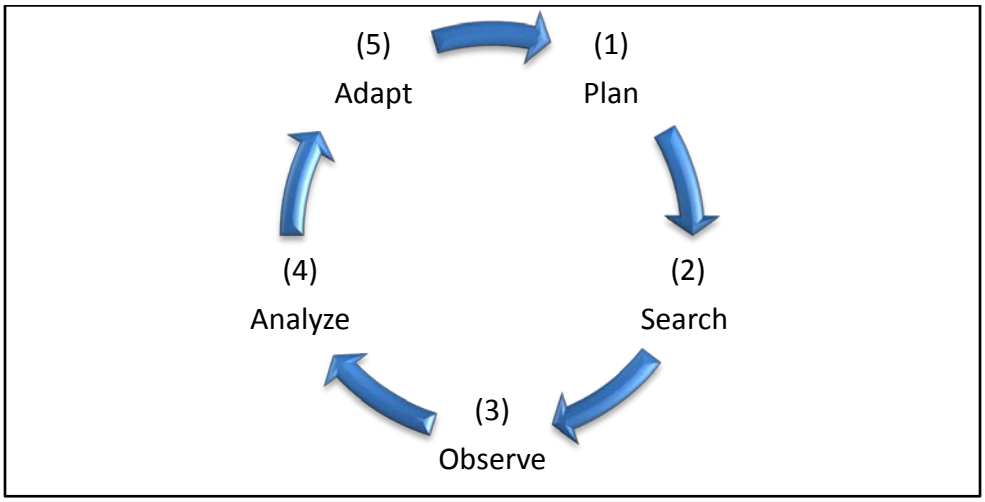

Figure 2. 2 A typical benchmarking Process Steps- *Source: Andersen and Petersen [1]*

Figure 2.2 above describes the typical benchmarking 5 steps, which are: planning, searching, observing, analyzing and finally adapting.

The planning phase includes roughly four activities:

1- Selection of the benchmarked process

2- Forming benchmarking team

3- Documenting and understanding of the benchmarked process

4- Establishment of performance measures of selected process

In this study, these steps are implemented as follows:

1- Selection of Benchmarked Process: The first step of the planning phase is to select the process the benchmarking study will focus on improving. The process selected in our research will be maintenance systems in Procter and Gamble. This process has been

selected based on the company's direction to choose Process Reliability as one of the key focus areas to be able to excel in this competitive market. This will include critical measures that were discussed previously.

2- Forming a Benchmarking Team: the team that has been developed for this research consists of maintenance experts representing their plants in the region: they are basically plant maintenance pillar leaders in: Dammam (Saudi Arabia), Cairo (Egypt), Gebze (turkey), Rakona (Czech Republic) and Pomezia (Italy). This team activity will be sponsored by Dammam business owner which happens to be the supply chain manager.

3- Document the Process: Figure 2.3 shows the relation between operations, maintenance and planning: where planning creates Process Orders (PO) for operations, to implement the production plan, as per specified quantities from specified production units or brands. This, of course, is based on the marketing and sales forecast. Clearly**:** Marketing and sales are customers for planning, planning is customer for operations, and operation is customer for maintenance.

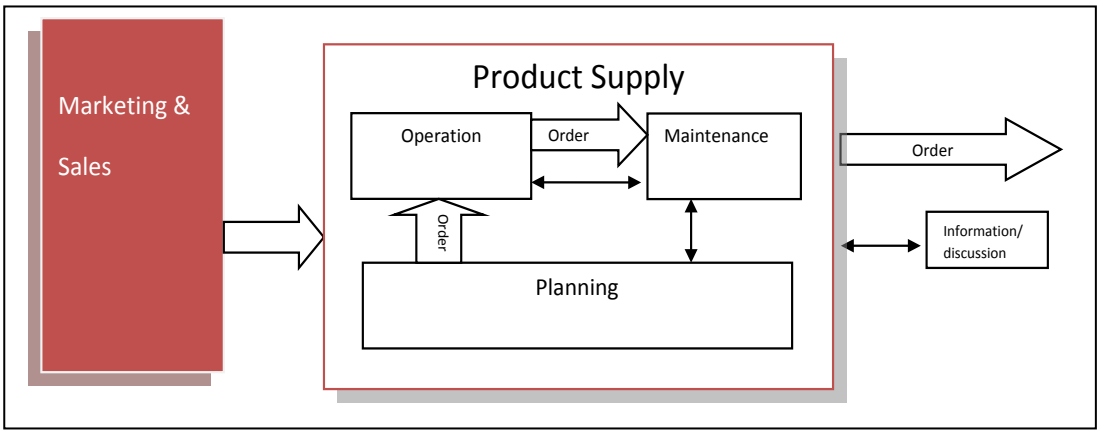

Figure 2. 3 Maintenance map in today's supply chain

So basically, in order to do a maintenance job: maintenance planner has to prepare a maintenance plan; this plan is revised with operations that, in their turn, revise this plan and align it with planning. Planning reflects these maintenance activities in their resources and recipes form, to ensure that their plan will allow for maintenance jobs to be executed. This is reflected in planning capacity sheets, which reflects the maximum capacity of production that can be got from each production line.

4- Establish Measures: here, the levels of performance in the agreed maintenance factors (or systems) would be determined and compared those to other P&G plants in the region.

The systems that will be benchmarked will be the maintenance factors (see [6]) identified by the selected five plants in the region. These key maintenance factors will be identified through a systemic method, the (AHP) and will be thoroughly discussed later in this research.

Completing the above activities in the planning phase including establishing the measures, the team felt that they had completed the planning phase satisfactorily, having gained thorough knowledge about the process.

The search phase consists of four main steps:

1- Design a list of criteria an ideal benchmarking partner should satisfy

2- Search for potential benchmark partners

3- Compare the candidates and select benchmarking partners

4- Establish contact with the selected benchmarking partner and gain acceptance for participation in the benchmarking study

These steps are implemented as follows:

1- List of criteria: The first step of the searching phase is to express the requirements an ideal benchmarking partner should satisfy such as industry, technology and products. In our study our partner is our worldwide selected sister plants working in packing dry laundry industry, volumetric filling technology and with medium size carton products (i.e. 200-500g). These criteria have been met in all participating plants in the region.

2- Identify partners: which are sources for information that can lead to high performance organizations; which are in our case sister PandG plants in the region working in fabric and homecare industries.

3- Select Benchmarking Partners: here Dammam, Cairo, Gebze, Rakona and Pomezia plants have been selected to be benchmarking partners. This has been aligned through leadership across these plants with fixed monthly meeting to discuss the progress and agreeing on next steps.

4- Establishing contact and gain acceptance: maintenance benchmarking study has been shared with prospective plants via email/phone. As mentioned above, the benchmarking objectives have been shared with a monthly time frame conference call.

The observe phase consists of three steps:

1- Assess information needs and sources

2- Select method and tool for information and data collection, and

3- Execute information collection and assess

These steps are implemented as follows:

1- Assess information needs and sources: in this step the ability to utilize information for own improvement is needed, where information is gathered in three different levels: performance level (comparing our partner to ourselves), practice (which makes it possible to reach this performance level) and key enablers (which enables using this practice for executing the process).

Some of the key enablers that have been studied are training, organization and staffing and support systems. This has been extensively demonstrated via attached questionnaire (see appendix A2). Practices have been noticed via daily management systems that are implemented in the participating plants.

2- Selecting method and tool for information and data collection: Methods are the means of establishing contact with benchmarking partners and tools are techniques that can be used within one or more of the methods.

In our study, our methods will be: Partner visits to plants in the region and monthly teleconference calls and our tools will be the developed questionnaire, interviews with maintenance experts and direct observations.

3- Execution: in this step, it is needed to ensure that the observation phase is properly executed. This is ensured via proper data collection of detailed information rather than having general information.

The Analyze phase consists of four steps:

1- Sort collected information and data

2- Quality controlling of information and data

3- Normalizing data

4- Identifying gaps and causes of these gaps

These steps are implemented as follows:

1- Sort collected information and data: After completing our data collection (survey) in the observe phase; data analysis and sorting will be performed in order to extract relevant data needed, where the key processes for benchmarking purpose are identified.

2- Quality controlling information and data: in this step a search for any "abnormality" that could be from misinterpreted data or information lacking is performed. Throughout this study the team has checked the reported benchmarking data ensuring data accuracy and consistency, there were no noted discrepancies.

3- Normalizing Data: in this step it is ensured to compare similar systems/processes or "apple to apple", rather than having a look at the final results. This helps to correctly identify gaps ensuring setting realistic and achievable improvement targets.

4- Identifying Gaps and causes of these gaps: via comparing systems for our own and selected plants, will give the ability to identify gaps and opportunities. After this, benchmarking systems and processes will be performed, followed by identifying direct and root causes of these gaps.

The Adapt phase consists of four steps:

1- Identify improvement opportunities based on identified benchmark performance

2- Set improvement targets

3- Develop an implementation plan and implement improvements

4- Write a final report from the benchmarking study

These steps are implemented as follows:

1- **Identify improvement opportunities based on identified benchmark:** in this step, a look in the root causes is developed via using root cause analysis for the gap between own performance and benchmarking plants performance. Main task is to translate best practice (benchmark) into improvement opportunity for own organization.

2- **Set improvement targets:** Targets should be: challenging, realistic and operative. Targets should not de-motivate the organization and should be understandable. In the same time targets should require real efforts to be reached.

3- **Implementation:** In this step, organizing implementation steps should happen, communicate the implementation steps to all participating plants and gain alignment and acceptance and develop a target action plan.

4- **Final report submission:** including all the data, analysis and documentation

2.4 Analytical Hierarchy Process (AHP)

AHP provides a proven, effective means to deal with complex decision making and can assist with identifying and weighting selection criteria, analyzing the data collected for the criteria and expediting the decision making process.

Saaty has described the analytic hierarchy process (AHP) as a decision making approach based on the "natural human ability to make sound judgments about small problems" [19] Desirable characteristics of such an approach include simplicity, usefulness, compromise, and consensus building, and without discrimination toward specialized skills or knowledge. Saaty, who has developed this methodology in the mid 1970's, suggested AHP as a process that requires structuring the decision problem to demonstrate key elements and relationships that brings out judgments reflecting feelings or emotions, and whose

judgments can be represented by meaningful numbers having ratio properties. These numerical representatives can be used to generate weights or priorities that represent the relative importance of decision criteria.

Finally, alternatives can be compared to some absolute standard, or to each other such that the comparison results and the criteria priorities can be produced.

The structure of AHP consists of a hierarchy of criteria and sub-criteria cascading from the decision objective or goal. By making comparisons at each level of the hierarchy, participants can develop relative weights, called priorities, to differentiate the importance of the criteria. The scale recommended by Saaty was 1 to 9, with 1 meaning no difference in importance of one criterion in relation to the other and 9 meaning one criterion is extremely more important than the other, with increasing degrees of importance in between.

AHP helps capture both subjective and objective evaluation measures, providing a useful mechanism for checking the consistency of the evaluation measures and alternatives suggested by the team thus reducing bias in decision making. Combined with meeting automation, organizations can minimize common pitfalls of team decision making process, such as lack of focus, planning, participation or ownership, which ultimately are costly distractions that can prevent teams from making the right choice.

CHAPTER 3

LITURETURE REVIEW

In this chapter, our objective will be to review and document some research and studies that have been found in the literature, which are related to both maintenance and benchmarking fields.

Benchmarking concepts has been discussed in details; types of benchmarking and benchmarking methodology have been also tackled; Fridley et al. [8] have explained benchmarking in their research, where they have shown an inside look of benchmarking process phases: starting with planning phase, moving to analysis phase, then to integration phase and finally into implementation phase, showing actionable steps suitable for manufacturing companies.

Wireman [17] has discussed Benchmarking Best Practices in Maintenance Management were benchmarking process in maintenance has been generally discussed. He has also assured that benchmarking should happen only in mature organizations were basic

competencies in core operations have been achieved, focusing on benchmarking should concentrate on true partnership to gain mutual benefits rather than copying what others did without sharing the learning.

Sole and Best [12] have discussed process benchmarking, and have provided an approach and a guide line to prepare for the benchmarking process, enabling organizations to improve bottom line results.

They have suggested the following steps to reach to significant process improvements and a world-class organizations operation:

1- Choose a specific, limited domain for your benchmark,

2- Establish a benchmarking team,

3- Select a benchmarking partner,

4- Initiate the benchmark, and

5- Make a site visit and finally 6- write a report and act on it.

In “Enhancement of maintenance management through benchmarking” Yam et al. [18], have presented a case on benchmarking for maintenance management in a power plant. They have implemented five steps in their benchmarking study:

1- Identify key performance variables for the benchmarking study,

2- Select good information sources of data,

3- Collect and measure maintenance data,

4- Analyze the maintenance data against top performing plants and finally,

5- Change and improve maintenance performance.

The authors have touched on certain maintenance systems they believed were important in a benchmarked plant, such as maintenance performance, maintenance approaches and strategies in addition to productivity and work order systems. They have concluded that the benchmarked power plant has been excessively using conventional preventive maintenance approach, resulting in excessive maintenance costs. They have recommended increasing predictive maintenance action which could help plants to avoid the accumulation of equipment problems causing major breakdowns. This will also help to reduce the quantity and value of spare parts required for emergency repairs.

Maintenance on the other hand, has been discussed extensively in the literature. Improving maintenance measures has also been a considerable research item in the past few years. In Vasinys et al. [15] research, key maintenance performance in nuclear industry in Europe has been discussed for the purpose of benchmarking.

Rosqvist et al. [10], has emphasized on value driven maintenance planning to support continuous improvement to maintenance performance and effectiveness as well as plant maintenance benchmarking within the industry. Maintenance performance indicators have been discussed as well. Waeyenbergh and Pintelon [16], presented maintenance concept development and implementation, and provided some tactical guidelines for proper maintenance policy selections.

In their book, Duffuaa et al. [6] have thoroughly discussed maintenance systems and methodologies. They have explained and defined maintenance strategies and philosophies used, enabling maintenance engineers/managers to model and simplify their daily problems by using prescribed models. The book also suggests a maintenance audit with the objective of continuous improvement of maintenance systems in companies/plants. The audit suggests 14 maintenance factors that heavily influence maintenance productivity and results, which will be used and discussed thoroughly in this research.

Some strategic aspects of maintenance management such as maintenance methodologies, culture and support as well as three maintenance strategies (predictive, preventive and corrective) has been presented by Eti et al. [7]. They have concluded that industries should sustain full production capabilities while minimizing investment. This means maximizing equipment reliability, thorough applying the three main maintenance strategies. They have identified the following necessary factors for effective maintenance: organizational design, maintenance methodology, adequate support systems, corporate culture and general management.

Cholasuke et al. [3] have analyzed current pressures of productivity enhancement, maximizing equipment effectiveness and having a solid maintenance program in UK manufacturing organizations. The authors have prepared a pilot survey and have discussed opportunities for improving maintenance management in these organizations. The survey was focusing on nine factors with 28 variables that contribute to effective maintenance, starting from policy deployment and organization up to continuous improvement.

Other maintenance performance measures such as reliability have been discussed by Zio [20] where the reliability concept evolution throughout the years in addition to interaction between reliability, maintenance and organization has been discussed.

Six Sigma has been a topic widely discussed to improve maintenance activities. Kahn [9] overviews Six Sigma methodology, and show how Six Sigma methods can be used to optimize and improve maintenance processes. He also utilizes the Six Steps Solution methodology to describe and detail the Six Sigma DMAIIC method (Design, Measure, Analyze, Improve, Implement and Control) as applied to maintenance management. There are several Six Sigma tools associated with each of these steps that can be integrated into a plant maintenance improvement program.

Analytic Hierarchy Process (AHP) has been proposed in recent literature as an effective solution to dynamic and complex real multi-criteria decision making problems. The Analytic Hierarchy Process was originally developed in the mid-1970's by Saaty [11] since then it has been used widely in many fields such as business, engineering and operations research. Yang et al. [19] have presented an application of the AHP in firms' long-term overall performance evaluation through a case study in China. Coulter et al. [4] have discussed AHP application in forest engineering applications, to get an expert judgment in more transparent and more objective way. They have presented a brief overview of AHP methodology and an example demonstrating the technique's potential usefulness in comparing alternatives with multiple criteria measured on different scales.

CHAPTER 4

APPLYING AHP TO IDENTIFY KEY MAINTENANCE FACTORS

This chapter's purpose is to determine and identify key maintenance elements or factors that will be used in our benchmarking study. This chapter starts by explaining AHP (Analytical Hierarchy Process) methodology, this will be followed by applying this AHP methodology among the 14 maintenance factors in each plant, and determining the weight of each maintenance factor in these plants through normalization. Finally, selection of the

key and the most important maintenance factors for our benchmarking purpose will be done.

AHP is a systematic method for comparing lists of objectives or alternatives, this model is widely used to determine favorable processes through a certain systemic approach. The selection of key maintenance factors is a complex multi-person, multi-criteria decision making problem. Our decision making process to select key maintenance processes can be improved by using a systematic and logical approach to assess priorities based on the inputs of several experts from different plants within the company. The analytic hierarchy process (AHP) can be very useful in involving several decision makers with different conflicting objectives to arrive at an agreement. Thus, AHP has been selected to focus our research towards the most important maintenance processes or factors, affecting maintenance system output.

In this study, the most important factors that greatly influence maintenance productivity and bottom line contribution to the business are outlined and thoroughly discussed.

These are the maintenance factors that are defined by Duffuaa et al. [6].

These factors are; organization and staffing, training, planner training, craft training, motivation, management control and budget, work order planning and scheduling, facilities, material and tool control, planned Maintenance and equipment History ,engineering and condition monitoring, work measurement and incentives, labor Productivity and finally information systems. These factors are compared in participating plants in this study, where a questionnaire was developed and sent to all participating plants (see Appendix A2 for details). Factors are assessed based on their importance to achieve maintenance objectives and bottom line results. Each plant maintenance experts

(maintenance managers) where asked to compare each factor vs. the other using the 1-9 scale- Saaty [11]- with:

1 if the two factors are equal in importance

3 if factor A is weakly more important than factor B

5 if factor A is strongly more important than factor B

7 if factor A is very strongly more important than factor B

9 If factor A is absolutely more important than factor B, and

1/3 if factor B is weakly more important than factor A

1/5 if factor B is strongly more important than factor A

1/7 if factor B is very strongly more important than factor A

1/9 If factor B is absolutely more important than factor A

Starting with Pomezia Plant (Italy) - table 4.1 below shows AHP methodology applied to determine key maintenance factors in Pomezia plant, as collected from the maintenance experts in the plant.

	Org & Staffing	Training	Planner Trng	Craft Trng	Motivation	Mangmt Ctrl & Budget	Work Order P&S	Facilities	Material & tool ctrl	Planned Maintenance	Eng & Condition Monitoring	Incentives	Labor Productivity	Information Systems
Org & Staffing	1	3	3	1	9	9	7	9	9	3	5	5	5	7
Training	1/3	1	1	1/3	9	9	5	9	9	3	5	5	5	7
Planner Trng	1/3	1/3	1	1/3	9	7	5	9	9	3	3	5	5	5
Craft Trng	1	3	3	1	9	9	7	9	9	3	5	5	5	7
Motivation	1/9	1/9	1/9	1/9	1	1/3	1/3	1/3	3	1/7	1/7	1/7	1/5	1/5
Mangmt Ctrl & Budget	1/9	1/9	1/7	1/9	3	1	1	1	1/3	1/7	1/5	1/3	1/5	1/3
Work Order P&S	1/7	1/7	1/7	1/9	3	3	1	3	5	1/5	1/5	1/3	1/3	1/3
Facilities	1/9	1/9	1/7	1/9	1	1/3	1/3	1	3	1/7	1/7	1/5	1/5	1/5
Material & tool ctrl	1/9	1/9	1/9	1/9	1	1/3	1/5	1/3	1	1/7	1/7	1/7	1/7	1/5
Planned Maintenance	1/3	1/3	1	1/3	9	7	5	7	9	1	3	3	3	5
Eng & Condition Monitoring	1/3	1/3	1/3	1/5	7	5	3	5	7	1/3	1	1	3	3
Incentives	1/5	1/5	1/3	1/7	5	5	3	5	5	1/5	1/3	1	1	3
Labor Productivity	1/3	1/3	1/3	1/5	7	5	3	5	7	1/3	1	1	1	3
Information Systems	1/5	1/5	1/3	1/7	5	3	3	3	5	1/5	1/3	1	1/3	1
sum	4.7	9.3	10.0	4.2	78.0	64.0	43.9	66.7	81.3	14.8	24.5	28.2	29.4	42.3

Table 4. 1 **Results of Applying AHP methodology in Pomezia Plant**

In table 4.1 above, row 1 and column 2 is showing 3. This means that, maintenance experts have indicated that in Pomezia plant, Organization and Staffing is weakly more important than training. Similarly, organization and staffing is very strongly more important than work order planning and scheduling (row 7, column 1).

Now, we go to the 2nd step of determining the weights of each maintenance factor. This is done through "normalization", where we divide each rating given to each maintenance factor over the sum of the column. For example, 0.21 (row1 , column 1 in figure 7.2 below) is a direct result of dividing 1 (row1 , column 1 above) over 4.7 (last row in column 1 above) in table 4.1 above.

	Org & Staffing	Training	Planner Trng	Craft Trng	Motivation	Mangmt Ctrl & Budget	Work Order P&S	Facilities	Material & tool ctrl	Planned Maintenance	Eng & Condition Monitoring	Incentives	Labor Productivity	Information Systems	Weights
Org & Staffing	0.21	0.32	0.30	0.24	0.12	0.14	0.16	0.13	0.11	0.20	0.20	0.18	0.17	0.17	**0.19**
Training	0.07	0.11	0.10	0.08	0.12	0.14	0.11	0.13	0.11	0.20	0.20	0.18	0.17	0.17	**0.14**
Planner Trng	0.07	0.04	0.10	0.08	0.12	0.11	0.11	0.13	0.11	0.20	0.12	0.18	0.17	0.12	**0.12**
Craft Trng	0.21	0.32	0.30	0.24	0.12	0.14	0.16	0.13	0.11	0.20	0.20	0.18	0.17	0.17	**0.19**
Motivation	0.02	0.01	0.01	0.03	0.01	0.01	0.01	0.00	0.04	0.01	0.01	0.01	0.01	0.00	**0.01**
Mangmt Ctrl & Budget	0.02	0.01	0.01	0.03	0.04	0.02	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.01	**0.02**
Work Order P&S	0.03	0.02	0.01	0.03	0.04	0.05	0.02	0.04	0.06	0.01	0.01	0.01	0.01	0.01	**0.03**
Facilities	0.02	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.04	0.01	0.01	0.01	0.01	0.00	**0.01**
Material & tool ctrl	0.02	0.01	0.01	0.03	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	**0.01**
Planned Maintenance	0.07	0.04	0.10	0.08	0.12	0.11	0.11	0.10	0.11	0.07	0.12	0.11	0.10	0.12	**0.10**
Eng & Condition Monitoring	0.07	0.04	0.03	0.05	0.09	0.08	0.07	0.07	0.09	0.02	0.04	0.04	0.10	0.07	**0.06**
Incentives	0.04	0.02	0.03	0.03	0.06	0.08	0.07	0.07	0.06	0.01	0.01	0.04	0.03	0.07	**0.05**
Labor Productivity	0.07	0.04	0.03	0.05	0.09	0.08	0.07	0.07	0.09	0.02	0.04	0.04	0.03	0.07	**0.06**
Information Systems	0.04	0.02	0.03	0.03	0.06	0.05	0.07	0.04	0.06	0.01	0.01	0.04	0.01	0.02	**0.04**

Table 4. 2 **Identifying Key factors in Pomezia after normalization**

Applying the same methodology for the rest of the plants (Gebze, Cairo, Rakona and Dammam), tables A1 to A8 are generated, see appendix A1 for details.

Combining tables 4.1 and 4.2 above and tables A1 to A8, a summary of the weights result from different plants is obtained:

	Pomezia	Gebze	Cairo	Rakona	Dammam	sum
Org & Staffing	0.19	0.20	0.16	0.07	0.09	0.70
Training	0.14	0.11	0.03	0.12	0.16	0.55
Planner Trng	0.12	0.02	0.04	0.04	0.04	0.26
Craft Trng	0.19	0.15	0.10	0.02	0.01	0.47
Motivation	0.01	0.02	0.08	0.01	0.13	0.25
Mangmt Ctrl & Budget	0.02	0.01	0.01	0.03	0.02	0.08
Work Order P&S	0.03	0.14	0.15	0.16	0.13	0.61
Facilities	0.01	0.01	0.01	0.01	0.05	0.11
Material & tool ctrl	0.01	0.01	0.01	0.01	0.02	0.07
Planned Maintenance	0.10	0.11	0.21	0.12	0.22	0.76
Eng & Condition Monitoring	0.06	0.07	0.03	0.06	0.02	0.24
Incentives	0.05	0.05	0.10	0.24	0.04	0.48
Labor Productivity	0.06	0.06	0.02	0.08	0.01	0.23
Information Systems	0.04	0.04	0.05	0.02	0.06	0.21

Table 4. 3 Normalized Maintenance factors weights in each of participating plants

Table 4.4 shows maintenance factors weights sorted from highest to lowest enabling us to determine key maintenance factors:

	Pomezia	Gebze	Cairo	Rakona	Dammam	sum
Planned Maintenance	0.10	0.11	0.21	0.12	0.22	0.76
Org & Staffing	0.19	0.20	0.16	0.07	0.09	0.70
Work Order P&S	0.03	0.14	0.15	0.16	0.13	0.61
Training	0.14	0.11	0.03	0.12	0.16	0.55
Incentives	0.05	0.05	0.10	0.24	0.04	0.48
Craft Training	0.19	0.15	0.10	0.02	0.01	0.47
Planner Training	0.12	0.02	0.04	0.04	0.04	0.26
Motivation	0.01	0.02	0.08	0.01	0.13	0.25
Eng & Condition Monitoring	0.06	0.07	0.03	0.06	0.02	0.24
Labor Productivity	0.06	0.06	0.02	0.08	0.01	0.23
Information Systems	0.04	0.04	0.05	0.02	0.06	0.21
Facilities	0.01	0.01	0.01	0.01	0.05	0.11
Management Control & Budget	0.02	0.01	0.01	0.03	0.02	0.08
Material & tool ctrl	0.01	0.01	0.01	0.01	0.02	0.07

Table 4. 4 **Key maintenance factors determined as a result of applying AHP methodology**

The table above concludes this chapter, where the key (and the most important) six maintenance elements for benchmarking purpose have been selected, and they are: 1- Planned Maintenance, 2- Organization and Staffing, 3- Work Order Planning and Scheduling, 4- Training , 5- Incentives and finally 6- craft training.

For the purpose of this study, and although craft training came 6^{th} , it will be considered (coupled with training) as one part, in our systems review in the coming chapter enabling to tackle both training and craft training under one training system review. The reason behind this is that separating both factors in the upcoming systems review will not add value to our research, due to the reason that P&G has a standard training system that covers both craft, staff and management, and this research's training systems review would be covering both factors.

The identified key maintenance processes will be used in the next chapter where best applied systems and practices in each of the identified key maintenance processes will be documented, for our benchmarking purpose.

CHAPTER 5

KEY MAINTENANCE PROCESSES AND DAILY MANAGEMENT SYSTEMS IN P&G

5.1 Introduction

In this chapter, key maintenance systems in Procter and Gamble will be thoroughly discussed. This will be a comprehensive documentation of the best practices in the company, system implementation methods, in process and output measures, as well as summarizing management systems used to ensure proper and effective equipment

maintenance and process conditions. The following sections will go over the key maintenance processes identified in the previous chapter: section 5.2 discusses planned maintenance systems and documentation, section 5.3 discusses organization and staffing systems, section 5.4 discusses work order planning and scheduling systems, section 5.5 presents training and craft training systems and finally section 5.6 discusses incentives systems in Procter and Gamble.

In the previous chapter, the following key maintenance factors were identified:

A- Planned Maintenance

B- Organization and staffing

C- Work Order Planning and Scheduling

D- Training (including craft training)

E- Incentives

A comprehensive discussion and documentation of these key maintenance factors, as practiced in Procter and Gamble, will now follow.

5.2 P&G Planned Maintenance Overview

The purpose of planned maintenance is to assure that the equipment are functioning satisfactory whenever needed at minimum cost, the maintenance activities are performed

to maximize equipment availability, extend equipment component technical life and to have and efficient, cost-effective maintenance.

The Planned Maintenance range of responsibilities includes the prevention of failures and problems, when they are beyond the capability of the operation team. An example of these failures or problems can be: equipment failures, process control problems, quality abnormalities, minor stoppages, excessive material usage or scrap, capacity or rate reductions, safety and environmental problems, utility problems and building and infrastructure problems.

Next, planned maintenance systems applied in P&G plants will be thoroughly discussed.

Planned Maintenance implementation follows the below 6 steps (see table 5.1 below):

1. Evaluate Equipment and Understand Conditions

2. Reverse Deterioration and Correct Weaknesses

3. Build a Computerized Information Management System

4. Build a Periodic Maintenance System

5. Build a Predictive Maintenance System

6. Evaluate the Planned Maintenance System

At each step of Planned Maintenance development, careful consideration is given to the business needs and then to the total system required to fulfill the next Planned Maintenance step. Each Plant must use Standard Operating Procedures (SOPs) where

required, an SOP on the way to examine and repair motors as an example, but also must use CBAs that meets all Standards and Guidelines. Ultimately, at each Plant, a single system must be selected, documented, and used.

Step-by-Step Development Process

Step	Activities
Step 1: Evaluate equipment and understand the situation	1. Prepare equipment logs 2. Evaluate equipment equipment and select priority equipment 3. Define and classify failures 4. Understand conditions and level of maintenance 5. Benchmarks and goals set 6. Prepare action plan 7. Assess team dynamics & results
Step 2: Reverse deterioration and correct weaknesses	1. Establish basic conditions (Support Autonomous Maintenance) 2. Investigate breakdowns and take steps to prevent similar breakdowns from happening 3. Introduce improvements to reduce process failures 4. Conduct Focused Improvement Activities to correct weaknesses and extend lifetimes 5. Assess team dynamics & results
Step 3: Build a computerized information management system	1. Build a computer database 2. Build a failure data management system 3. Build an equipment management system. 4. Build a maintenance cost management system 5. Build systems for controlling spare parts, drawings, technical data, etc 6. Assess team dynamics & results
Step 4: Build a periodic Maintenance system	1. Prepare for Time Based periodic maintenance 2. Prepare periodic maintenance system 3. Select equipment and components to be maintained, and formulate a maintenance plan 4. Prepare new and update existing standards 5. Improve efficiency of shutdown maintenance and improve control of subcontracted work 6. Assess team dynamics & results
Step 5: Build a predictive Maintenance system	1. Introduce diagnostic equipment 2. Prepare predictive maintenance system 3. Select equipment and components for predictive maintenance and extend gradually 4. Develop diagnostic equipment and technology 5. Assess team dynamics & results
Step 6: Evaluate the planned Maintenance system	1. Evaluate the planned maintenance system 2. Evaluate reliability improvement 3. Evaluate maintainability improvements 4. Evaluate cost savings 5. Assess team dynamics & results

Table 5.1 **Planned Maintenance system Steps-** *Source: P&G's progressive maintenance guide*

In P&G, maintenance performance is measured by key indicators in three categories: cost, reliability and maintainability and efficiency. Table 5.2 gives the maintenance cost indicator as measured in P&G.

Indicator	Formula	Remarks
Overall maintenance cost rate	Total maintenance cost X 100 /Total production cost	Indicates the proportion of total costs spent on maintenance

Table 5.2 **Maintenance cost Measure-** *Source: P&G progressive maintenance guidebook*

Table 5.3 below gives the reliability and maintainability indicators, as measured in P&G:

Indicator	Formula	Remarks
Breakdown Frequency	(Total # of stops due to Breakdown X 100) /Scheduled Run Time	
Emergency Maintenance Rate	Number of EM jobs x100 / (TBM jobs + CBM jobs + BD jobs + EM jobs)	TBM = Time Based Maintenance CBM = Conditioned Based Maintenance BD = Breakdown Maintenance EM = Emergency Maintenance
Cost of stoppages due to breakdowns	Stoppage time X cost per unit time	
MTBF	Total operating time (uptime) / (Minor stops + Breakdowns + Process Failures)	Average Failure Interval
MTTR	Sum of repair job times / Number of repair jobs	Mean Time To Repair

Table 5.3 **Reliability and Maintainability Measures-** *Source: P&G progressive maintenance guidebook*

Table 5.4 below gives the maintenance efficiency indicators, as measured in P&G:

Indicator	Formula	Remarks
Planned Maintenance impact to Reliability	Down Time due to Planned Maintenance/ Scheduled Run Time	the goal is to extend intervals , reduce MTTR, convert downtime tasks to uptime tasks
Shutdown Maintenance Days reduction (SMD)	Previous SMD / Present SMD	The goal is to extend the numbers of days of continuous production
Vertical startup after shutdown maintenance	Trend in number of startup problems after shutdown maintenance	Prevent early failures after shutdown maintenance
Maintenance Schedule Adherence	Number of PM Jobs completed / No of jobs planned and scheduled	Indicates level of planning and scheduling of maintenance

Table 5.4 **Maintenance Efficiency Measures-** *Source: P&G progressive maintenance guidebook*

In tables 5.5 and 5.6, P&G's methodology in eliminating breakdowns is presented, and its main process measures. The methodology is called "breakdown elimination daily management system".

SYSTEM PRODUCTS (What tangible product or service does this system deliver to someone outside of system)	• Reduction of Breakdowns and Breakdowns recurrence, in order to increase Process Reliability through analyze root cause countermeasures
BUSINESS PURPOSE (Why is it profitable for the business that this system exists)	• Eliminate Breakdowns and Breakdowns Recurrence
CUSTOMER (The names of the people who receive the products/services of the system)	• Operation Teams • Maintenance Teams
CUSTOMER REQUIREMENTS (The requirements identified and quantified by the customers)	• Zero Breakdown and Zero Breakdown recurrence • 100 % Breakdowns analyzed to root cause • Extend reapplication to similar components and equipment
SYSTEM MEASURES **(What measures does the system owner use to know if the system is performing and that customer requirements are being met)** **(In-Process & Output Measures)**	*Business Measures* • Maintenance & Repair cost • Equipment Reliability (% PR) *Customer Measures* • % of Breakdowns Eliminated. *In-Process Measures* • % of Breakdowns Analyzed • % of Repeated Breakdowns • # of Breakdowns analysis
STRATEGIC INTENT	• Prevent similar breakdown • Accelerate achieving zero breakdown • Increase problem solving/ analytical skills
MAINTAIN PLAN (What is the plan to standardize this work to ensure that if in control it stays in control)	• Conduct reviews by department owners • Conduct training by using one-point lessons

Table 5.5 **Breakdown elimination system Summary-** *Source: P&G progressive maintenance guidebook*

Output Measures
Major Breakdowns
% Total Repeated Breakdowns
% PR Loss due to Breakdowns
In Process Measures
% Site Health Check adherence
% DMS Health Check Score
% People trained & qualified on DMS
% of Breakdowns Notified in system
% Action Plans Adherence
% Initial Failure Reports Issued & Approved within required time frame
% Final Failure Reports Issued and Approved within required time frame

Table 5.6 **Breakdown elimination system measures-** *Source: P&G progressive maintenance guidebook*

Another very important system is the process failure elimination daily management system (DMS)- table 5.7, where this system deals with any failure (other than breakdown) that does not require part changes, welding or overhauling.

SYSTEM PRODUCTS **(What tangible product or service does this system deliver to someone outside of system)**	• Reduction of Process Failures and Process Failure Downtime
BUSINESS PURPOSE **(Why is it profitable for the business that this system exists)**	• Eliminate Process Failures , and its route cause
CUSTOMER **(The names of the people who receive the products/services of the system)**	• Operations • Progressive maintenance team • Process team
CUSTOMER REQUIREMENTS (The requirements identified & quantified by the customers)	• Zero Process failures • 100 % Process Failures analyzed to root cause and learning shared with team • Extend reapplication to similar components & equipment
SYSTEM MEASURES (What measures does the system owner use to know if the system is performing and that customer requirements are being met) (In-Process & Output Measures)	**Business Measures** • Process failure downtime (% PR) • # of Process failures **Customer Measures** • % of Process Failures Eliminated. • % of process failures not repeated In-Process Measures • % of process failures analyzed • % of Repeated process failures
STRATEGIC INTENT	• Prevent similar process failures • Accelerate achieving zero process failures • Increase problem solving/ analytical skills reduce change over time
MAINTAIN PLAN (What is the plan to standardize this work to ensure that if in control it stays in control)	• Train all related people on process failures DMS • Conduct training by using developed OPL

Table 5.7 **Process failures elimination system summary-** *Source: P&G progressive maintenance guidebook*

Output Measures
of Major Process Failures per Line / Unit
% of Total repeated Process Failures
%of total process failures Vs. Baseline
% PR Loss Due to PF
In Process Measures
% Site Health check Adherence
% DMS Health check score
% Trained and qualified people on DMS
% Of PF notified in system
% of action plans Adherence
% issue failure report
% of updating Trouble-Shooting Manual

Table 5.8 **Process failures elimination system measures-** *Source: P&G progressive maintenance guidebook*

5.3 Organization and Staffing Overview

5.3.1 Performance Rating System Overview

Procter and Gamble is a “pay for performance” company. This means that the company pays higher for high performance individuals. The system to enable the “pay for performance” concept is the rating system, in which employees get rated based on their performance on an annual basis.

Assigning ratings to employees is necessary to differentiate performance among employees and enable fair and accurate Pay for Performance. Ratings are also a key factor in helping to manage performance. Low rated contributors should understand their areas needing improvement and work with their immediate managers to put in place a plan for strengthening their performance. Highly rated contributors should also know where they stand, and talent and compensation practices should be managed in line with their contributions.

The rating is an assessment of an individual’s contributions relative to peers for the previous year performance. The rating is reflective of performance only and is not intended as a measure of potential or anticipated performance or contributions not yet delivered.

Ratings are determined through a data-based process by which the employees are first rated by their Immediate Manager based on results delivered versus expectations as aligned

in the year work plan and reviewed quarterly (i.e., backward looking assessment). Contributions are then calibrated against contributions of peers to determine final relative rating. The following are the performance rating principles in P&G.

1. The immediate manager is closest to the performance of the direct report and is in the best position to recommend the rating.

2. Each employee's rating will be calibrated once. This calibration will be relative to peers - doing similar work at the same level (i.e., within a function at the same level of responsibility).

3. Business Leaders will review the ratings calibrated by the function leadership team. Offsets will be managed by the function - within the functional pool of talent to ensure the required distribution.

4. Promotions will be based on a combined judgment of performance, potential, readiness and fit with the assignment opportunity.

5. A systemic assessment of potential is a crucial requirement in P&G's Build From Within system.

6. Individuals need to know where they stand in terms of their performance and potential.

The process of performance rating is described as follows:

Step One – Immediate Manager Proposes Rating

Immediate Managers provide a proposed rating for each of their direct reports (all levels) based on contributions to the business and the organization in the previous performance period (last year). The Immediate Manager is in the best position to assess performance versus expectations.

Ratings should not be based on anticipated future performance or potential.

Step Two – Function Calibrates Proposed Ratings versus Peers

Organizations calibrate and finalize ratings following a robust process facilitated by the organization's HR Manager. This process consists of a calibration meeting during which the contributions of employees at the same level doing similar work are compared with one another to differentiate the top and bottom performers from all others. Below are the base expectations for the calibration meeting:

Step Three – Business Leader Reviews Calibrated Ratings

Once functional calibrations are final, Business Unit leaders will have an opportunity to review the complete list of calibrated ratings for all employees in their organization to ensure they are consistent with relative contributions in the business.

Before the final ratings are loaded into information system (SAP in P&G case), there is a final review to ensure all organizations are meeting the required distribution. The ratings database will be frozen during this period to address and correct any issues that are discovered. As soon as all issues are resolved, the data will be loaded into SAP. Managers

will be informed as soon as data is finalized in SAP so that final calibrated ratings can be shared by managers with their employees.

The rating distributions should be in line as per the following

Rating	Description
1	Exceeded Expectations relative to peers
2	Met Expectations relative to peers
3	Did Not Meet expectations relative to peers

5.3.2 Work and Development Overview

An Action Plan is used to plan a technician's key work priorities and track results. The action plan can be described as follows:

-Prepared at the beginning of the year and reviewed once per quarter (at a minimum) in a focused short discussion (15-30 min)

-The technician has input to the action plan and the manager is responsible for the overall statement

-Indentifying priorities by quarter, or annual priorities with quarterly milestones.

Throughout the year (at least quarterly), the technician and manager should:

-Capture any results to date and adjust the plan (if necessary) to reflect changes in priorities

-Have an objective discussion to ensure the individual clearly understands their results to date versus expectations

At the end of the year (to close out the Action Plan):

-The technician should enter their yearend results and make the Action Plan available to the manager

-The manager should add a brief, concise Overall Statement (2 to 4 sentences) that: Is objective and data based -- per cumulative quarterly and annual results, reflects the performance message the manager wants to convey, relative to how the technician has performed against the expectations of their Action Plan and shares key business and organization accomplishments.

5.4 Work Order Planning and Scheduling Overview

Planning and scheduling is a well known maintenance system for its contribution towards increasing machine's reliability and MTBF and reducing MTTR. In figure 5.1 below, taken from P&G's Progressive Maintenance guidebook training materials, we will explain the importance of having a planning and scheduling system in place to reduce the effect of work planning during machine downtime. The figure shows activities that are conducted after failure, such as troubleshooting, obtaining spares and tools that are performed before resuming normal operation. By planning and scheduling, all preparation activities can be done before failure reducing the downtime to repair time only.

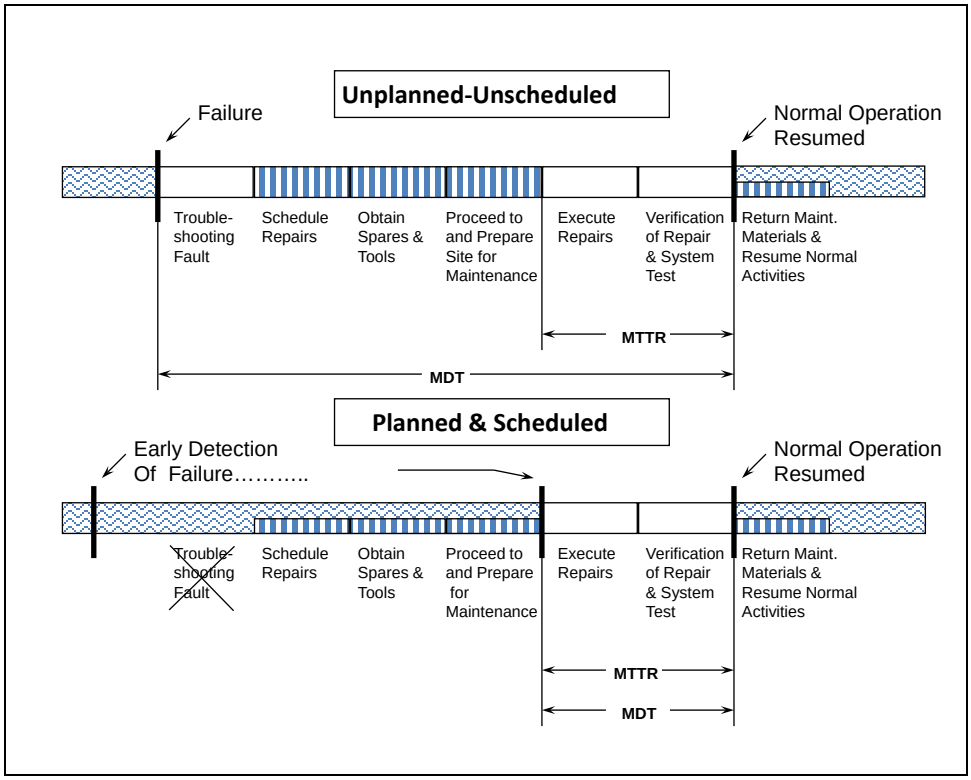

Figure 5. 1 Unplanned and Unscheduled vs. Planned and scheduled maintenance work process-

Because of the plan and executing the work to the plan, MDT (mean down time) may not be too much greater than MTTR. Of course there will be many circumstances which control this, but in any case MDT will have been reduced and in most instances the reduction will be drastic.

As can be seen, the work can be done while the machine is running, no stress or time constraints. When the work will be done, who will do the work and how much down time is required to execute the work is known.

Now, the behavior of the equipment is controlled in order to eliminate or reduce MTTR. There are different techniques and strategies to use and they will be dependent upon the

equipment, skills and business needs. For example, a gearbox assembly which needs to be rebuilt may require 16 hours for repair. A spare ready assembly may be kept in the storeroom, and instead of rebuilding the assembly on the running machine requiring it to stop, a changeover is planned. Only 2 hours are required to change out the assembly and another spare assembly can be done in the shop prior to the next scheduled maintenance.

MTTR will be reduced as breakdowns are eliminated and as work plans are developed, executed and critiqued.

Next, planning and scheduling daily management system (DMS) in P&G (table 5.9), output and in-process measures (table 5.10) will be presented.

SYSTEM PRODUCTS (What tangible product or service does this system deliver to someone outside)	• Provide 100 % necessary and required maintenance to the key components at appropriate timing
BUSINESS PURPOSE (Why is it profitable for the business that this system exists)	• Provide a clear and effective control for maintenance activities that eliminates rework and reduce cost.
CUSTOMER (The names of the people who receive the products/services of the system)	• PM Planners • Operating/ AM Team
CUSTOMER REQUIREMENTS (The requirements identified & quantified by the customers)	• Priorities for maintenance to be set for next maintenance period. • Related project put into next plan. • Required & necessary M/T should be listed up & defined date. • Identify current equipment condition.
SYSTEM MEASURES (What measures does the system owner use to know if the system is performing and that customer requirements are being met) (In-Process & Output Measures)	**Business Measures** • Maintenance and repair Cost • Equipment Availability **Customer Measures** • Process Reliability **In-Process Measures** • % of work planned • % of work planned & scheduled in 24 hours • % of works done according to 24 hrs in advance scheduling
ASSESSMENT OF SYSTEM PERFORMANCE (Description of how system is performing)	• % Break down because of maintenance
STRATEGIC INTENT	• Ensure effective maintenance with minimum time and cost. • Ensure to execute necessary and required maintenance.
MAINTAIN PLAN (What is the plan to standardize this work to ensure that if in control it stays in control)	• Train related people on system summary. • Share maintenance plan with schedule to related people • Conduct review meeting after execution with records.

Table 5.9 **Planning and scheduling System Summary-** *Source: P&G progressive maintenance guidebook*

Output Measures
Major Breakdowns
% PR loss due to Maintenance
Process Reliability
In Process Measures
Weekly Maintenance Scheduling Adherence (MSA)
Monthly Maintenance Scheduling Adherence (MSA)
Yearly Maintenance Scheduling Adherence (MSA)
% Planned Maintenance 24 hours ahead
% DMS Health Check Score
% People trained and qualified on DMS

Table 5.10 **Planning and scheduling System measures-** *Source: P&G progressive maintenance guidebook*

5.5 Training (including craft training) Overview

P&G follows a rigorous and a very effective and detailed training process. As mentioned earlier, this training (and craft training) key maintenance factors systems review, will cover both training programs that are intended for employees, management and craft/technicians. The reason behind that is that P&G uses one training system covering both training and craft training maintenance factors, and it does not split between the two in its systems flow and outputs. Training program at P&G consists of seven work processes that construct an effective training process. Find below in table 5.11, noted from P&G's training standard work process, the seven work processes along with their output and measures, followed by an overview explaining each of the seven work processes.

Work Processes	Outputs	Measures
1.Skill Needs Assessment and Prioritization	• Help plant to identify individual and group training needs • Develop a skill matrix • A prioritized list of all skill gaps, identified for an individual or a group. • Visible Skill Matrices	• % Skill matrices in place (number vs. total) • % Skill assessments complete
2. Site Training Plan Development and Implementation	• An approach that enables the ranking of training needs, consistent with business needs. • A list of prioritized capability gaps • Action plan to close high priority capability gaps that have been selected and quantified • Prioritized list at individual, team and department level	• Training plan for the total organization exists and is current • % of individuals/ teams/ departments that have current documented training plans
3. Training Facilities and Materials Management	• An approach that enables plant / organizations to develop a sequence of events to address skill acquisition needs. • Training Facility	• Sufficient training facilities for current skill gap closure plan exists • Sufficient training materials for current skill gap closure plan exist
4. Training Delivery Method and Strategy Selection	• An approach / decision tree to develop and qualify training materials based training methodologies • Virtual Floor University	• % of training packages developed and qualified on time • % Training materials and delivery strategy for all identified skills
5. Training and Trainer Development	• Training packages/ materials are in place • Performance based curriculums	• Learning materials in place for identified skills • % Trainers qualified as subject matter experts • Effective and appropriate learning materials exist for all required skills
6. Qualification Process Development	• An approach to identify, develop and qualify trainers • Qualified trainers by subject matter area	• % employees with knowledge and skills to perform role
7.Self-Directed Learning	• % at target skill profiles as defined by the individual's skill matrix • List of trainers and training resources	• % employees with self-directed development plans • % of learning resources in place for self-learning vs. target

Table 5. 11 **Training standard work processes chart** *-Source: P&G Training Pillar Website*

The seven work processes are further detailed and outlined as in P&G Training pillar website. The skill needs assessment and prioritization system is outlined in table 5.12, Site Training Plan Development and Implementation system is outlined in table 5.13, Training Facilities and Materials Management system is outlined in table 5.14, Training Delivery Method and Strategy Selection system is outlined in table 5.15, Training and Trainer Development system is outlined in table 5.16, Qualification Process Development system is outlined in table 5.17 and Self-Directed Learning system is outlined in table 5.18.

System	Skill Needs Assessment and Prioritization Process
System Products	The output for this process is a list that includes what (Priority skills), whom (audience) and which losses to eliminate.
Business Purpose	Provide key information to develop a training plan which covers current and future skill needs and drive the organization to higher levels of performance.
Customer	1. Training owners and training committee members 2. Organization leaders who want to identify the skills need in his organization.
Customer Requirements	Establish the criteria to define the skill matrices. Clarify the proper detail level in the skill matrices and capture the organization design input.
System Measures	% of Skill Matrices in place (number vs. total) % Skill Assessment Complete
Assessment Of system Performance	Current quarter vs. goal for quarter

Table 5. 12 **Skill Needs Assessment and Prioritization System Summary**- *Source: P&G Training Pillar*

System	Site Training Plan Development and Implementation System
System Product	An approach on how to develop a training plan.
Business Purpose	Build capability to meet the site business need by eliminating losses due to lack of skill
Customer	All employees
Customer Requirements	Individual Training Plans, Business (Site) Training Calendar, Standardized Scheduling / Requesting Tool, Curriculum and Course Development, Qualified trainers list by topic/feature and Master Catalog / Course List
System Measures	% Training Completed (business/plant prioritized training) % Department Training Completed (department prioritized training) % Team Training Completed (prioritized training) % Individual Training Plan Completed % of Qualification or Annual Training Profile Completed Average Days to Qualification
Assessment Of system Performance	% of qualified individuals on their work processes

Table 5. 13 Site Training Plan Development and Implementation System Summary- *Source: P&G Training Pillar website*

System	Training Facilities and Materials Management system
System Products	• On plant training facilities that support the organization's capability development needs that must be in place to deliver the required business result • Up to date and adequate learning materials for all required skills and knowledge
Business Purpose	Ensure adequate facilities and learning materials are available to enable the capability development needed within an organization to ensure people are adequately skilled to perform the work required to meet the business need
Customers	Employees and Shareholders
Customer Requirements	• Adequate facilities and materials available to learn required skills when skill gaps exist • Appropriately skilled and knowledgeable people who execute the required work effectively and efficiently
System/ Process Measures	• Adequate learning facilities exist – to close identified skill gaps • % Training/ learning materials in place for identified, required skills
Assessment of System Performance	% Training/ learning materials in place for identified skills will increase with plant progression
Strategic Intent	• Facility development will be organization specific and will support varied learning methodologies • Learning materials will be stored and easily accessible by all (24/7 access) • Learning materials will be up to date and relevant to the skills needed to do the work

Table 5.14 **Training Facilities and Materials Management System Summary-** *Source: P&G Training Pillar website*

System	Training Delivery Method and Strategy Selection System Summary
System Products	Provide guidelines to standardize the training delivery method selection process to ensure that the training delivery is effective and efficient in order to eliminate or prevent losses due to lack of skills.
Business Purpose	Process by which any leader can (1) decide how to conduct training and (2) decide what type of training to conduct
Customers	Training Leaders and Organization's capability Leaders
Customer Requirements	Standard way to choose the correct training method
System/ Process Measures	Improved capability; Selection of the best training method
Assessment of System Performance	1) Process used each time there is a new need identified; 2) Process re-evaluated annually for effectiveness and 3) Assessment after each training to evaluate its effectiveness

Table 5. 15 **Training Delivery Method and Strategy Selection System Summary-** *Source: P&G Training Pillar website*

System	Training Development
System **Products**	The best training principles and methods are available for the businesses/sites to develop training. Qualified training packages and materials are in place for required skills.
Business **Purpose**	Training development is done for the purpose of delivering training for the skills required to deliver the business result and to close the knowledge gaps that result in losses in our business, as efficiently as possible.
Customer	All employees
Customer Requirements	All training developed uses the Training Method and Qualification best suited for the subject matter.
System **Measures**	• Learning materials in place for identified skills • % Trainers qualified as subject matter experts • Effective and appropriate learning materials exist for all required skills
Assessment of system performance	Current quarter results versus goal for quarter.

Table 5.16 **Training and Trainer development System Summary-** *Source: P&G Training Pillar website*

System	Training Qualification Process
System **Products**	-Each individual and team have needed skills and knowledge required to perform the job.
Business **Purpose**	Qualified individuals and teams have required knowledge and skills to achieve business results.
Customer	Trainers and people who need qualification
Customer **Requirements**	Each training has defined proper qualification method, which helps verify and confirm knowledge or skills.
System **Measures**	% People qualified with knowledge and skills to perform role according to defined qualification method.

Table 5.17 **Qualification Process development System Summary-** *Source: P&G Training Pillar website*

System	Self directed learning system
System **Products**	Individuals in site are developed and qualified on their own pace and learning styles
Business **Purpose**	Every employee in the site is enabled to learn and develop just in time by so that they are able to perform their assigned roles to deliver desired results in the fast changing business situation. The facilities and resources are properly managed so that the loss of the self-learning and development is minimized.
Customer	• All employees
Customer **Requirements**	Employees have knowledge and skills required to develop themselves on the self-pace, under the available information platforms.
System **Measures**	*In process measures:* - % of learning resources in place for self learning vs. the target - % of employees have their self development plan in place - % At target skill profile (as defined by the individual's skill matrix)

Table 5.18 **Self Directed learning System Summary-** *Source: P&G Training Pillar website*

5.6 Incentives Overview

Timely recognition is essential in order to encourage bold breakthrough thinking and sustained long-term results. It is well known that high performance is the standard at P&G, and it's important to show appreciation for outstanding performance. Appropriate and timely recognition contributes to employee satisfaction and enhances overall work environment.

There are general guidelines for the Reward and Recognition system which are:

- Reward and recognition system is based on rewarding achievements, behaviors and performance.

- The awards are linked to contribution and targets.

- Procter and Gamble incentives system is either “structured incentives” which comes in the form of salary increases, or, “un-structured incentives”, which comes in the form of the rewarding system widely used in the company.

1- Structured Incentives:

Structured incentives come in the form of base pay salary increase. This is linked to the company’s Global Compensation System, where rating is the main factor behind driving salary increase; refer to P&G rating system (under organization and staffing over view) above.

2- Unstructured incentives:

Unstructured incentives come in the form of rewards, recognition or even a simple “thank you”.

P&G uses the “Reward and Recognition (R&R) system for that.

Awards can be classified into 2 types:

A. Individual Awards: Those are awards related to outstanding efforts done by a person Each Manager will have a quota of “Power of you Awards” which should be depleted before end of year.

B. On the Spot Rewards and Recognition (R&R): which is rewarding specific behaviors consistent with values, principles or desired culture and behaviors demonstrate that individual and team efforts are valued. Examples of on the spot R&R are:

Simply say, "Thank you," in person, make a phone call to thank the person, print appreciation letter and present it to the person, set up a recognition telephone call or note from a one-up manager, send a handwritten note or greeting card, send an e-mail, when appropriate, copy the supervisor of the person you are thanking and verbally acknowledge the person's contribution in a meeting.

CHAPTER 6

P&G PLANTS REVIEW AND EVALUTAION

6.1 Introduction

In this chapter, a review and documentation of P&G plants observations that was collected during the study and an evaluation of its maintenance output measures performance is performed. The following sections will be reviewing and evaluating the benchmarked plants in main maintenance output measures. Pomezia plant will be discussed in section 6.2, Gebze plant in section 6.3, Cairo plant in section 6.4, Rakona plant in section 6.5 and finally Dammam plant in section 6.6.

For the purpose of this benchmarking study, the below plants review is focusing on benchmarking in carton packing departments. This review was done based on actual plants visit (Dammam, Pomizia, Gebze and Cairo plants) and over the phone discussions (Rakona

plant). The data shown here was collected through the period starting January till end of October 2010. The review was done on carton packing technology which is known for its relative low MTBF and reliability and high MTTR.

The three main maintenance measures have been chosen for our benchmarking purpose, these measures represents the top 3 measures most commonly used to distinguish and single out maintenance and productivity excellence.

6.2 Pomezia Plant Review

Pomezia plant is located near Rome- Italy. The plant enjoys a high skill profile in maintenance teams coupled with high technical mastery. The plant measures are as follows:

Year To Date (YTD) Reliability:	89%
Year To Date (YTD) MTBF:	125 min
Year To Date (YTD) MTTR:	3 min

In our visit to this plant, it was noticed that the leadership of this plant believes on the effect of individuals focused training to achieve desirable outcomes ensuring having a predictable operations.

There is a strong focus on results and 'no excuses' culture coupled with a huge external focus to deliver customer and consumer needs, great Supply Chain culture and partnership with market.

In addition to that, the capability of people to use loss analysis tools and techniques is solid, maintenance teams are one of the strongest globally. Team leaders are very capable technically.

Plant organization focus is high, up to department and team levels. This was clear in maintenance teams maintaining clear roles and responsibilities for each individual, and linking maintenance activities to business bigger picture.

The plant is continuously benchmarking with other plants to improve standards and rise up total plant capability. Benchmarking is being used to drive action plans rather than recognizing the plant.

It was also noticed that maintenance support teams are equally distributed among shifts, and not focusing only in main day shift. This is obviously strengthening other shifts output and transferring the knowledge among all technicians.

6.3 Gebze Plant Review

Gebze plant is located near Istanbul- Turkey. It was noticed during our plant visit that the plant is one of the new built plants for Procter and Gamble and enjoys very high standard equipment and facilities. This is also coupled with a high skill profile in maintenance teams .

The plant measures are as follows:

Year To Date (YTD) Reliability:	87%
Year To Date (YTD) MTBF:	95 min
Year To Date (YTD) MTTR:	5 min

The plant leadership is focusing towards ensuring hiring the best talents in the area to drive results. In addition to building a strong training program and building individuals' capability.

The strong daily management systems mentality and the discipline into adhering to these systems were also noticed. It was also noticed that their people are highly capable of performing maintenance jobs and procedures; they are of high calibre profile and well trained.

The plant is becoming a benchmark focus in the area due to the high standard work place and well trained individuals.

6.4 Cairo Plant Review:

Cairo plant is located in the 6th of October City close to Cairo-Egypt. The plant is one of the oldest established plants in the region, manufacturing dry laundry, bar soaps and diapers.

The plant measures are as follows:

Year To Date (YTD) Reliability:	83%
Year To Date (YTD) MTBF:	40 min
Year To Date (YTD) MTTR:	7 min

In the visit, strong people engagement was observed; with individuals highly committed and energized. The plant is working towards exporting talents and being a hub in the region.

6.5 Rakona Plant Review

Rakona plant is located in Czech republic. The plant is the largest plant P&G operates in central and Eastern Europe (CEE).

The plant is a strategic plant in terms of business expansion and size in CEE.

The plant measures are as follows:

Year To Date (YTD) Reliability:	86%
Year To Date (YTD) MTBF:	70 min
Year To Date (YTD) MTTR:	5 min

The plant leadership gives a great support towards building the technical mastery of its employees. This is obvious form their strong training management system and their focus into building the “how can we continuously improve productivity?” culture among its employees. There is a strong focus on results including waste and loss analysis. Maintenance teams are well recognized in CEE and are highly capable of performing maintenance jobs and able to transfer the knowledge to other teams internally and externally.

Plant focuses on benchmarking with other plants in CEE and middle east to improve work place standards and people capability.

6.6 Dammam Plant Review:

Dammam plant is located in the Eastern Province – Saudi Arabia. The plant is the largest manufacturer of detergent (dry laundry) and hair care products in middle east and Africa (MEA) region. The plant is well known for its benchmark work place standard. People are very energetic with high desire to learn and benchmark.

The plant measures are as follows:

Year To Date (YTD) Reliability:	85%
Year To Date (YTD) MTBF:	60 min
Year To Date (YTD) MTTR:	6 min

The plant is extremely focused on product supply fundamentals: safety, quality and financial controls.

Plant has recently recognized the importance of benchmarking in the region and getting the benefits of other experienced talents and skills, and is working aggressively towards this objective.

Table 6.1 below summarizes the observations and findings in each plant:

Site	Reliability	MTBF	MTTR	Observation
Pomezia	89%	125	3	• high skill profile in maintenance teams • Maintenance teams fairly distributed among shifts • strong focus on results
Gebze	87%	95	5	• Strong training program • High workplace standard
Cairo	83%	40	7	• Highly energized and committed individuals
Rakona	86%	70	5	• Individual's technical mastery • Strong focus toward loss and re-work elimination • Powerful training and capability building system
Dammam	85%	60	6	• Work place standard • High ability to learn individuals

Figure 6. 1 **Plants Review summary table**

It is clear from the table above that Pomezia plant is the most reliable among the five plants with the least frequent failures and the fastest in failure repair. Pomezia plant is followed by Gebze, Rakona, Dammam and Cairo plants respectively.

CHAPTER 7

BENCHMARKING STUDY

RESULTS

In this chapter, P&G plants input to the benchmarking questionnaire that was developed (see appendix A2) will be discussed, and the obtained outputs will be thoroughly explained for the purpose of identifying different practices that are used, among benchmarked plants, in every maintenance element or factor.

Maintenance factors were sent to all 5 participating plants for the purpose of ranking the based on their importance, from plant's point of view. As there are 14 factors to be scored, maintenance experts in each plant were asked to fill in a questionnaire (see appendix A1) based on their plant current practices and expertise. The questionnaire consists of a set of

questions to tackle each of the identified factors. A brief description of each of the 14 maintenance factors, as suggested by Duffuua et al. [6], is explained in the appendix.

Table 7.1 below shows the results of this ranking, which came from 1 to 14 (with 1 as highest and 14 as lowest in importance).

For example, “organization and staffing” was ranking high in almost all plants, whereas “material and tool control” was ranked the least important (14) by almost all plants, except for Dammam where it came 10^{th}.

Factor	Pomezia	Gebze	Cairo	Rakona	Dammam
1- Organization & Staffing	2	1	2	6	5
2- Training	3	4	10	3	2
3- Planner Training	4	11	8	8	9
4- Craft Training	1	2	4	10	13
5- Motivation	13	10	6	12	3
6- Management Control & Budget	11	13	14	9	12
7-Work Order Planning and scheduling	10	3	3	2	4
8-Facilities	12	12	12	13	7
9- Material and tool control	14	14	13	14	10
10-Planned Maintenance and Equipment History	5	6	1	4	1
11- Engineering and Condition Monitoring	6	5	9	7	11
12- Work Measurement and Incentives	8	7	5	1	8
13- Labor Productivity	7	9	11	5	14
14- Information Systems	9	8	7	11	6

Table 7. 1 **Maintenance Factors questionnaire scoring per plant**

In our research appendix, specific questions were asked in each maintenance factor, to be able to determine different practices used by each plant in every factor.

These questions were put into the scale of 1 to 5, where 1 stands for “strongly disagree” and 5 stands for “strongly agree”. See appendix for the full questionnaire details sent to participating plants.

Example:

- *In your maintenance organization, are Mission and Objective clearly defined*

-A-Strongly Agree, B- Agree, C- Neither Agree or Disagree, D- Disagree, E- Strongly Disagree

A table is generated reflecting the scoring of the questionnaire in each maintenance factor, as well as showing the gap between the benchmark practice in each plant and Dammam. A "spider chart" was used for each maintenance factor, explaining this difference as well. The spider chart was selected as it provides an excellent visual control for the reader, to be able to identify any possible opportunities, merely by looking at the graph.

Organization & Staffing	Pomezia	Gebze	Cairo	Rakona	Dammam	Benchmark	Gap
Mission and Objective is clearly defined	5	5	4	4	4	5	**1**
Organization Chart current, complete, and reviewed periodically	4	4	4	5	5	5	0
Proper Job Description exists for each supervisor and his team	4	4	4	4	2	4	**2**
Worker to supervisor Ratio?	1	1	1	1	1	1	0
Support Functions exists	5	5	5	5	5	5	0
A strong goal setting exists as recommended by management	4	4	4	4	4	4	0

Table 7. 2 **Organization and staffing scoring results per plant**

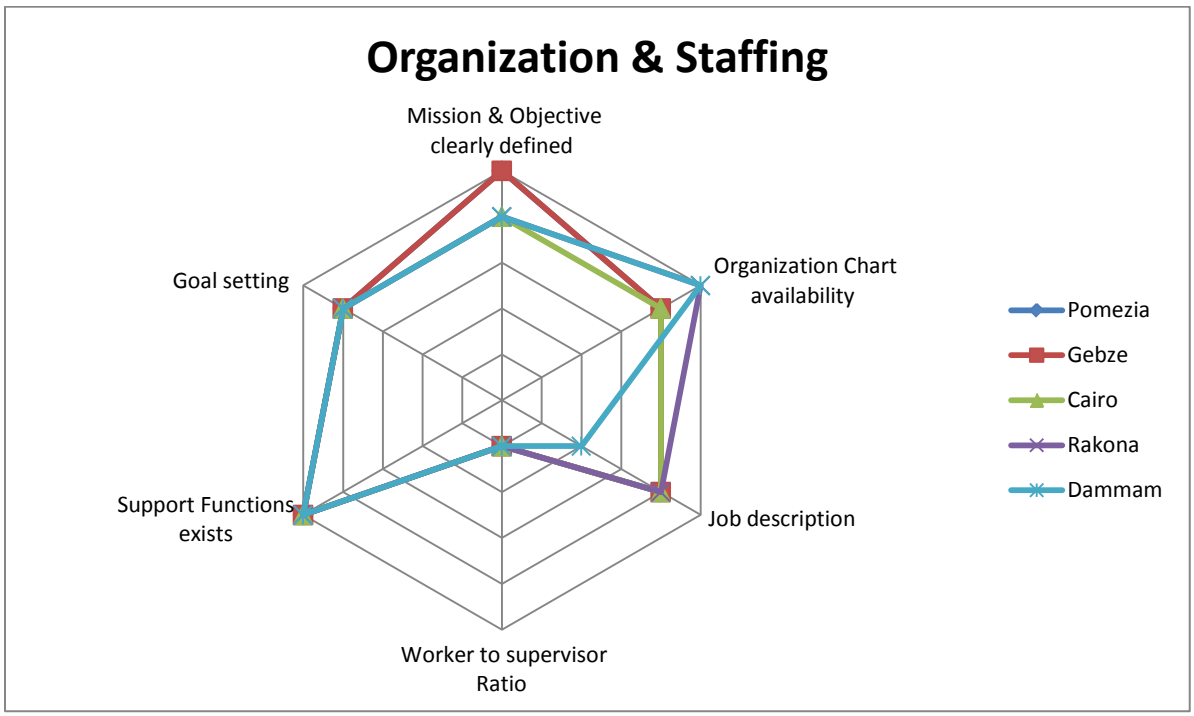

Figure 7. 1 **A Spider Chart showing Organization and staffing scoring per plant**

From figure 7.1 above, the following is concluded:

- In almost all of the benchmarked plants, organization charts, structure are reviewed, updated and shared among individuals

- Worker to supervisor ratio where similar among benchmarked plants, and they were all in the range of below 8:1.

- Dammam plant needs to have a more in depth of the missions and objectives for their maintenance teams.

- All benchmarked plants where similar in terms of goals and target setting.

- Support functions to maintenance teams where similar in all plants, the support functions include maintenance engineering, planning engineering, planner, Material coordinator, training coordinator, stores.

- A proper Job description needs to be more clearly defined in Dammam for each supervisor and his team members

2- Training	Pomezia	Gebze	Cairo	Rakona	Dammam	Benchmark	Gap
A training master plan exists for all levels of maintenance team (higher management, support, supervisors and technicians)	5	5	5	4	5	5	0
Productivity training is included for all	4	3	3	4	3	4	**1**
Types of Training Programs	5	5	5	5	5	5	0

Table 7.3 **Training scoring results per plant**

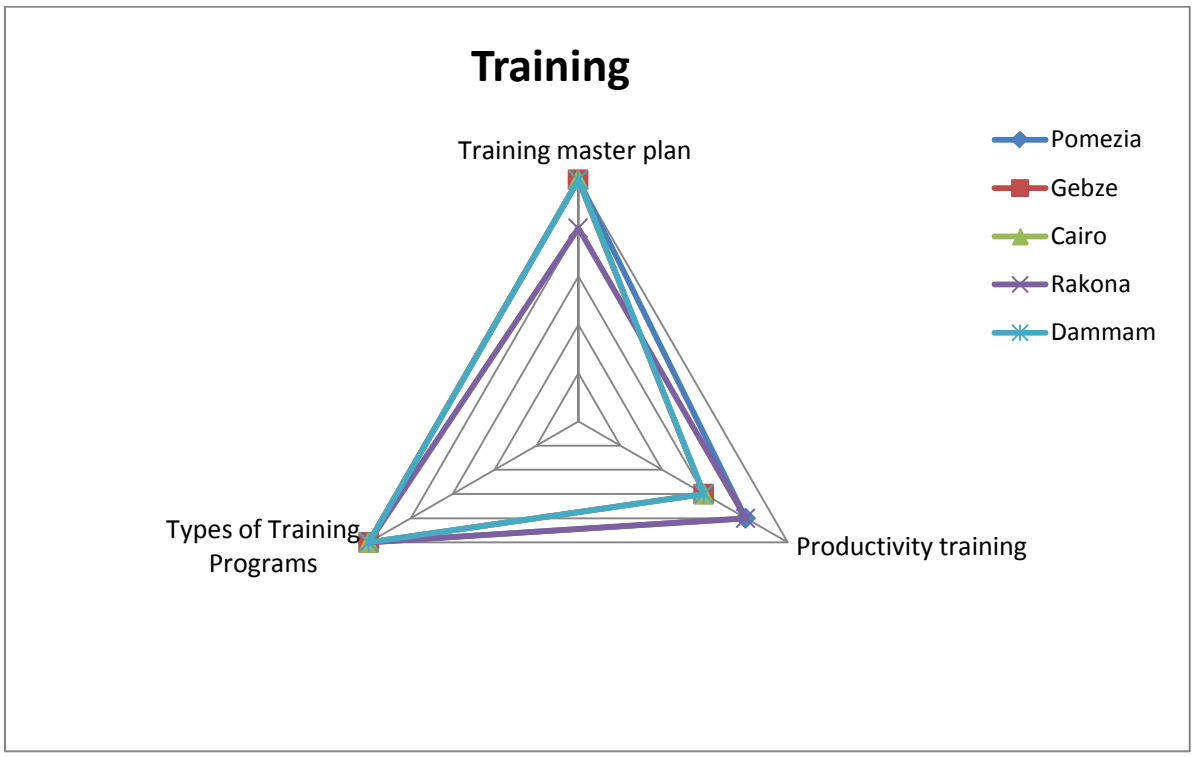

Figure 7.2 **A Spider Chart showing Training scoring per plant**

From figure 7.2 above, the following is concluded:

- In almost all of the benchmarked plants, a training master plan exists for all levels of maintenance teams. This includes higher management, support, supervisors and technician.

- Types of training programs in all plants where including formal and on job training.

- Productivity training for Dammam where only included for higher management and supervisors and not for operators/technicians.

-

3- Planner Training	Pomezia	Gebze	Cairo	Rakona	Dammam	Benchmark	Gap
planner Job Role and expectations exists	4	4	2	4	2	4	**2**
Planner job includes: work requests, planning and scheduling, productivity, methods improvements, material planning, project planning, maintenance practices, job standard timing, and computer communication?	4	3	3	3	4	4	**0**
Types of Training Programs for planner	4	4	1	4	1	4	**3**

Table 7. 4 **Planner Training scoring results per plant**

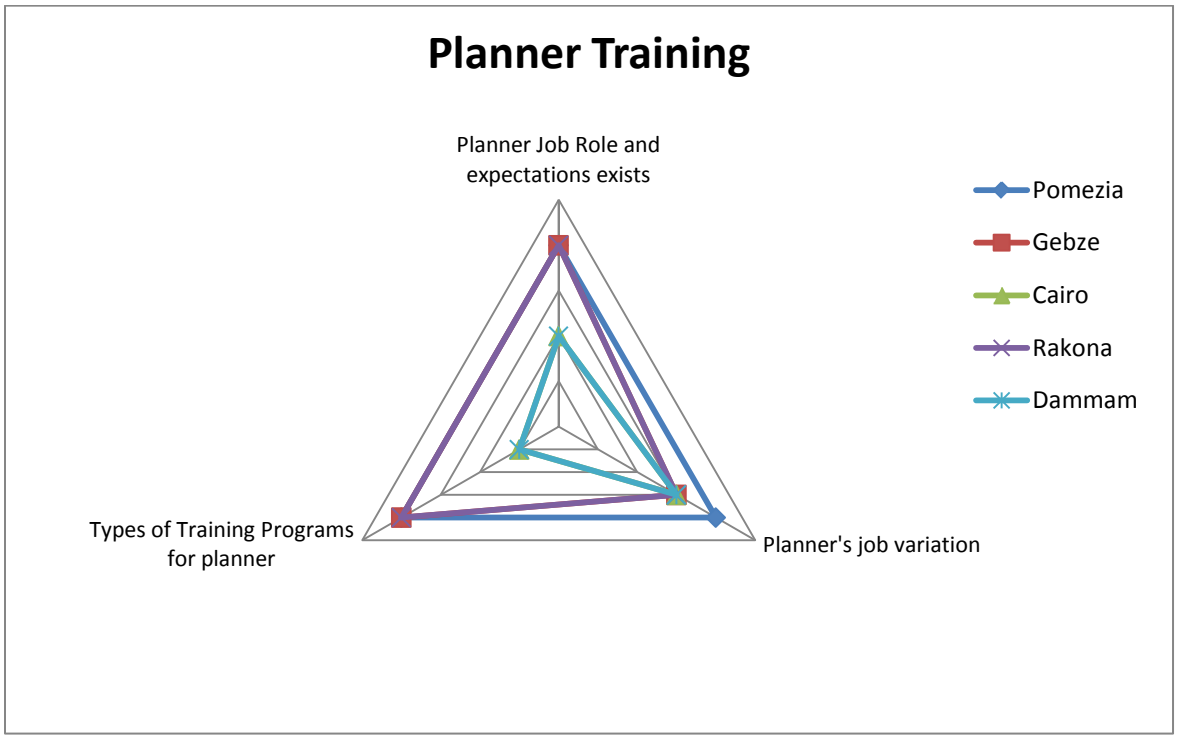

Figure 7. 3 **A Spider Chart showing Planner Training scoring per plant**

From figure 7.3 above, the following is concluded:

- In Cairo and Dammam, planner job roles and expectations does not exist

- In almost all plants, planner job includes work requests, planning and scheduling, productivity, methods improvements, material planning, project planning, maintenance practices, job standard timing, and computer communication.

- Types of training programs for Dammam where only targeting formal training, and not tackling on job training.

4- Craft Training	Pomezia	Gebze	Cairo	Rakona	Dammam	Benchmark	Gap
Formal craft training plan exists	5	5	5	5	5	5	0
Who performs the training?	5	5	5	5	5	5	0
Does minimum skill Requirements exists for each job?	4	4	4	4	4	4	0
% of craft included in training	5	5	5	5	5	5	0

Table 7. 5 **Craft Training scoring results per plant**

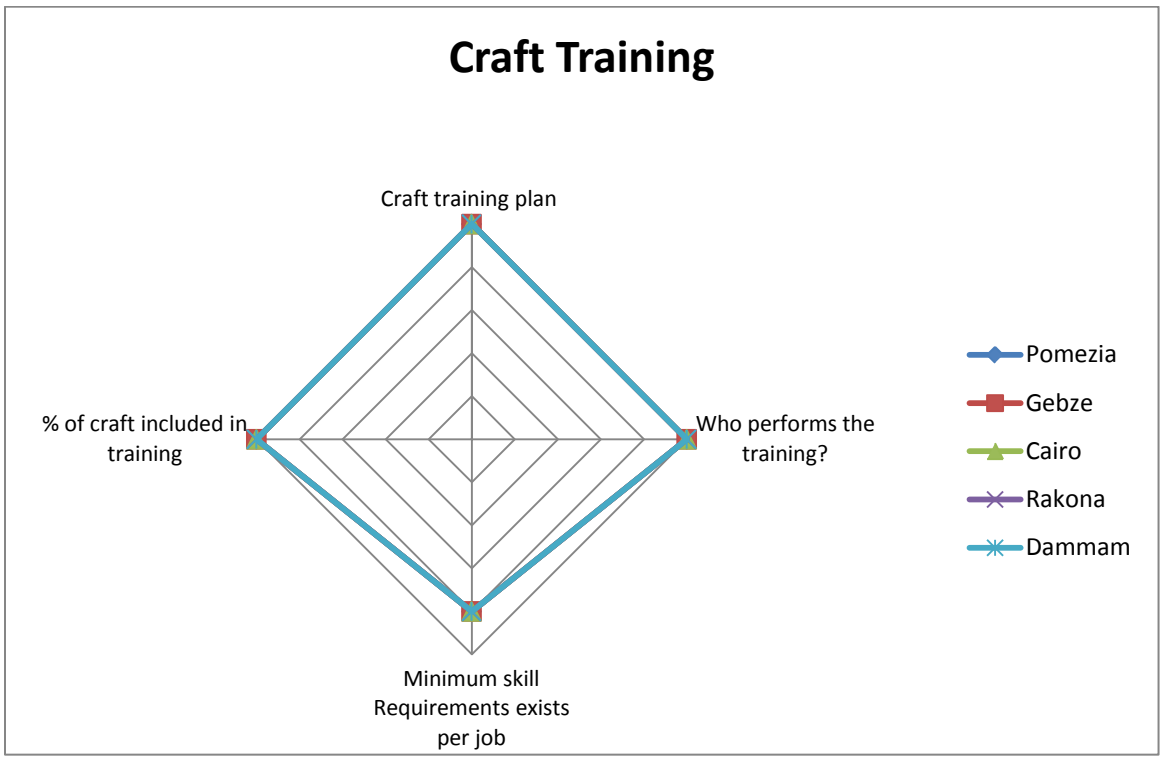

Figure 7.4 **A Spider Chart showing Craft Training scoring per plant**

From figure 7.4 above, the following is concluded:

- In almost all benchmarked plants, formal craft training (formal and on job training) exists.
- In almost all benchmarked plants, staff and line management performs craft training
- In all benchmarked plants, around 75% of the jobs have minimum skill requirement identified
- In all benchmarked plants, almost all craft have been included and targeted in training

-

5- Motivation	Pomezia	Gebze	Cairo	Rakona	Dammam	Benchmark	Gap
Work Climate is healthy between management and staff/labor	4	4	3	4	3	4	1
A "climate" survey has been completed recently	5	5	5	5	5	5	0
Turnover due to resignations and quits	4	4	3	4	2	4	2

Table 7. 6 **Motivation scoring results per plant**

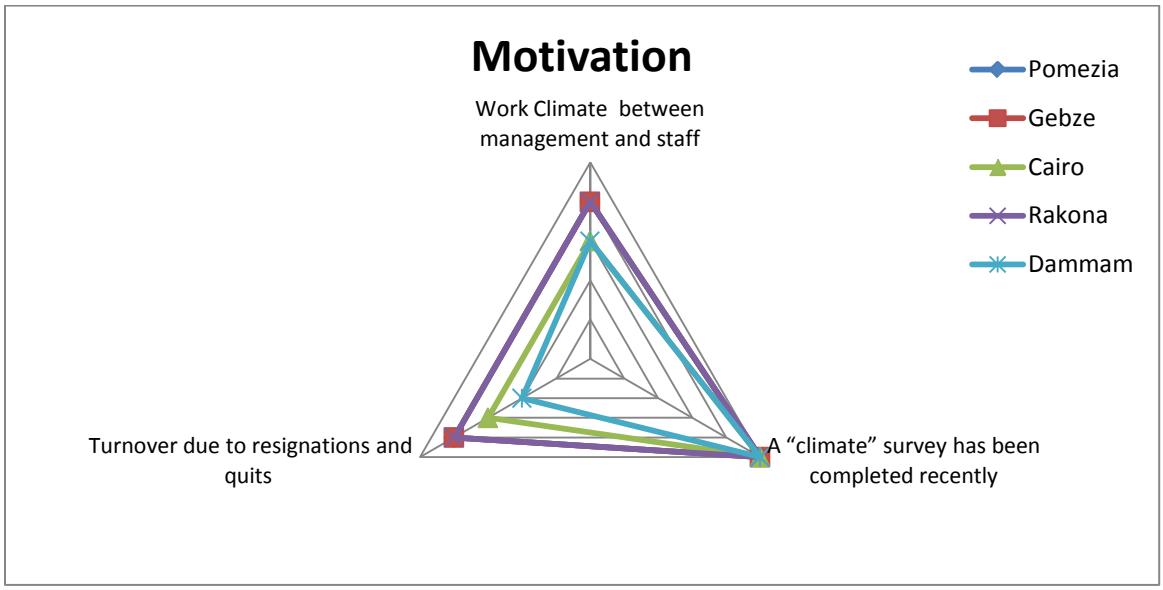

Figure 7.5 **A Spider Chart showing motivation scoring per plant**

From figure 7.5 above, the following is concluded:

- In all benchmarked plants, Work Climate was healthy between management and staff/labor

- In all benchmarked plants, a “climate” survey has been completed recently

- The turnover (due to resignations and quitting) was higher in Dammam than the rest of the plants (in the range of 6-8%)

6- Management Control & Budget	Pomezia	Gebze	Cairo	Rakona	Dammam	Benchmark	Gap
Budget concept being used to control maintenance costs	5	5	5	5	5	5	0
Following controls are used: Downtime %, performance, cost/ standard hour, productivity, backlog, service level and overtime	4	4	4	4	4	4	0
Time lag between period end and issuance of budget control report	5	5	5	5	5	5	0
Frequency of control reports issuance	4	3	3	4	5	5	0
Time and work reporting	5	5	5	5	5	5	0
Distribution criteria for report	4	4	4	4	4	4	0

Table 7. 7 **Management control and budget scoring results per plant**

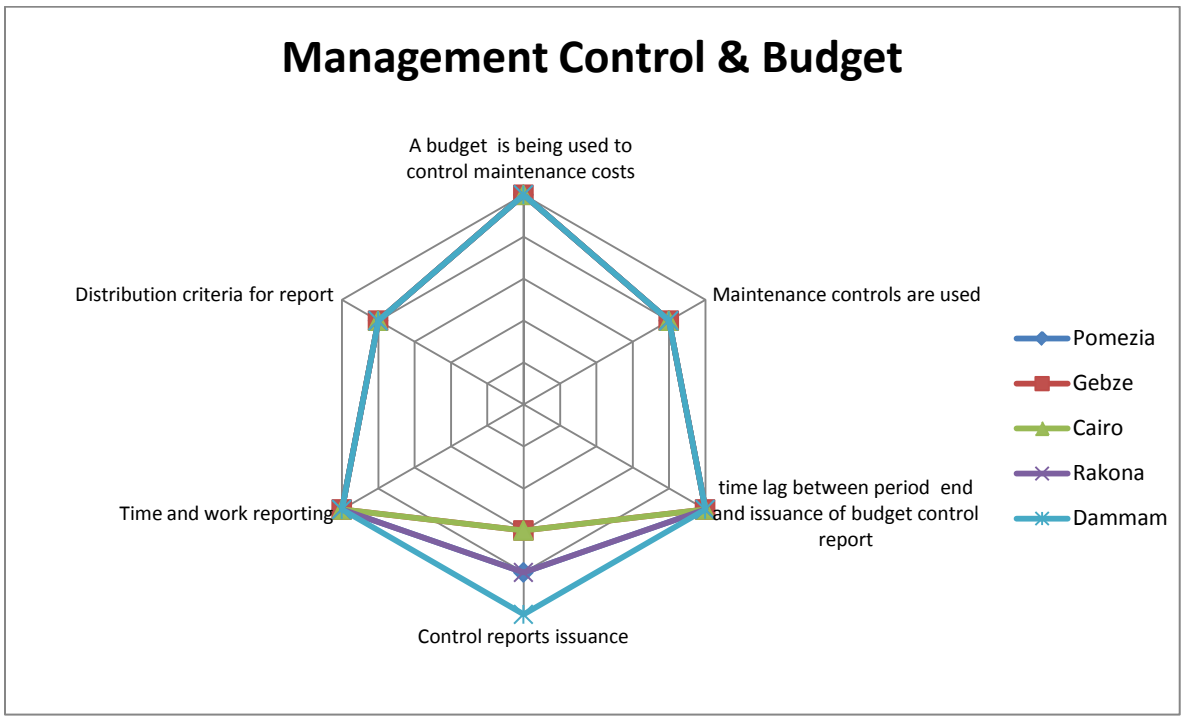

Figure 7.6 **A Spider Chart showing management control and budget scoring per plant**

From figure 7.6 above, the following is concluded:

- In all benchmarked plants, the budget concept being used to control maintenance costs and purchase orders, in addition to historical data tracking to control spending

- In all benchmarked plants, the following controls are used: Downtime %, performance, cost/ standard hour, productivity, backlog, service level and overtime

- In all benchmarked plants, time lag between period end and issuance of budget control report where less than one day

- In most of the benchmarked plants, control reports are issued on a daily basis.

- In all benchmarked plants, time and work are reported by individual and by job.

- The distribution of the reports where to supervisors in all benchmarked plants.

7- Work Order Planning and scheduling	Pomezia	Gebze	Cairo	Rakona	Dammam	Benchmark	Gap
% of man hours covered by written work request	5	5	5	5	5	5	0
Percentage of work orders have enough planning times (2-4 weeks)	5	5	5	5	5	5	0
Percentage of work request planned: crew size, work content, materials, special tools, sequencing, time standard and scheduled date	4	4	4	4	4	4	0
Overhaul work pre-planned and scheduled	5	5	5	5	5	5	0
Quality check by supervisor on the quality of work done	5	5	5	5	5	5	0

Table 7.8 **Work order planning and scheduling scoring results per plant**

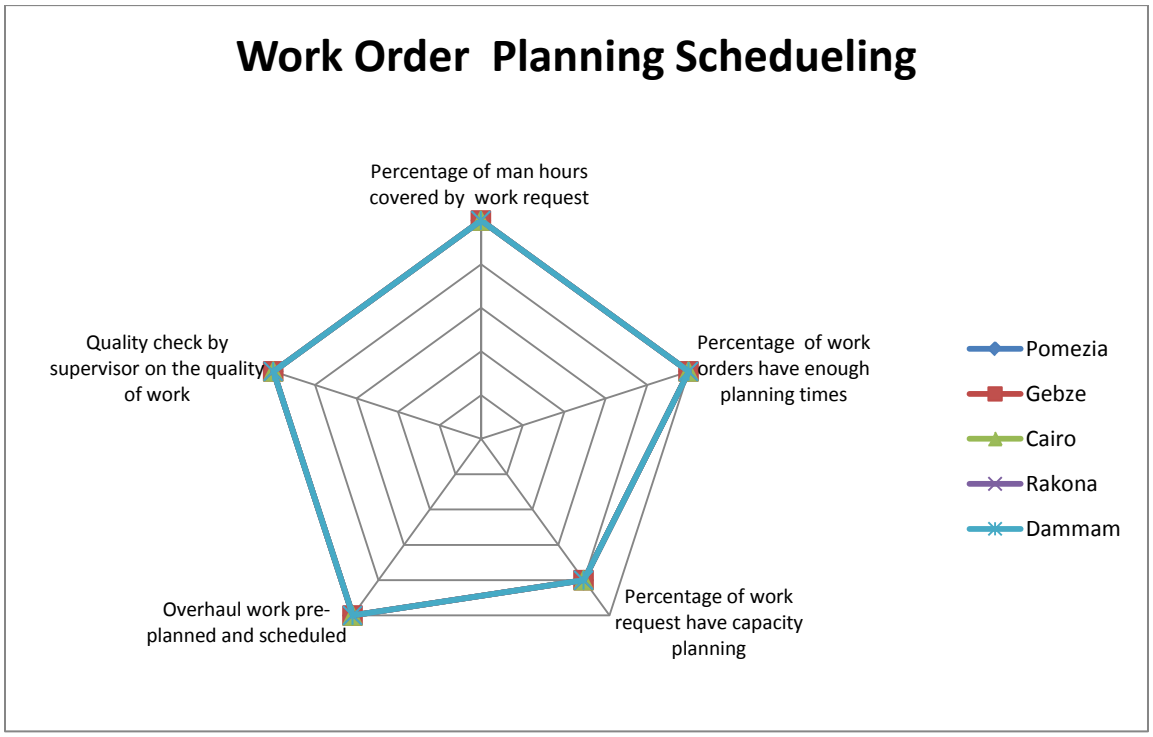

Figure 7.7 **A Spider Chart showing Work order planning and scheduling scoring per plant**

From figure 7.7 above, the following is concluded, in all benchmarked plants:

- More than 90 % of man hours were covered by written work requests
- More than 90 % Percentage of work orders have around 2-4 weeks of planning time
- More than 90% of work requests were having the following items planned: crew size, work content, materials, special tools, sequencing, time standard and scheduled date
- More than 90% of overhaul work was pre-planned and scheduled
- More than 90% of the work have been quality checked by supervisors

8-Facilities	Pomezia	Gebze	Cairo	Rakona	Dammam	Benchmark	Gap
Maintenance shops and layouts are designed in a satisfactory way	5	5	5	5	5	5	0
Level of housekeeping	4	4	4	4	5	5	0
Safety equipment and signs (such as lock out tag out, wet floor, Hazardous area…) is being used?	5	5	5	5	5	5	0
Equipment and tools effectively located	5	5	5	5	5	5	0
Availability of tools to operators and mechanics:	5	4	4	5	4	5	1
Cranes, lifts and doors covered by PM Program	5	5	5	5	5	5	0

Table 7. 9 **Facilities scoring results per plant**

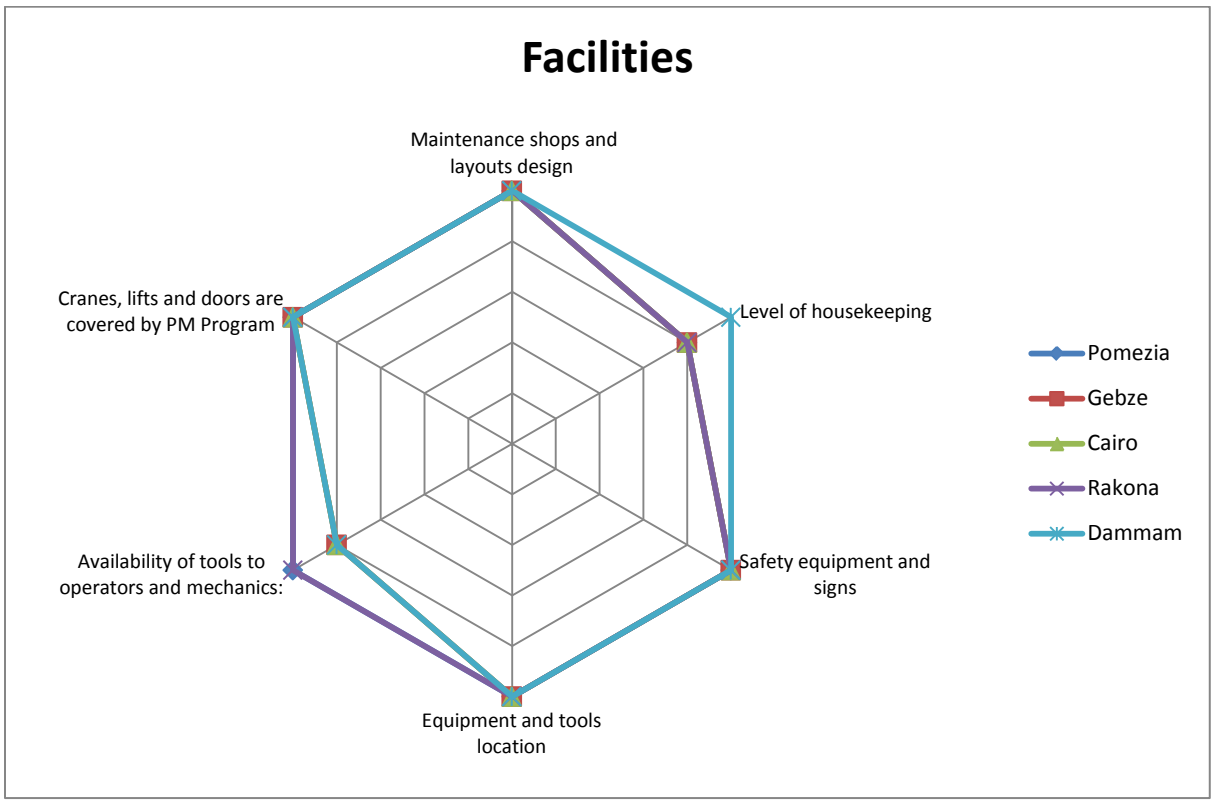

Figure 7.8 **A Spider Chart showing facilities scoring per plant**

From figure 7.8 above, the following is concluded:

- In all benchmarked plants, maintenance shops and layouts are designed in a satisfactory way
- Majority of benchmarked plants had a satisfactory level of housekeeping
- In all benchmarked plants, more than 90% of Safety equipment and signs (such as lock out tag out, wet floor, Hazardous area…) is being used
- In all benchmarked plants, Equipment and tools were effectively located
- Majority of benchmarked plants had the tools to operators and mechanics available
- Are cranes, lifts and doors were covered by PM Program in all benchmarked plants

9- Material and tool control	Pomezia	Gebze	Cairo	Rakona	Dammam	Benchmark	Gap
An up-date Store Catalog exists	4	3	3	4	4	4	0
Iinventory system for major items and spares	5	5	5	5	5	5	0
Re-ordering system for high volume, low cost items	5	5	5	5	5	5	0
Items and spare parts are controlled with use withdrawal procedure	5	5	5	5	5	5	0
A control procedure on use of company tools	4	3	3	3	3	4	1
A standard list of tools provided to the individuals by the company	5	5	4	5	5	5	0
Tools that are out of service for repair	2	2	2	2	1	2	1
Economic order quantities calculated	0	0	0	0	0	0	0
Maximum/minimum levels are set and maintained	5	4	4	5	5	5	0
Purchasing maintain a vendor rating system for suppliers	4	5	5	5	5	5	0
Percentage of material orders are delivered on time	5	5	5	5	5	5	0

Table 7. 10 Material and tool control scoring results per plant

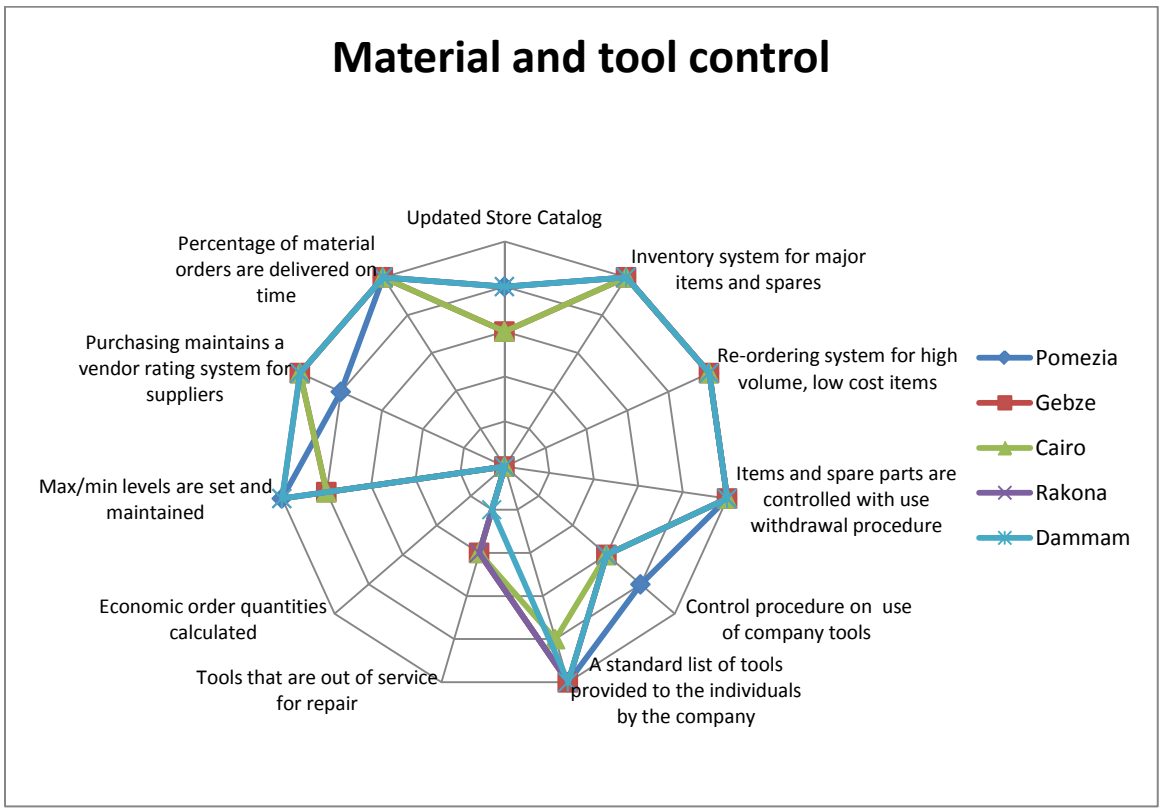

Figure 7. 9 **A Spider Chart showing material and tool control scoring per plant**

From figure 7.9 above, the following is concluded:

- Most plants have an up-date Store Catalog for major items
- An inventory system for major items and spares exists in all benchmarked plants
- A re-ordering system for high volume, low cost items exists in all benchmarked plants
- Items and spare parts are controlled with use of withdrawal procedure in all benchmarked plants
- More than 50% of company tools are controlled with a use procedure in all benchmarked plants
- Almost all plants have a full standard list of tools provided to their individuals

10-Planned Maintenance and Equipment History	Pomezia	Gebze	Cairo	Rakona	Dammam	Benchmark	Gap
Percentage of equipment that has a maintenance repair history	4	5	4	4	4	5	1
Maintenance records that are reviewed at least once a year	5	5	5	5	5	5	0
Percentage of major equipment are included in Planned Maintenance routines	5	5	5	5	5	5	0
Equipment percentage that is covered by downtime trends, PM compliance with schedule, written PM instructions, total PM-man hours, high repair item man-hours	4	4	4	4	4	4	0
Reports frequency	4	4	3	4	3	4	1

Table 7. 11 Planned Maintenance and equipment history scoring results per plant

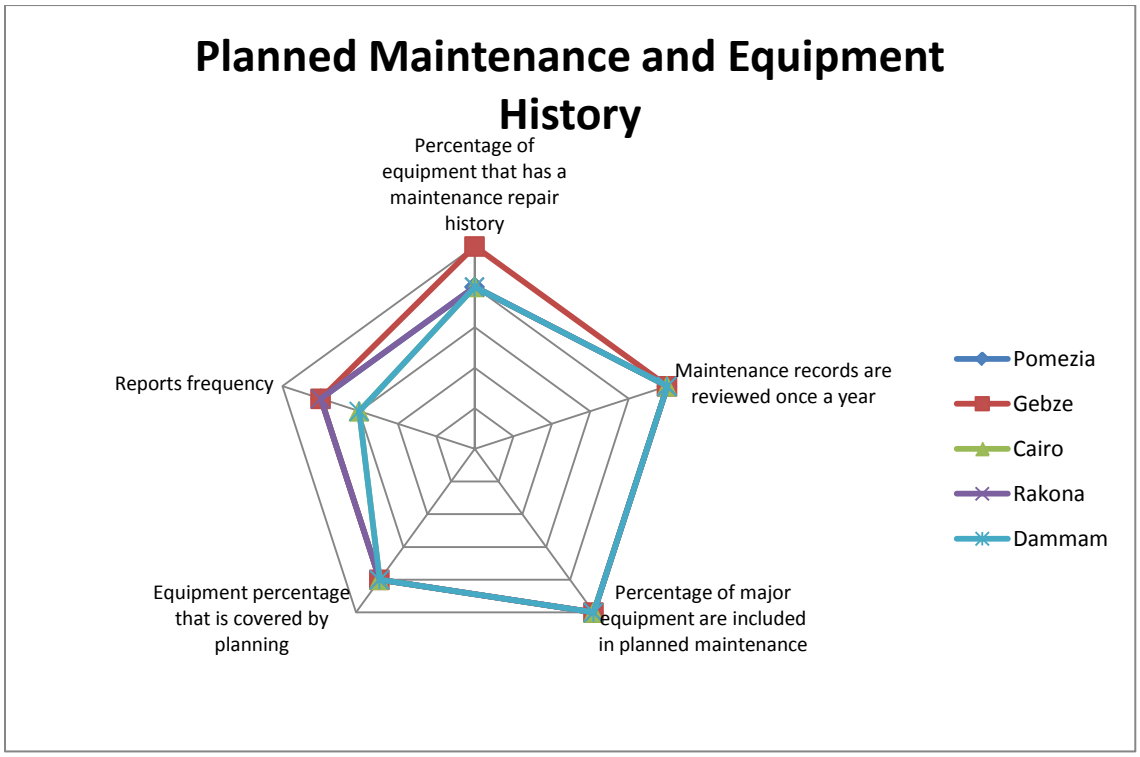

Figure 7.10 A Spider Chart showing planned maintenance and equipment history scoring per plant

From figure 7.10 above, the following is concluded:

- Dammam has a maintenance repair history for around 75% of their equipments; however, some of the benchmarked plants have it for almost all of their equipments.

- In all benchmarked plants, all maintenance records were reviewed at least once per year.

- In all benchmarked plants, all equipments were included in Planned Maintenance routines

- In all benchmarked plants, around 75% of equipment were covered the following systems: downtime trends, PM compliance with schedule, written PM instructions, total PM-man hours, high repair item man-hours

- In most of the plants, reports are prepared on a weekly basis. Both Dammam and Cairo reports were issued monthly rather than weekly

11- Engineering and Condition Monitoring	Pomezia	Gebze	Cairo	Rakona	Dammam	Benchmark	Gap
Reliability Engineering is used to control downtime on the major equipment in what percentage?	5	5	5	5	5	5	0
Percentage of equipment is using MTBF and MTTR measures	2	3	3	2	3	3	0
Percentage of major repairs and construction projects have an engineer assigned?	4	4	4	4	4	4	0
Reliability Engineering is used to control downtime on the major equipment in what percentage?	5	5	5	5	5	5	0
Percentage of major equipment is using the following diagnostic routines: vibration analysis, heat sensing, erosion, corrosion, electrical, gauging):	1	1	1	1	1	1	0
A ranking system exists for your equipment?	5	5	5	5	5	5	0
A clear criteria of ranking your equipment	5	5	5	5	5	5	0
Percentage of your equipment that is currently ranked	5	5	5	5	5	5	0

Table 7.12 **Engineering and condition monitoring scoring results per plant**

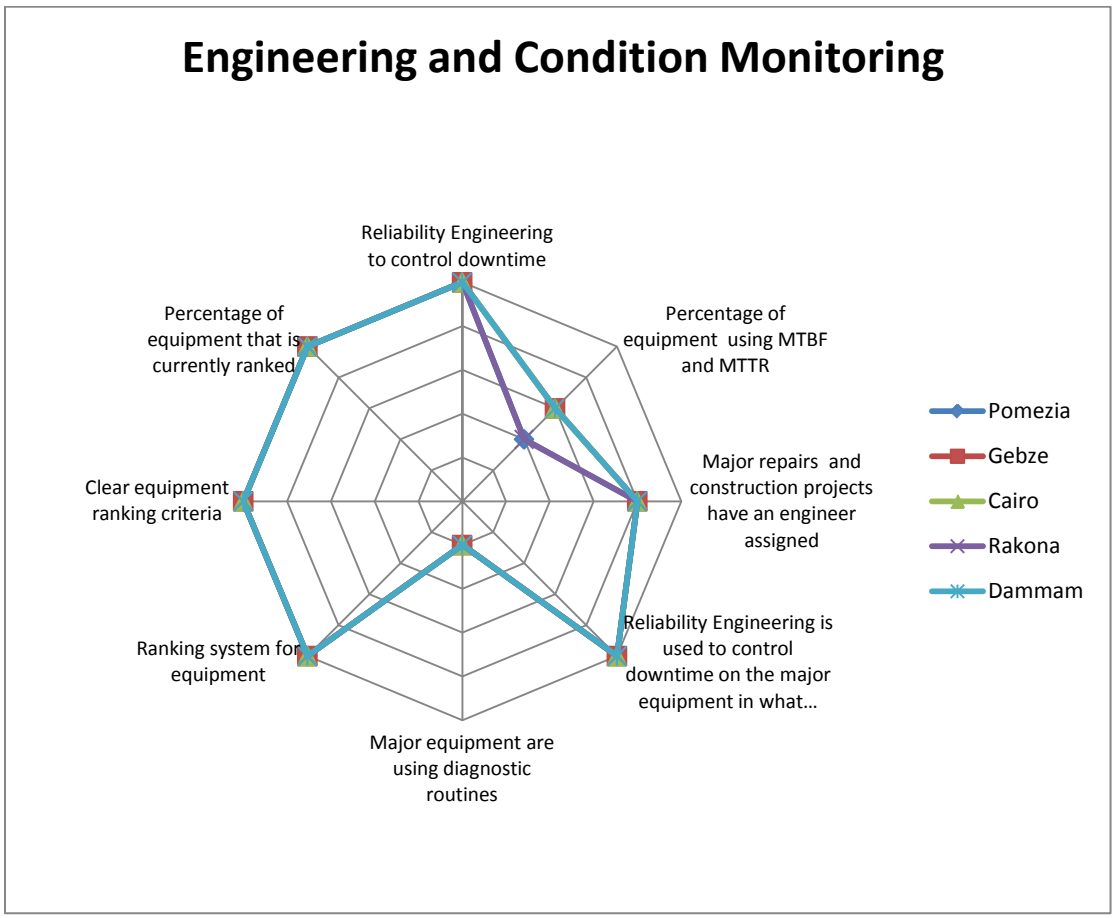

Figure 7.11 A Spider Chart showing engineering and condition monitoring scoring per plant

From figure 7.11 above, the following is concluded:

- In all benchmarked plants, reliability engineering is used to control downtime on the major equipment.
- 25-50% of equipment were under MTBF and MTTR measures across plants
- In all plants, around 75% of major repairs and construction projects have an engineer assigned
- In all plants, reliability engineering is used to control downtime on almost all major equipment

- Around 25% of major equipment is using the following diagnostic routines: vibration analysis, heat sensing, erosion, corrosion, electrical, gauging)

- A ranking system for almost all equipment exists for all plants

- A clear equipment ranking criteria exists for all participating plants.

- Almost all equipments are covered by the ranking system in all plants.

12- Work Measurement and Incentives	Pomezia	Gebze	Cairo	Rakona	Dammam	Benchmark	Gap
Time maintenance standards	4	3	3	5	3	5	2
Percent of actual hours worked are covered by time standards	3	2	2	3	2	3	1
Job times written on the work request for the worker and the supervisor to see	3	0	0	3	0	3	3
Percentage of workers are paid by incentives plan related to output	5	5	5	5	5	5	0
Type of incentive plan used	4	4	4	4	5	5	0

Table 7.13 Work measurement and incentives scoring results per plant

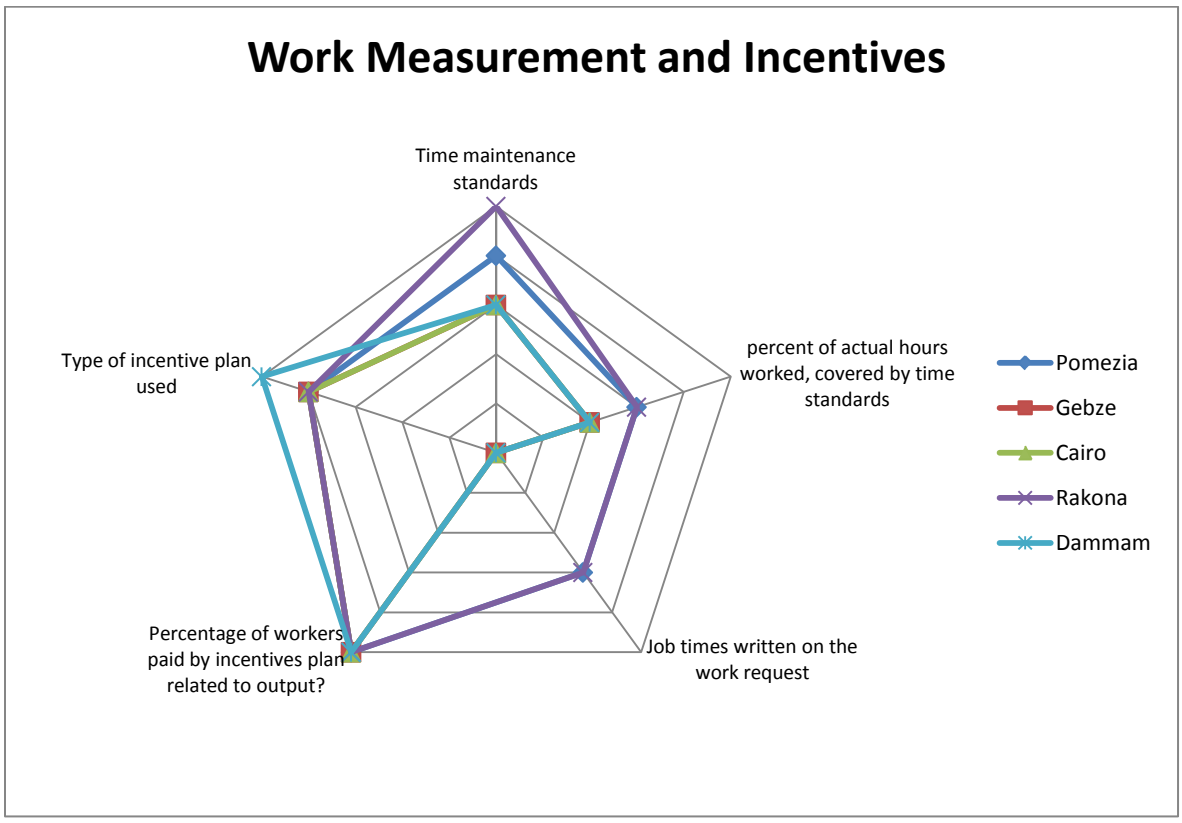

Figure 7. 12 **A Spider Chart showing work measurement and incentives scoring per plant**

From figure 7.12 above, the following is concluded:

- In Dammam, time maintenance standards are set by estimate, however, in some plants such as Rakona, time maintenance standards are set with predetermined time, time study and standard data.

- In Dammam, percentage of actual hours worked that are covered by time standards is less than 50%. In other benchmarked plants (Pomezia/Rakona), this percentage was in the range of 50-74% (less than 75%).

- In most of the plants, job times are not written on the work request for the worker and the supervisor to see, however, for both Pomezia and Rakona plants, job times are clearly mentioned on the work request for both worker and supervisor visibility.

- In all benchmarked plants, more than 90% of workers are paid by incentives plan related to their output.

- Most plants uses salary adjustment or bonuses as an incentive for the workers.

13- Labor Productivity	Pomezia	Gebze	Cairo	Rakona	Dammam	Benchmark	Gap
Maintenance productivity	5	4	2	4	3	5	2
Daily work time card for all workers	4	3	3	4	3	4	1
Productivity reports are prepared:	2	2	2	2	2	2	0

Table 7.14 Labor productivity scoring results per plant

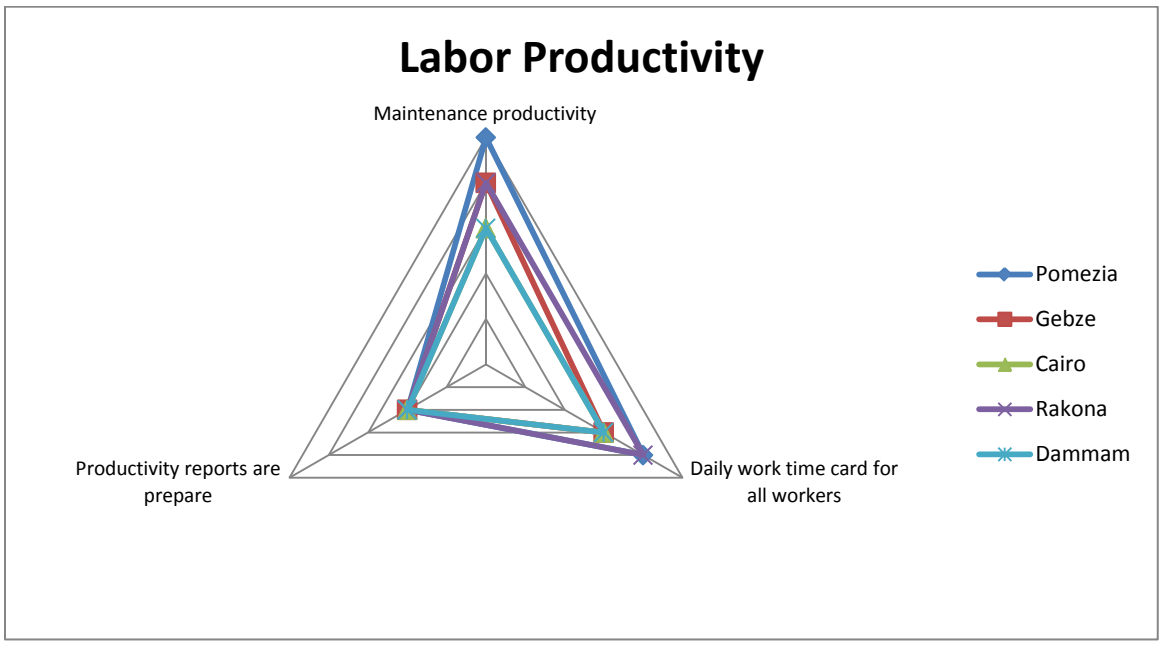

Figure 7. 13 **A Spider Chart showing labor productivity scoring per plant**

From figure 7.13 above, the following is concluded:

- In Dammam, maintenance productivity was in the range of 50-75 statistical units/person/month, where it was more than 100 in benchmark plant (Pomezia)

- A daily work time card exists for around 50-74% of workers in Dammam, where it was in the range of 75 to 89% in the benchmark plant.

- In all benchmarked plants, productivity reports are prepared for departments only, and not by individuals.

14- Information Systems	Pomezia	Gebze	Cairo	Rakona	Dammam	Benchmark	Gap
Maintenance system includes computer support	5	5	5	5	5	5	0
Available information categories	4	3	2	3	3	4	1
System match capability with individual responsibility	4	4	4	4	4	4	0
Reports timing	3	3	3	3	3	3	0
Information is complete and reliable	5	5	5	5	5	5	0
Security system controlling who has access and to what level	4	4	4	4	4	4	0

Table 7.15 **Information system scoring results per plant**

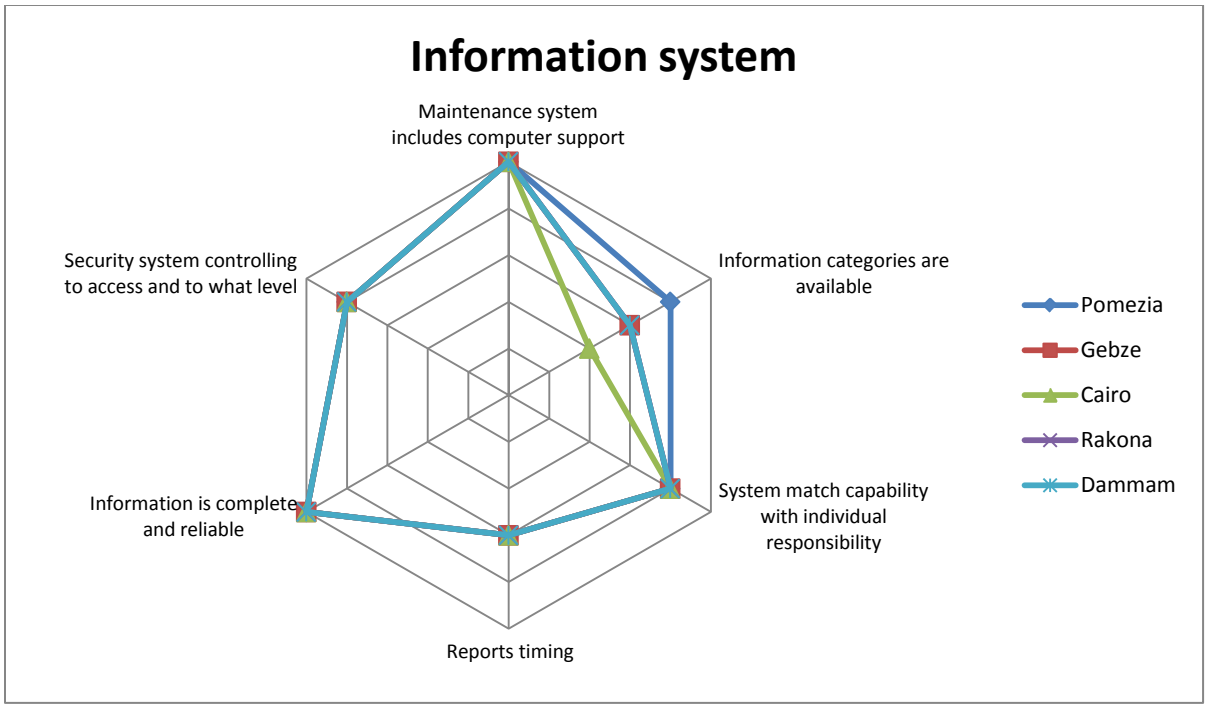

Figure 7.14 A Spider Chart showing Information system scoring per plant

From figure 7.14 above, the following is concluded:

- All plants maintenance systems include computer support

- In Dammam plant, around 50% of the following information systems where available: Payroll, time reporting, work request, job planning, daily schedule for routine work, long range scheduling for projects, management control reports, downtime, equipment history, planned maintenance, stores and material control, statistical analysis, cost justification. In the benchmark plant (Pomezia) the result was 75%.

- All plants mentioned that their system match capability with individual responsibility

- In all benchmarked plants, reports are issued on a weekly frequency.

- All benchmarked plants have identified that their information are complete and reliable

- All plants have mentioned that their security system controlling access/ level is excellent.

CHAPTER 8

SUGGESTIONS AND IMPROVEMENTS

This chapter summarizes suggestions and improvements that were developed based on our benchmarking study in each of the identified key maintenance factors. The main outcomes of planned maintenance is presented in section 8.1, similarly, section 8.2 will present outcomes found in organization and staffing, section 8.3 will present suggestions and improvements in work order planning and scheduling, section 8.4 will present outcomes found in training and craft training and finally section 8.5 will present outcomes found in work measurement and incentives.

8.1 Planned Maintenance

Reviweing planned maintenance system in Dammam (as well as other plants), it can be noticed that the plant has been following the standard in terms of covering majority of

equipment under the maintenance program, this comes as well with good record keeping and frequent reviews.

As seen in our benchmark study (figure 7.10) Dammam can benefit from the good historical maintenance repair at Gebze plant, where the record keeping extends to almost 100% of its equipment vs. around 75% of equipment at Dammam plant. This includes documenting current system work flow, staffing and skill requirements.

It was noticed that in all benchmarked plants, all maintenance records were reviewed at least once per year; all equipments were included in Planned Maintenance routines.

Dammam can also start issuing maintenance reports on a weekly basis rather than on a monthly basis, and here the plant can benefit from the strong daily management systems (DMS) applied in Gebze plant where they are applying breakdown elimination and Process Failure eliminations DMS (tables 5.5 and 5.7), in addition to applying systems measures (both output and in process) ensuring system sustainability and predictability (tables 5.6 and 5.8). System output measures include: number of major breakdowns, percentage of repeated breakdowns, and reliability loss due to breakdowns. In addition, Gebze plant is focusing on the following planned maintenance indicators Reliability and maintainability, maintenance efficiency and maintenance cost (see tables 5.3, 5.4 and 5.5).

8.2 Organization and Staffing

It can be seen from our benchmarking study, done in organization and staffing (figure 7.1), that Dammam plant needs to have a more in depth missions and objectives for their maintenance teams: good examples here are seen in both Gebze and Pomezia plants: where a clear mission and objective exists for maintenance teams, coming as a partial mission from the total site's mission and objective.

Dammam plant needs to have a clear job description for each maintenance team member, again, Pomezia plant is excelling here. Dammam can start benchmarking roles and responsibilities used in Pomezia plant (there are some good examples in Rakona and Gebze as well). Here is an example used form Pomezia plant, for the site breakdown elimination DMS owner:

The role of the Site Breakdown DMS Owner is to implement, and or maintain and continuously improve the Breakdown Elimination DMS for the site, and to provide a continuity link to other maintenance systems. It is also the role of this system owner to actively participate in Global Benchmark/Reapplication efforts.

Results are: 1-Reduced # of breakdowns, 2-Reduction in repeatable breakdowns nearing zero, 3-Reduction in break-in maintenance activities, 4- Reducing maintenance cost (parts and labor) through the updating of standards and procedures, in line with budget or on glide path 5-Equipment performance is controlled and predictable, due to percent increase of planned maintenance work, 6-Improved Equipment availability and 7-Increased MTBF

The responsibilities are: 1-Renewal of BDE DMS as a site progresses, 2- Training of other Site DMS owners on execution of the DMS (to include capturing data, root cause analysis, development of themes, reapplication tracking), 3-Health Checks developed and executed across departments

4-Ensure meetings are established on a set frequency by department with clear meeting expectations (everyone knows what the tasks for this DMS are daily, weekly, monthly)

5-Ensuring tracking of Breakdowns is done by department and results trending properly as it links to site business need, 6-Global Benchmarking of results, 7-Sharing of re-application opportunities, 8-Identifying losses in DMS execution and build action plans to resolve and 9-Responsible to ensure action plans are built by department to close gaps on any targets not on track to deliver projected results.

Reports to: Operations Leader

Skills/training required: Strong organizational and technical skills, strong Leadership skills, priority setting, communication and training Skills, SAP Maintenance and Store room skills and basic PC Skills.

8.3 Work Order Planning and Scheduling

Dammam plant is implementing a benchmark planning and scheduling system. This is obvious from the systems that are in place in this area, where we can find a detailed planning and scheduling system (see table 5.9), coupled with thorough output and in process system measures (table 5.10). System measures are mainly similar to those

mentioned in planned maintenance: number of major breakdowns, percentage of PR loss due to maintenance and process reliability. The in-process measures include: weekly/monthly/yearly maintenance adherence (MSA) percentage, percentage of maintenance scheduled 24 hours ahead, percentage of people trained on the system, percentage of work requests planned and percentage of those completed.

There were no major differences between other plants and Dammam on the effective implementation of this system.

In our benchmarking study, it was noticed (see figure 7.7) that majority (above 90%) of man hours were covered by written work requests, and more than 90% of work orders are planned within 2-4 weeks of time.

It was also noticed that majority of overhaul work was pre-planned and scheduled and majority of work done have been quality checked by supervisors.

8.4 Training (including craft training)

Dammam training program needs to focus on productivity training for all employees. Currently, productivity in Dammam (measured by: Production units/individual/year) training is only given to high and mid-level management. This needs to be expanded covering all employees including staff and technicians.

As seen in both tables 7.5 and figure 7.4, it was noticed that in almost all of our benchmarked plants formal and on job craft training exists, staff and line management performs craft training, around 75% of the technicians' jobs have minimum skill requirement identified and almost all craft have been included and targeted in training

Dammam can also benefit from the training offering and enrollment system used in other plants and below is the system suggested, similar to the system adopted by Rakona plant:

The purpose of the system is to standardize training offering, announcement, registration and enrollment processes for trainings offered in Rakona Plant.

Training systems leader is the process system owner, his/her responsibilities include:

- Training leader is responsible for the plant adherence.
- Trainings' owners are responsible to follow this SOP on how to offer trainings and manage enrollment.
- Department Leaders are responsible for SOP adherence in their department and accountable for their department capability (skill completion level).

General system guidelines are as follows:

- Training Offering and enrollment System explains how trainings are offered, announced and when it can be canceled. It also explains how to enroll in trainings, how the enrollment is managed and how to drop from trainings if needed.

- Training announcement is a process initiated by Training center to ensure that all targeted individuals for a specific training are informed about the training time and place. It is also considered a commitment from training center to all targeted individuals and their managers to deliver the training in the specified date, time and place.
- All trainings are considered confirmed once announced; No training confirmation will be shared. In case trainings are cancelled, targeted individuals will be notified.
- Registration is a request from the individual or his manager to enroll in training.
- Enrollment is a confirmation that the individual is eligible and has to attend the training.
- In any condition, no individual should attend any training without enrollment.
- Drop out is a request from the individual or his manager to cancel his registration or enrollment.
- It is the responsibility of the individual to attend the training once his enrollment is confirmed.
- An individual should register for trainings that are needed by his skill matrix only.

The system procedure will be as followed:

I. Site Annual Training Plan

1) Site training leader, the system owner and other department representatives develop the site annual training plan based on the prioritized training list developed after need assessment.
2) Site training leader announces next year site annual training plan no later than end of year

3) The site annual training plan is revised at the beginning of each quarter.

II. Monthly Training Calendar

1) Department owners send their monthly training calendars (date and time) for next month to the system owner no later than the 5th working day of the current month.
2) The system owner resolves any time conflicts with the alignments of department owners.
3) The system owner announces the site monthly training calendar for next month no later than the 10th working day of the current month. The announcement is sent via email to all plant
4) Training administrator posts the monthly training calendar on training master plan board,
5) The monthly training calendar specifies next month trainings' dates, times, trainers, locations and way of registration
6) The monthly training calendar is considered training offering and announcement for all trainings specified in it.

III. Non - Monthly Training Offering:

1) While it is possible to offer trainings after the announcement of monthly training calendar, training leaders should make every effort to ensure that all of their trainings are announced in the monthly training calendar.
2) Trainings' owners may offer training after the announcement of the monthly training calendar provided that there is at least 10 working days before the training. Otherwise the training is considered ad hoc (see next section).

3) The system owner announces the training to the targeted individuals specified by the training owner.

IV. Ad hoc Training offering:

1) Trainings offered less than ten working days before the training are considered ad hoc.
2) For ad hoc trainings, the training owner manages announcement and offering and handles enrollment.
3) The system owner offers a place for the training if available and document attendance and evaluation only.

V. Enrollment planning

1) Individual checks his skill matrix to identify his gap.
2) Training systems leaders in each department shares monthly calendar and identify potential gaps (according to site skill completion report) in their departments meetings.
3) Each representative in the department checks the gap in his department.
4) Each representative in the department leads his training enrollment process by working with the individuals and their managers according to monthly calendar, gap and business needs.

VI. Registration for trainings offered traditionally

1) Each representative in each department manages the enrollment of his department individuals for his pillar trainings.
2) The department representative nominates trainees to their managers using enrollment request form
3) The department representative sends (email) the agreed enrollment list (individuals should be notified before) to the system owner

4) Training administrator updates Training database and post enrollment on training master plan board and training website. This update should be on a daily basis.
5) Department representatives verify their department enrollments from training master plan board or SharePoint website and communicate this to individuals (for individuals working in day time) and to operation systems leader (for individuals working in shifts).
6) At this stage the individual is considered enrolled in this training.

VII. Drop Out:

1) Individual may drop from training if needed with the alignment of his manager while he is enrolled without any further consequences if he did so at least 5 working days prior to the training.
2) The individual has to fill the drop out form in case he is enrolled and the drop out was less than 5 working days prior to the training, at the day of the training or after the training. This drop out case should be only under emergency (business or personal) and if the emergency was business related, his manager alignment should be taken prior to the drop out.
3) Individuals working in shifts are not required to submit drop out form. However, their direct managers are still accountable on their drop outs.
4) The drop out from must be signed and submitted to the system owner no later than 4 working days after the training.
5) If the form was not submitted, the drop out will be documented by training leader using the drop out form.
6) If the justification was acceptable, training administrator mark his attendance excused in database.

7) If the justification was not acceptable or the drop out form was not submitted within four working days after the training, training administrator mark his attendance absent in database and the original record of the drop out form should be kept for six months.
8) In all cases, individual should be informed about the result of his drop out no later than 5 working days after he submitted his drop out form.

VIII. Training cancellation:

1) If training has to be cancelled, the training owner must ask for this at least 4 working days before the training and the training leader should be aligned. Otherwise, the training will be conducted with the current conditions.
2) An exception is when the trainer has personal emergency.
3) The system owner announces the cancellation to the concerned department representatives.
4) The concerned department representatives convey the cancellation to the targeted individuals.

IX. System Effectiveness Check

1) Annual training plan announced no later than end of year
2) Trainings' calendars are received before the end of 5rd working day.
3) Monthly Training calendar announced before the end of 10th working day.
4) Drop out not less than 5 working days before the training (if any).
5) Trainings not canceled less than 4 working days before the training (if any).

----------END OF System Procedure----------

8.5 Work Measurement and Incentives

Dammam maintenance teams are looking to have a better work-life balance, coupled with good incentives and rewarding system. Dammam can benchmark with plants in Europe where labor force do exert pressures on organization for raising incentives and abiding by a certain work hour timings. Employees have the right to accept or reject proposed overtime by their managers.

Benchmarking Dammam plant results with other plants (see figure. 7.12), the following can be suggested:

- The percentage of actual hours worked that are covered by time standards should not be less than 50% as in Pomezia/Rakona plants, where the percentage was in the range of 50-74%

- Dammam should benchmark the work request system applied in both Pomezia and Rakona plants where job times are clearly mentioned on the work request for both worker and supervisor visibility.

- In all benchmarked plants, more than 90% of workers are paid by incentives plan related to their output.

- Most plants uses salary adjustment or bonuses as an incentive for the workers.

In addition to the above, Dammam can benefit from the detailed incentives system used across other P&G plants, see chapter 5 incentives system review.

CHAPTER 9

CONCLUSIONS

9.1 Summary

This research has answered the question of how to improve maintenance practices and processes in a Dammam plant via benchmarking other plants operation in the region. This study methodology has been done via benchmarking six key maintenance factors, determined via using analytic hierarchy process (AHP) methodology. This study has proven that these maintenance factors are applicable to our researched industry.

The plants review chapter shows the key output maintenance measure among the benchmarked plants, and the key observations during our benchmarking visits, and the previous chapter summarizes the key suggestions and improvements in the 6 maintenance factors that need to be done, in order to improve Dammam plant maintenance systems, reaching to a benchmark maintenance standards.

9.2 Main Recommendations and Further Research

As thoroughly discussed in the previous chapter, the main recommendations for Dammam plant would be focusing on achieving maintenance output measures through applying strong daily management system for planned maintenance, such as the one applied in Gebze plant; this includes issuing weekly maintenance reports tracking those measures, rather than monthly ones.

Dammam plant needs to develop more in depth missions and objectives for its maintenance teams, preferably coming as a partial mission from the total plant's mission and objective. In addition to that, benchmarking roles and responsibilities for this team, such as the one that is applied Pomezia's plant, would be of great value.

In training, Dammam plant program needs to focus on productivity training for all employees, rather than management only. Dammam can also benefit from the training offering and enrollment system used in other plants such as the one used in Rakona plant.

In work measurement and incentives, the recommendation is that Dammam plant should benchmark the work request system applied in Rakona plant where job times are clearly mentioned on the work request for both worker and supervisor visibility, as well as that, it is recommended that the plant should work on increasing the percentage of actual hours worked that are covered by time standards, to be above 50% as in Pomezia/Rakona plants. Finally, it is recommended that the plant should implement the incentives system, found in other P&G plants, such as the one thoroughly discussed in chapter 5.

Further research for this study can be focused towards the outcomes of implementing the suggested recommendations, the correlation between the presented fourteen (14) maintenance factors, in addition to adding possible extra maintenance factors that were not part of this research.

APPENDIX A1

AHP Methodology Applied to Identify Key Maintenance Processes

Tables A1 to A8 below shows the results of applying AHP methodology to benchmarked plants and identifying key maintenance processes (Gebze, Cairo, Rakona and Dammam) in each plant:

	Org & Staffing	Training	Planner Trng	Craft Trng	Motivation	Mangmt Ctrl & Budget	Work Order P&S	Facilities	Material & tool ctrl	Planned Maintenance	Eng & Condition Monitoring	Incentives	Labor Productivity	Information Systems
Org & Staffing	1	3	7	3	7	9	3	9	9	5	3	5	7	7
Training	1/3	1	5	1/3	5	7	1/3	7	9	3	3	3	5	3
Planner Trng	1/7	1/5	1	1/7	1/3	3	1/7	3	3	1/7	1/7	1/5	1/3	1/3
Craft Trng	1/3	3	7	1	7	9	1	9	9	3	3	3	5	7
Motivation	1/7	1/5	1	1/7	1	3	1/7	3	3	1/5	1/5	1/3	1/3	1/3
Mangmt Ctrl & Budget	1/9	1/7	1/3	1/9	1/3	1	1/9	1	1	1/7	1/7	1/5	1/5	1/5
Work Order P&S	1/3	3	5	1	7	9	1	7	9	3	3	5	5	5
Facilities	1/9	1/7	1/3	1/7	1/3	1	1/7	1	3	1/7	1/7	1/5	1/3	1/3
Material & tool ctrl	1/9	1/9	1/9	1/9	1	1/3	1/5	1/3	1	1/7	1/7	1/7	1/7	1/5
Planned Maintenance	1/3	1/3	1	1/3	9	7	5	7	9	1	3	3	3	5
Eng & Condition Monitoring	1/3	1/3	1/3	1/5	7	5	3	5	7	1/3	1	1	3	3
Incentives	1/5	1/3	3	1/5	3	5	1/5	5	7	1/3	1/3	1	3	3
Labor Productivity	1/3	1/3	1/3	1/5	7	5	3	5	7	1/3	1	1	1	3
Information Systems	1/5	1/5	1/3	1/7	5	3	3	3	5	1/5	1/3	1	1/3	1
Sum	4.0	12.3	31.8	7.1	60.0	67.3	20.3	65.3	82.0	17.0	18.4	24.1	33.7	38.4

Table A. 1 **Results of Applying AHP methodology in Gebze Plant**

	Org & Staffing	*Training*	*Planner Trng*	*Craft Trng*	*Motivation*	*Mangmt Ctrl & Budget*	*Work Order P&S*	*Facilities*	*Material & tool ctrl*	*Planned Maintenance*	*Eng & Condition Monitoring*	*Incentives*	*Labor Productivity*	*Information Systems*	*Weights*
Org & Staffing	*0.25*	*0.24*	*0.22*	*0.42*	*0.12*	*0.13*	*0.15*	*0.14*	*0.11*	*0.29*	*0.16*	*0.21*	*0.21*	*0.18*	*0.20*
Training	*0.08*	*0.08*	*0.16*	*0.05*	*0.08*	*0.10*	*0.02*	*0.11*	*0.11*	*0.18*	*0.16*	*0.12*	*0.15*	*0.08*	*0.11*
Planner Trng	*0.04*	*0.02*	*0.03*	*0.02*	*0.01*	*0.04*	*0.01*	*0.05*	*0.04*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.02*
Craft Trng	*0.08*	*0.24*	*0.22*	*0.14*	*0.12*	*0.13*	*0.05*	*0.14*	*0.11*	*0.18*	*0.16*	*0.12*	*0.15*	*0.18*	*0.15*
Motivation	*0.04*	*0.02*	*0.03*	*0.02*	*0.02*	*0.04*	*0.01*	*0.05*	*0.04*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.02*
Mangmt Ctrl & Budget	*0.03*	*0.01*	*0.01*	*0.02*	*0.01*	*0.01*	*0.01*	*0.02*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Work Order P&S	*0.08*	*0.24*	*0.16*	*0.14*	*0.12*	*0.13*	*0.05*	*0.11*	*0.11*	*0.18*	*0.16*	*0.21*	*0.15*	*0.13*	*0.14*
Facilities	*0.03*	*0.01*	*0.01*	*0.02*	*0.01*	*0.01*	*0.01*	*0.02*	*0.04*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Material & tool ctrl	*0.03*	*0.01*	*0.00*	*0.02*	*0.02*	*0.00*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.00*	*0.01*	*0.01*
Planned Maintenance	*0.08*	*0.03*	*0.03*	*0.05*	*0.15*	*0.10*	*0.25*	*0.11*	*0.11*	*0.06*	*0.16*	*0.12*	*0.09*	*0.13*	*0.11*
Eng & Condition Monitoring	*0.08*	*0.03*	*0.01*	*0.03*	*0.12*	*0.07*	*0.15*	*0.08*	*0.09*	*0.02*	*0.05*	*0.04*	*0.09*	*0.08*	*0.07*
Incentives	*0.05*	*0.03*	*0.09*	*0.03*	*0.05*	*0.07*	*0.01*	*0.08*	*0.09*	*0.02*	*0.02*	*0.04*	*0.09*	*0.08*	*0.05*
Labor Productivity	*0.08*	*0.03*	*0.01*	*0.03*	*0.12*	*0.07*	*0.15*	*0.08*	*0.09*	*0.02*	*0.05*	*0.04*	*0.03*	*0.08*	*0.06*
Information Systems	*0.05*	*0.02*	*0.01*	*0.02*	*0.08*	*0.04*	*0.15*	*0.05*	*0.06*	*0.01*	*0.02*	*0.04*	*0.01*	*0.03*	*0.04*

Table A. 2 **Identifying Key factors in Gebze after normalization**

	Org & Staffing	Training	Planner Trng	Craft Trng	Motivation	Mangmt Ctrl & Budget	Work Order P&S	Facilities	Material & tool ctrl	Planned Maintenance	Eng & Condition Monitoring	Incentives	Labor Productivity	Information Systems
Org & Staffing	1	5	5	3	3	9	1	7	9	1	3	3	7	5
Training	1/7	1	1	1/3	1/3	3	1/5	3	3	1/7	1	1/5	1	1/3
Planner Trng	1/5	3	1	1/3	1/3	5	1/5	3	5	1/7	3	1/3	1/3	1/3
Craft Trng	1/3	5	3	1	3	9	1/3	7	7	1/3	5	1	5	3
Motivation	1/3	3	3	1/3	1	7	1/5	7	7	1/5	3	1	5	3
Mangmt Ctrl & Budget	1/9	1/5	1/7	1/7	1/7	1	1/9	1	1	1/9	1/5	1/7	1/3	1/5
Work Order P&S	1	7	5	3	3	9	1	7	9	1/3	5	3	7	5
Facilities	1/7	1/3	1/3	1/7	1/5	3	1/7	1	1	1/9	1/3	1/7	1/3	1/5
Material & tool ctrl	1/9	1/3	1/5	1/9	1/7	3	1/9	1	1	1/9	1/3	1/7	1/3	1/5
Planned Maintenance	3	9	1	3	5	9	3	9	9	1	7	3	9	5
Eng & Condition Monitoring	1/7	1	1/3	1/5	1/3	5	1/7	3	3	1/7	1	1/3	3	1/3
Incentives	1/3	5	3	1	3	9	1/3	7	7	1/3	5	1	5	3
Labor Productivity	1/7	1	1/3	1/7	1/5	3	1/7	1	3	1/9	1/3	1/5	1	1/3
Information Systems	1/5	3	1	1/3	1	7	1/5	5	5	1/5	3	1/3	3	1
sum	7.2	43.9	24.3	13.1	20.7	82.0	7.1	62.0	70.0	4.3	37.2	13.8	47.3	26.9

Table A. 3 **Results of Applying AHP methodology in Cairo Plant**

Normalizing Cairo Plant Matrix

	Org & Staffing	Training	Planner Trng	Craft Trng	Motivation	Mangmt Ctrl & Budget	Work Order P&S	Facilities	Material & tool ctrl	Planned Maintenance	Eng & Condition Monitoring	Incentives	Labor Productivity	Information Systems	Org & Staffing	Weights
Org & Staffing	*0.14*	*0.11*	*0.21*	*0.23*	*0.15*	*0.11*	*0.14*	*0.11*	*0.13*	*0.23*	*0.08*	*0.22*	*0.15*	*0.19*	*0.16*	*0.16*
Training	*0.02*	*0.02*	*0.04*	*0.03*	*0.02*	*0.04*	*0.03*	*0.05*	*0.04*	*0.03*	*0.03*	*0.01*	*0.02*	*0.01*	*0.03*	*0.03*
Planner Trng	*0.03*	*0.07*	*0.04*	*0.03*	*0.02*	*0.06*	*0.03*	*0.05*	*0.07*	*0.03*	*0.08*	*0.02*	*0.01*	*0.01*	*0.04*	*0.04*
Craft Trng	*0.05*	*0.11*	*0.12*	*0.08*	*0.15*	*0.11*	*0.05*	*0.11*	*0.10*	*0.08*	*0.13*	*0.07*	*0.11*	*0.11*	*0.10*	*0.10*
Motivation	*0.05*	*0.07*	*0.12*	*0.03*	*0.05*	*0.09*	*0.03*	*0.11*	*0.10*	*0.05*	*0.08*	*0.07*	*0.11*	*0.11*	*0.08*	*0.08*
Mangmt Ctrl & Budget	*0.02*	*0.00*	*0.01*	*0.01*	*0.01*	*0.01*	*0.02*	*0.02*	*0.01*	*0.03*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Work Order P&S	*0.14*	*0.16*	*0.21*	*0.23*	*0.15*	*0.11*	*0.14*	*0.11*	*0.13*	*0.08*	*0.13*	*0.22*	*0.15*	*0.19*	*0.15*	*0.15*
Facilities	*0.02*	*0.01*	*0.01*	*0.01*	*0.01*	*0.04*	*0.02*	*0.02*	*0.01*	*0.03*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Material & tool ctrl	*0.02*	*0.01*	*0.01*	*0.01*	*0.01*	*0.04*	*0.02*	*0.02*	*0.01*	*0.03*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Planned Maintenance	*0.42*	*0.21*	*0.04*	*0.23*	*0.24*	*0.11*	*0.42*	*0.15*	*0.13*	*0.23*	*0.19*	*0.22*	*0.19*	*0.19*	*0.21*	*0.21*
Eng & Condition Monitoring	*0.02*	*0.02*	*0.01*	*0.02*	*0.02*	*0.06*	*0.02*	*0.05*	*0.04*	*0.03*	*0.03*	*0.02*	*0.06*	*0.01*	*0.03*	*0.03*
Incentives	*0.05*	*0.11*	*0.12*	*0.08*	*0.15*	*0.11*	*0.05*	*0.11*	*0.10*	*0.08*	*0.13*	*0.07*	*0.11*	*0.11*	*0.10*	*0.10*
Labor Productivity	*0.02*	*0.02*	*0.01*	*0.01*	*0.01*	*0.04*	*0.02*	*0.02*	*0.04*	*0.03*	*0.01*	*0.01*	*0.02*	*0.01*	*0.02*	*0.02*
Information Systems	*0.03*	*0.07*	*0.04*	*0.03*	*0.05*	*0.09*	*0.03*	*0.08*	*0.07*	*0.05*	*0.08*	*0.02*	*0.06*	*0.04*	*0.05*	*0.05*

Table A. 4 **Identifying Key factors in Cairo after normalization**

	Org & Staffing	Training	Planner Trng	Craft Trng	Motivation	Mangmt Ctrl & Budget	Work Order P&S	Facilities	Material & tool ctrl	Planned Maintenance	Eng & Condition Monitoring	Incentives	Labor Productivity	Information Systems
Org & Staffing	1	1/3	3	3	5	3	1/5	7	7	1/3	1	1/5	1	5
Training	1/3	1	5	7	7	5	1/3	9	9	1	3	1/3	3	7
Planner Trng	1/3	1/5	1	3	3	1	1/5	5	5	1/5	1	1/7	1/3	3
Craft Trng	1/3	1/7	1/3	1	3	1/3	1/7	3	3	1/7	1/3	1/9	1/5	1
Motivation	1/5	1/9	1/3	1/3	1	1/3	1/9	1	1/3	1/7	1/5	1/9	1/7	1
Mangmt Ctrl & Budget	1/3	1/5	1/3	1/3	3	1	1/7	3	5	1/5	1/3	1/7	1/3	3
Work Order P&S	3	1	5	7	9	1/7	1	9	9	3	5	1	3	9
Facilities	1/5	1/9	1/5	1/3	1	1/3	1/9	1	3	1/7	1/7	1/9	1/9	1/3
Material & tool ctrl	1/7	1/9	1/5	1/3	1/3	1/5	1/9	1	1	1/9	1/7	1/9	1/7	1/3
Planned Maintenance	3	1	3	5	7	5	1/3	7	9	1	3	1/3	3	7
Eng & Condition Monitoring	1/3	1/3	3	3	5	5	1/5	5	7	1/3	1	1/5	1/3	3
Incentives	5	3	7	7	9	7	3	9	9	3	7	1	3	9
Labor Productivity	1	1/3	3	5	7	3	1/3	7	9	1/3	3	1/5	1	5
Information Systems	1/5	1/7	1/3	1/3	1	1/3	1/9	3	3	1/7	1/3	1/9	1/5	1
sum	15.4	8.0	31.7	42.7	61.3	31.7	6.3	70.0	79.3	10.1	25.5	4.1	15.8	54.7

Table A. 5 **Results of Applying AHP methodology in Rakona Plant**

Normalizing Rakona Plant Matrix

	Org & Staffing	*Training*	*Planner Trng*	*Craft Trng*	*Motivation*	*Mangmt Ctrl & Budget*	*Work Order P&S*	*Facilities*	*Material & tool ctrl*	*Planned Maintenance*	*Eng & Condition Monitoring*	*Incentives*	*Labor Productivity*	*Information Systems*	*Weights*
Org & Staffing	*0.06*	*0.04*	*0.09*	*0.07*	*0.08*	*0.09*	*0.03*	*0.10*	*0.09*	*0.03*	*0.04*	*0.05*	*0.06*	*0.09*	*0.07*
Training	*0.02*	*0.12*	*0.16*	*0.16*	*0.11*	*0.16*	*0.05*	*0.13*	*0.11*	*0.10*	*0.12*	*0.08*	*0.19*	*0.13*	*0.12*
Planner Trng	*0.02*	*0.02*	*0.03*	*0.07*	*0.05*	*0.03*	*0.03*	*0.07*	*0.06*	*0.02*	*0.04*	*0.03*	*0.02*	*0.05*	*0.04*
Craft Trng	*0.02*	*0.02*	*0.01*	*0.02*	*0.05*	*0.01*	*0.02*	*0.04*	*0.04*	*0.01*	*0.01*	*0.03*	*0.01*	*0.02*	*0.02*
Motivation	*0.01*	*0.01*	*0.01*	*0.01*	*0.02*	*0.01*	*0.02*	*0.01*	*0.00*	*0.01*	*0.01*	*0.03*	*0.01*	*0.02*	*0.01*
Mangmt Ctrl & Budget	*0.02*	*0.02*	*0.01*	*0.01*	*0.05*	*0.03*	*0.02*	*0.04*	*0.06*	*0.02*	*0.01*	*0.03*	*0.02*	*0.05*	*0.03*
Work Order P&S	*0.19*	*0.12*	*0.16*	*0.16*	*0.15*	*0.00*	*0.16*	*0.13*	*0.11*	*0.30*	*0.20*	*0.24*	*0.19*	*0.16*	*0.16*
Facilities	*0.01*	*0.01*	*0.01*	*0.01*	*0.02*	*0.01*	*0.02*	*0.01*	*0.04*	*0.01*	*0.01*	*0.03*	*0.01*	*0.01*	*0.01*
Material & tool ctrl	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.02*	*0.01*	*0.01*	*0.01*	*0.01*	*0.03*	*0.01*	*0.01*	*0.01*
Planned Maintenance	*0.19*	*0.12*	*0.09*	*0.12*	*0.11*	*0.16*	*0.05*	*0.10*	*0.11*	*0.10*	*0.12*	*0.08*	*0.19*	*0.13*	*0.12*
Eng & Condition Monitoring	*0.02*	*0.04*	*0.09*	*0.07*	*0.08*	*0.16*	*0.03*	*0.07*	*0.09*	*0.03*	*0.04*	*0.05*	*0.02*	*0.05*	*0.06*
Incentives	*0.32*	*0.37*	*0.22*	*0.16*	*0.15*	*0.22*	*0.47*	*0.13*	*0.11*	*0.30*	*0.27*	*0.24*	*0.19*	*0.16*	*0.24*
Labor Productivity	*0.06*	*0.04*	*0.09*	*0.12*	*0.11*	*0.09*	*0.05*	*0.10*	*0.11*	*0.03*	*0.12*	*0.05*	*0.06*	*0.09*	*0.08*
Information Systems	*0.01*	*0.02*	*0.01*	*0.01*	*0.02*	*0.01*	*0.02*	*0.04*	*0.04*	*0.01*	*0.01*	*0.03*	*0.01*	*0.02*	*0.02*

Table A. 6 **Identifying Key factors in Rakona after normalization**

	Org & Staffing	Training	Planner Trng	Craft Trng	Motivation	Mangmt Ctrl & Budget	Work Order P&S	Facilities	Material & tool ctrl	Planned Maintenance	Eng & Condition Monitoring	Incentives	Labor Productivity	Information Systems
Org & Staffing	1	1/3	3	7	1/3	7	1/3	3	5	1/5	5	3	9	3
Training	3	1	7	9	1	9	3	5	7	1/3	9	5	9	3
Planner Trng	1/3	1/7	1	3	1/5	3	1/5	1/3	1	1/7	3	1	5	3
Craft Trng	1/7	1/9	1/5	1	1/9	1/3	1/9	1/5	1/3	1/9	1/3	1/5	1	1/7
Motivation	3	1/3	7	9	1	9	1	3	7	1/3	7	5	9	3
Mangmt Ctrl & Budget	1/7	1/9	1/3	3	1/9	1	1/7	1/5	1/3	1/9	1/3	1/3	3	1/5
Work Order P&S	3	1	5	9	1	7	1	3	5	1/3	7	5	9	3
Facilities	1/3	1/5	3	5	1/3	5	1/3	1	3	1/7	3	1	7	1
Material & tool ctrl	1/5	1/7	1	3	1/7	3	1/7	1/3	1	1/9	1	1/3	3	1/3
Planned Maintenance	3	3	7	9	3	9	3	5	7	1	9	7	9	5
Eng & Condition Monitoring	1/5	1/7	1/3	3	1/7	1	1/7	1/3	1	1/9	1	1/3	3	1/5
Incentives	1/3	1/5	3	5	1/5	1/3	1/5	1	3	1/5	3	1	5	1/3
Labor Productivity	1/7	1/9	1/5	1/3	1/7	1/3	1/9	1/7	1/3	1/9	1/3	1/5	1	1/7
Information Systems	1/3	1/5	3	7	1/3	5	1/3	1	3	1/5	5	3	7	1
sum	15.2	7.0	41.1	73.3	8.1	60.0	10.1	23.5	44.0	3.4	54.0	32.4	80.0	23.4

Table A. 7 **Results of Applying AHP methodology in Dammam Plant**

Normalizing Dammam Plant Matrix

	Org & Staffing	*Training*	*Planner Trng*	*Craft Trng*	*Motivation*	*Mangmt Ctrl & Budget*	*Work Order P&S*	*Facilities*	*Material & tool ctrl*	*Planned Maintenance*	*Eng & Condition Monitoring*	*Incentives*	*Labor Productivity*	*Information Systems*	*Weights*
Org & Staffing	*0.07*	*0.05*	*0.07*	*0.10*	*0.04*	*0.12*	*0.03*	*0.13*	*0.11*	*0.06*	*0.09*	*0.09*	*0.11*	*0.13*	*0.09*
Training	*0.20*	*0.14*	*0.17*	*0.12*	*0.12*	*0.15*	*0.30*	*0.21*	*0.16*	*0.10*	*0.17*	*0.15*	*0.11*	*0.13*	*0.16*
Planner Trng	*0.02*	*0.02*	*0.02*	*0.04*	*0.02*	*0.05*	*0.02*	*0.01*	*0.02*	*0.04*	*0.06*	*0.03*	*0.06*	*0.13*	*0.04*
Craft Trng	*0.01*	*0.02*	*0.00*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.03*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Motivation	*0.20*	*0.05*	*0.17*	*0.12*	*0.12*	*0.15*	*0.10*	*0.13*	*0.16*	*0.10*	*0.13*	*0.15*	*0.11*	*0.13*	*0.13*
Mangmt Ctrl & Budget	*0.01*	*0.02*	*0.01*	*0.04*	*0.01*	*0.02*	*0.01*	*0.01*	*0.01*	*0.03*	*0.01*	*0.01*	*0.04*	*0.01*	*0.02*
Work Order P&S	*0.20*	*0.14*	*0.12*	*0.12*	*0.12*	*0.12*	*0.10*	*0.13*	*0.11*	*0.10*	*0.13*	*0.15*	*0.11*	*0.13*	*0.13*
Facilities	*0.02*	*0.03*	*0.07*	*0.07*	*0.04*	*0.08*	*0.03*	*0.04*	*0.07*	*0.04*	*0.06*	*0.03*	*0.09*	*0.04*	*0.05*
Material & tool ctrl	*0.01*	*0.02*	*0.02*	*0.04*	*0.02*	*0.05*	*0.01*	*0.01*	*0.02*	*0.03*	*0.02*	*0.01*	*0.04*	*0.01*	*0.02*
Planned Maintenance	*0.20*	*0.43*	*0.17*	*0.12*	*0.37*	*0.15*	*0.30*	*0.21*	*0.16*	*0.29*	*0.17*	*0.22*	*0.11*	*0.21*	*0.22*
Eng & Condition Monitoring	*0.01*	*0.02*	*0.01*	*0.04*	*0.02*	*0.02*	*0.01*	*0.01*	*0.02*	*0.03*	*0.02*	*0.01*	*0.04*	*0.01*	*0.02*
Incentives	*0.02*	*0.03*	*0.07*	*0.07*	*0.02*	*0.01*	*0.02*	*0.04*	*0.07*	*0.06*	*0.06*	*0.03*	*0.06*	*0.01*	*0.04*
Labor Productivity	*0.01*	*0.02*	*0.00*	*0.00*	*0.02*	*0.01*	*0.01*	*0.01*	*0.01*	*0.03*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Information Systems	*0.02*	*0.03*	*0.07*	*0.10*	*0.04*	*0.08*	*0.03*	*0.04*	*0.07*	*0.06*	*0.09*	*0.09*	*0.09*	*0.04*	*0.06*

Table A. 8 **Identifying Key factors in Dammam after normalization**

APPENDIX A2

The Questionnaire

We are currently researching maintenance systems for the purpose of benchmarking across P&G.

There have been 14 maintenance factors which are identified; there is a brief description at the end of this report for more clarification.

Please fill in this report based on your plant current practices, this data will be extrapolated for the purpose of research only.

As for the answers, to make it easy, just reply back with your answer, deleting other options.

Example:

- *In your maintenance organization, are Mission & Objective is clearly defined*

-A-Strongly Agree, B- Agree, C- Neither Agree or Disagree, D- Disagree, E- Strongly Disagree

If you answer is B- Agree, just leave this option and delete others:

So,

- *In your maintenance organization, are Mission and Objective is clearly define*

B- Agree

Appreciate your cooperation,

1- Organization and Staffing

- *In your maintenance organization, are Mission and Objective is clearly defined*

A-Strongly Agree, B- Agree, C- Neither Agree or Disagree, D- Disagree, E- Strongly Disagree

- *Is Organization Chart current, complete, and reviewed periodically*

A-Strongly Agree, B- Agree, C- Neither Agree or Disagree, D- Disagree, E- Strongly Disagree

- *Proper Job Description exists for each supervisor and his team*

A-Strongly Agree, B- Agree, C- Neither Agree or Disagree, D- Disagree, E- Strongly Disagree

- *What is the current worker to supervisor Ratio?*

A- Above 20:1, B- 16-20:1, C- 15-12:1, D- 8-11:1, E- Less than 8:1

- *Support Functions exists: maintenance engineering, planning engineering, planner, Material coordinator, training coordinator, stores*

A- All 6, B- 4-5 with no planner, C- 2-3, D- 1, E-0

- *A strong goal setting exists as recommended by management*

A-Strongly Agree, B- Agree, C- Neither Agree or Disagree, D- Disagree, E- Strongly Disagree

2- Training

- *A training master plan exists for all levels of maintenance team (higher management, support, supervisors and technicians)*

A-All , B- 3, C- 2, D-1, E- None

- *Productivity training is included for:*

A- All , B- 3, C- 2, D-1, E- None

- *Types of Training Programs*

A- On job training and formal B- On job only C- Formal only D- None

3- Planner Training

- *Planner Job Role and expectations exists*

A-Strongly Agree, B- Agree, C- Neither Agree or Disagree, D- Disagree, E- Strongly Disagree

-Types of Training Programs for planner

A- On job training and formal B- On job only C- Formal only D- None

- Planner job includes : work requests, planning and scheduling, productivity, methods improvements, material planning, project planning, maintenance practices, job standard timing, computer communication?

A-100%, B- 75%, C-50%, D-25%, E- 0%

4- Craft Training

-Formal craft training plan exists

A- On job training and formal B- On job only C- Formal only D- None

- *Who performs the training?*

A- Staff, B-Staff and Line management, C- Line management, D- Other, E- None

-Does minimum skill Requirements exists for each job?

A-100%, B- 75%, C-50%, D-25%, E- 0%

-% of craft included in training

A-100%, B- 75%, C-50%, D-25%, E- 0%

5- Motivation

- *Work Climate is healthy between management and staff/labor*

A-Strongly Agree, B- Agree, C- Neither Agree or Disagree, D- Disagree, E- Strongly Disagree

- *A "climate" survey has been completed recently*

A- Yes, B- within past 6 months C- within past year, D- Within past 2 years, E- None

- Turnover due to resignations and quits:

A- Less than 2%, B- 2-4%, C- 4-6% , D- 6-8%, E- more than 8%

6- Management Control and Budget

-Is the budget concept being used to control maintenance costs and purchase orders, in addition to historical data tracking to control spending?

A-100%, B- 75%, C-50%, D-25%, E- 0%

- *Which of the following controls are used: Downtime %, performance, cost/ standard hour, productivity, backlog, service level and overtime?*

A- All, B- 6 , C- 4 or 5, D- 2-3, E- Less than 2

- *What is the time lag between period end and issuance of budget control report?*

A- Day or less, B- 1-2 Days, C- 3-4 Days, D- 5 days, E- More than 5 days

- *How often are control reports issued?*

A- Daily, B- Weekly, C- Monthly, D- Bi-monthly, E- Less frequent

- *How is time and work reported?*

A- by individual and job, B- by day, C- By week, D- by month, E- none

- *What are the distribution criteria for report?*

A- Supervisor and higher management, B- Supervisor, C- maintenance team, D-None

7- Work Order Planning and scheduling

- *% of man hours covered by written work request*

A-90% or above, B- 75-89%, C-50-74%, D-25-49%, E- less than 25%

- *Percentage of work orders have enough planning times (2-4 weeks)*

A-90% or above, B- 75-89%, C-50-74%, D-25-49%, E- less than 25%

- *What percentage of work request have the following items planned: crew size, work content, materials, special tools, sequencing, time standard and scheduled date?*

A-90% or above, B- 75-89%, C-50-74%, D-25-49%, E- less than 25%

- *Is all overhaul work pre-planned and scheduled?*

A-90% or above, B- 75-89%, C-50-74%, D-25-49%, E- less than 25%

- *Quality check by supervisor on the quality of check done*

A-90% or above, B- 75-89%, C-50-74%, D-25-49%, E- less than 25%

8- Facilities

- *Maintenance shops and layouts are designed in a satisfactory way*

A- Superior, B- Excellent, C- Good, D- Fair, E- Poor

- *Level of housekeeping*

A- Superior, B- Excellent, C- Good, D- Fair, E- Poor

- *Safety equipment and signs (such as lock out tag out, wet floor, Hazardous area…) is being used?*

A-90% or above, B- 75-89%, C-50-74%, D-25-49%, E- less than 25%

- *Are Equipment and tools effectively located?*

A- Superior, B- Excellent, C- Good, D- Fair, E- Poor

- *Availability of tools to operators and mechanics:*

A-Superior, B- Excellent, C- Good, D- Fair, E- Poor

- *Are cranes, lifts and doors covered by PM Program?*

A-All, B- 75%, C- 50%, D- 25%, E- None

9- Material and tool control

- *Do you have an up-date Store Catalog?*

A- All items, B- Major Items, C- Some items, D- None

- *Do you have an inventory system for major items and spares?*

A- All, B- 75%, C- 50%, D- 25%, E- None

- *Do you have a re-ordering system for high volume, low cost items?*

A- All, B- 75%, C- 50%, D- 25%, E- None

- *Items and spare parts are controlled with use withdrawal procedure*

A- All, B- 75%, C- 50%, D- 25%, E- None

- Is *there a control procedure on use of company tools?*

A- All, B- 75%, C- 50%, D- 25%, E- None

- *Is there a standard list of tools provided to the individuals by the company?*

A-Yes (Full) , B- Yes (partial) C- None

- *How many tools are out of service for repair?*

A- none, B-10%, C- 20%, D- 30% , E- more

- *Are economic order quantities calculated?*

A- All, B- 75%, C- 50%, D- 25%, E- None

- *Are maximum/minimum levels are set and maintained?*

A- All, B- 75%, C- 50%, D- 25%, E- None

- *Does purchasing maintain a vendor rating system for suppliers?*

A- All, B- 75%, C- 50%, D- 25%, E- None

- *What percentage of material orders are delivered on time?*

A-90% or above, B- 75-89%, C-50-74%, D-25-49%, E- less than 25%

10- Planned Maintenance and Equipment History

- *What percentage of equipment has a maintenance repair history*

A- All, B- 75%, C- 50%, D- 25%, E- None

- *How many maintenance records are reviewed at least once a year?*

A- All, B- 75%, C- 50%, D- 25%, E- None

- Percentage of major equipment are included in Planned Maintenance routines

A- All, B- 75%, C- 50%, D- 25%, E- None

- *What is the equipment percentage that is covered by the following: downtime trends, PM compliance with schedule, written PM instructions, total PM-man hours, high repair item man-hours?*

A- All, B- 75%, C- 50%, D- 25%, E- None

- *How frequently are the reports prepared?*

A- Daily, B- Weekly, C- Monthly, D- Bi-monthly, E- Less frequent

11- Engineering and Condition Monitoring

- *Reliability Engineering is used to control downtime on the major equipment in what percentage?*

A- All, B- 75%, C- 50%, D- 25%, E- None

- *What percentage of equipment is using MTBF and MTTR measures?*

A- All, B- 75%, C- 50%, D- 25%, E- None

- *What percentage of major repairs and construction projects have an engineer assigned?*

A- All, B- 75%, C- 50%, D- 25%, E- None

- *What percentage of major equipment is using the following diagnostic routines: vibration analysis, heat sensing, erosion, corrosion, electrical, gauging):*

- A- All, B- 75%, C- 50%, D- 25%, E- None

- *Do you have a ranking system for your equipment?*

A- Yes, B-No

- Do you have a clear criteria of ranking your equipment?

A- Yes, B- No

- *What is the percentage of your equipment that is currently ranked?*

A- All, B- 75%, C- 50%, D- 25%, E- None

12- Work Measurement and Incentives

- *How are time maintenance standards set?*

A-Predetermined time, time study and standard data, B- direct measurement and time study, C- work samplings, D- Estimates, E- none

- *What percent of actual hours worked are covered by time standards?*

A-90% or above, B- 75-89%, C-50-74%, D-less than 50%, E- None

- *Are job times written on the work request for the worker and the supervisor to see?*

A- Yes, B- Supervisor only, C- None

- *What percentage of workers are paid by incentives plan related to output?*

A-90% or above, B- 75-89%, C-50-74%, D-less than 50%, E- None

- *What type of incentive plan are you using?*

A- Salary adjustment, B- Bonus, C- Award or gift, D- All, E- None

13- Labor Productivity

-Maintenance productivity = production units /individual (or standard time / actual time)

A- > 0.8 B- >0.7 C- >0.5 D- < 0.5

Or put in your number

…….

-Do you have a daily work time card for all workers?

A-90% or above, B- 75-89%, C-50-74%, D-less than 50%, E- None

-Productivity reports are prepared:

A- By individual, B- By area, C- For all department, D- None

14- Information Systems

-Does maintenance system includes computer support?

A- Yes B- No

-Which information categories are available:

Payroll, time reporting, work request, job planning, daily schedule for routine work, long range scheduling for projects, management control reports, downtime, equipment history, planned maintenance, stores and material control, statistical analysis, cost justification?

A- All, B-75% C- 50% D-25% E- None

- *Does your system match capability with individual responsibility?*

A- Always, B- most of the time, C- some times, D- Rarely, E- Never

- *Reports timing*

A- Daily, B- Bi-daily, C- Weekly, D- Monthly

- *Is information complete and reliable?*

A- Always, B- most of the time, C- some times, D- Rarely, E- Never

- *How good is your security system controlling who has access and to what level?*

A- world class , B- Excellent, C- Adequate, D- Inadequate, E- none

Brief Description of the 14 factors:

1- Organization and Staffing

Organizations are designed to facilitate proper and effective execution of maintenance plans. This is shown through roles and responsibilities, reporting line and structure. Having a healthy, strong and effective stricture is vital for an effective and reliable maintenance program.

2- overall Training

This factor shows the importance of having a training program for individuals such as job standards, tools , new maintenance techniques and productivity improvement.

3- Planner Training

In this factor a special attention for the planner role in maintenance team is focused. Trainings for scheduling maintenance jobs are of vital importance to have an effective maintenance system in place.

4- Craft Training

In this factor the focus is on having a solid and annual training plan for all workers performing maintenance activities.

5- Motivation

This factor is focusing on employee-management relationship and more specifically: moral. We discuss here issues such as productivity and turn over.

6- Management Control and Budget

Here, the need for a control reports and proper intervention levels to control spending is discussed.

7- Work Order Planning and scheduling

Here, work requests as a necessary tool for any effective planning and scheduling system is discussed. In addition to work requests or orders, here we focus on the quality of maintenance jobs.

8- Facilities

Proper layout of maintenance shops, tools availability, safety equipment and safety and Job working conditions, such as light, etc.. are addressed here.

9- Material and tool control

Material Control and policies, need for an updated inventory system, spare parts availability and necessary tools and equipments are addressed here.

10- Planned Maintenance and Equipment History

Discussion here is on preventive measures to prevent re-occurred failures, how to control maintenance planning and scheduling time. Need for improving maintenance program will be identified.

11- Engineering and Condition Monitoring

This factor discusses the need for establishing a condition based maintenance program . This establishes a diagnostic routine for major equipment.

12- Work Measurement and Incentives

This factor discusses developing standard time for standard jobs. This is an essential part for effective maintenance planning and control.

13- Labor Productivity

Labor productivity is defined as Standard Time/Actual Time. This identifies workers with low productivity and tackles the root cause behind it. Training might be key here.

14- Information System

Information systems are tools for effective maintenance management and control. Such tools must be designed to satisfy maintenance program requirements. This system(s) should enable us for effective reporting, workload calculation and control.

NOMENCLATURE

P&G	*Procter and Gamble*
DMS	*Daily Management System*
MTTR	*Mean Time To Repair*
MTBF	*Mean Time Between Failures*
YTD	*Year To Date*
MTD	*Month To Date*
PR	*Process Reliability*
MSA	*Maintenance Scheduling Adherence*
TBM	*Time Based Maintenance*
SAP	*System Analysis and Program Development, P&G's system*
R&R	*Reward and Recognition*
PM	*Planned Maintenance*
MDT	*Mean Down Time*

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