Spare parts management potential in production sector

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Product and process development
Production and Logistics

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ABSTRACT

Spare parts management (SPM) is an important branch of management which could lead the company to success or bankruptcy. It is also full of potential improvements that can increase the company profits, productivity, and reliability. Wise inventory management would eliminate all the delay risks of unplanned breakdowns, and reduce process time and cost.

To understand the importance of the spare parts, a fundamental knowledge of maintenance types, spare parts, spare parts management, spare parts classifications, ABC analysis, Economic order quantity, suppliers’ management, purchase management, and management computer program SAP, have been viewed.

Companies realize the spare parts importance and try to develop the system to increase the benefits. Many ways has been taken to achieve that. Each company has its own management system that the company has developed in years.

In this research, spare parts management system of seven companies has been studied. By comparing of the management systems, we highlight the areas that would have negative or positive impact on the system. We would also analysis why the companies have chosen these systems, how they develop the system, and where they aim throw the development.

Reviewing case studies would have many advantages, it would expand the vision to develop the management system and focus on the points that have permanent value instead of focus on temporary improvement.

Two check lists of points that could have potential improvement, have been presented and in which improvement type.

Keywords: spare parts, management, Maintenance, preventive maintenance, based conditions maintenance, SAP, Systems, Applications & Products implementation, Management Computer Program.
ACKNOWLEDGEMENTS

I would like to thank my family for supporting me to finish this program.

I would thank also my supervisor and the program Coordinator PhD Antti Salonen from Mälardalen University for his time, help, and patient. His experience and knowledge in the field has been important to achieve a successful result.

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The biggest problem that the company faced because of the spare parts is:

1. Improving the spare parts managing system
2. Repeated problem
3. Preparing spare parts time
4. Maximum shipping and receiving time
5. Purchasing time
6. Storing time

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### ABBREVIATIONS

Here you list and explain the abbreviations used in your thesis. E.g.:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCs</td>
<td>Distribution Centers</td>
</tr>
<tr>
<td>CAG</td>
<td>ConAGra Company</td>
</tr>
<tr>
<td>CBM</td>
<td>Conditions Based Maintenance</td>
</tr>
<tr>
<td>CM</td>
<td>Corrective maintenance</td>
</tr>
<tr>
<td>HEESCo</td>
<td>Heavy Engineering Equipment State Company</td>
</tr>
<tr>
<td>IDT</td>
<td>School of Innovation, Design and Engineering</td>
</tr>
<tr>
<td>JIT</td>
<td>Just In Time</td>
</tr>
<tr>
<td>Mdh</td>
<td>Mälardalen University</td>
</tr>
<tr>
<td>MRC</td>
<td>Midland Refineries Company</td>
</tr>
<tr>
<td>NSC</td>
<td>Al-Nasser State Company</td>
</tr>
<tr>
<td>PM</td>
<td>Preventive Maintenance</td>
</tr>
<tr>
<td>SAP</td>
<td>Management Computer Program: Systems, Applications &amp; Products implementation</td>
</tr>
<tr>
<td>SCM</td>
<td>Supply Chain Management</td>
</tr>
<tr>
<td>SME</td>
<td>Small and Medium size Enterprises</td>
</tr>
<tr>
<td>SPM</td>
<td>Spare parts management</td>
</tr>
<tr>
<td>TPM</td>
<td>Total Productive Maintenance</td>
</tr>
<tr>
<td>TPS</td>
<td>Toyota Production System</td>
</tr>
<tr>
<td>TQM</td>
<td>Total Quality Management</td>
</tr>
<tr>
<td>WCM</td>
<td>World Class Manufacturing</td>
</tr>
</tbody>
</table>
1. INTRODUCTION

Maintenance was a part of the production and manufacturing from the beginning, without maintenance machines, tools, equipment, and buildings will stop after a period of time, maintenance ensure everything work correctly until the end of cycle life. With industry market expanding, maintenance has been developed to satisfy machine’s needs.

Spare part Management is an important element of maintenance, and it developed also. Any delay in delivering the spare parts means also delay in the production. The delay could be happen in finding the right spare parts, delivering, processing, and handling. From another angle, having many spare parts will mean extra cost, time, and resources that the companies have to supply.

In order to develop SPM to fits the needs, reduce the cost, and eliminate any delay that could happen, companies started to develop their management systems. Companies invested in improve the inventory process, improve personal skills, practice modern technique such as computer program, electronic scanning, etc., and maintain the relationship with other inventories and suppliers.

Nowadays, SPM has big potential to evaluated the internet revolution, overseas suppliers, fast communications, and tracking the shipping orders. New ways of SPM development are opened, most of the companies still have not taken full advantages, and perhaps they realized some of the advantages. Each company has its own conditions and policies, and each has its own vision on improving the management system.

This research will investigate:

How much benefits those are available in spare parts management?

How much potential benefits available in each company?

What are the KPIs that would estimate the quality of SPM?

Which KPIs that companies have used to improve? Which still unused? In general view.

What is the important area for improvements (from the workshop view)?

Throw answering these questions we could have a better vision on present situation of spare parts management and future situation.
1.1. Background

Maintenance is all the function to replace or repair to a machine, equipment, or production line in order to restore or prevent the production processes. Maintenance considered from the fastest growing disciplines in the industry region and this is happen with the production expanding and its sophistication equipment, maximize the return of the investment, minimize the maintenance cost, and simplify the complexity of the maintenance functions (Coetzee, 2004).

Wilson (1999) identified Maintenance in the manufacturing section, as a naturally to meet the standards set for safety and availability of all engineering plant and buildings.

With the expansion of the industry production, the maintenance is expanding also, and this lead to increase and the cost of maintenance. Spare parts considered as one of the important element of the maintenance, where having a lot of spare parts leads to big inventory, which cost a lot of resources, in the same time, it will minimize the waiting time for the spare parts. In the other hand, minimize spare parts inventories leads to reduce the needed resources and increase the maintenance time, where in some cases several spare parts need long time to be available. By good management for the spare parts, cost, time, and inventories can be balanced in order to save money, increase productivity, and minimize resources.

Gajpal and others (1999) stated that spare parts management acts a decisive part in any manufacturing sector. By using scientific approach in SPM, it can minimize spare parts, inventories and down time. Spare parts inventories are linked to spare parts minimum no. and orders time and quantities.

Huiskonen, (2001), claimed that the range of the operational control characteristics of spare parts is taken as a foundation for building spare parts logistics system.

Companies are searching for designing a spare parts logistic system that can reduce the cost and down time, at the same time increase the efficient of manufacturing by increase the reliability and availability. Big manufacturing companies need more advanced spare parts management systems, because of the bigger size of the spare parts that they need. In the other hand small companies mostly they do not use a management system because they have small verity in spare parts which can be handled with a simple management system.

Most of the companies they designed inventories according to their needs, but they always trying to reduce them. There are few tools to standardize the spare parts in the inventory according to its price, needs and importance. These tools help to classify the spare parts to give better organization to the inventory. In the other hand there is no way that can that can prove which inventory design is the best because of the variety of spare parts and the company need for them.
1.2. Problem formulation

Whenever the market competition increase the companies search for new methods to decrease the cost and put themselves in better competitive place. Maintenance is one of the major fields that has direct effects on the production cost (Al-Najjar, 2007), and spare parts are important branch of the maintenance. Bad management can lead to cost resources that the company would use in other improvements. Choosing the right type of maintenance would affect the inventory size and cost. Regardless the management model which can reduce the error fell, unwanted, and over process.

Most of the companies thinks that their SPM system is good and fulfill their needs, and they loss many hidden development opportunities plus they can reduce the cost. This research will investigate the spare parts management models in several companies, and will analysis the benefits and weakness of each model. Then it will try to address the spare parts inventories status in general in the manufacturing companies, and the KPIs that lead to improvements.

The research will highlight the potential and waste in spare parts inventories in few companies inside manufacturing sector.

1.3. Aim and Research questions

There are several questions that this research investigates:

<table>
<thead>
<tr>
<th>Question</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- What are the KPIs that would estimate the quality of SPM?</td>
<td></td>
</tr>
<tr>
<td>2- Which KPIs that companies have used to improve? And which still unused? In general view.</td>
<td></td>
</tr>
<tr>
<td>3- What is the average time of production stop because of SPM?</td>
<td></td>
</tr>
<tr>
<td>4- What is the important area for improvements? From the workshop view?</td>
<td></td>
</tr>
</tbody>
</table>

1.4. Project limitations

The research is limited to be in the manufacturing sector. The research analysis the management of the spare parts, supplier’s relationship, and spare parts orders periods and quantities. Several global companies are interviewed about how they manage the spare parts inventories, and the analysis will be based on this interviews information. All the information from the companies represents the present situation and it could be change in the future.
2. RESEARCH METHOD

This is an analytical research, where the main point of the research is analysis SPM in manufacturing companies. Several interviews with company’s representative hold to collect information about how their companies manage their spare parts inventories, orders, quantities, and what type of analysis they use to manage them. This information will be analyzed in order to make critical evaluation for the research subject.

This research consider as fundamental research also, where the main concern is gathering knowledge for knowledge’s sake. The research aims at analysis the situation of spare parts management, in order to show the waste and the potential in this area. This research can be fundamental for farther research’s that evaluate the situation in order to eliminate all the waste and use all the potential in many directions (economic, time, polices, administration, and inventories).

The research is qualitative type, where the goal is to analysis the quality in spare parts management in manufacturing. It is not quantities research because there is no quantity measuring or amount will be taken. From another angle, this research is Motivation Research, which is an important type of qualitative research. This type of research attends to discover the potential and trend, throw interviews for the purpose. Where, it motivates the company’s representatives to be aware of the research importance throw highlights the benefits and weakness.

Because there is no standard model to manage spare parts, the companies have evaluated their own model according to their experience and experts. This research is empirical research, where it’s data-base research, are coming up with conclusions which are capable of being verified by observation or experiment.
2.1. Research approach:

The approach is Qualitative approach where it concern with subjective assessment of attitudes, opinions and behavior. Generally, the techniques of focus group interviews, projective techniques and depth interviews are used.

2.2. Research Data:

The research depend on two resources for the data the first part is the literature data that are collected from previous books, articles, researches, journals, data bases, case study, scientific papers, conferences and reports. The literature resources are collected from MDH library, Google scholar data base, Mandalay data base, Diva, LIBRIS, etc.

**Keywords:** Maintenance, spare parts, spare parts management, maintenance management, spare parts inventories, inventories management, and waste in spare parts management.

The second part for data is the interviews with several companies representatives, who have gave data about how their companies manage spare parts, and what strategies they use and how do they evaluate it. Each company uses their own experts to improve their strategy, which lead to using different strategies among the companies. A list of the questions that have been used in the interviews is in appendix 01.
2.3. Research Method:

The research started with searching for data about the subject to know and estimate the current situation, and also to know if there are other researches who have wrote about the same problem and how far deep they went in their researches.

Whenever a book was reading a notes where wrote immediately. I wrote the notice in Excel sheet. I started the first block in the raw to write the book reference and the second and other blocks in the row to write the notes. In this way, I could manage the data that I have collect easily. Some time I just copy and paste the parts from the book that I can use later in the blocks, and other time, I put in my own words what the author claimed in the book, which it make it easier to be used in my research later.

After I collect the data, I start to manage them to establish a fundamental literature for the research subject. At the same time, it will allow me to understand the present situation for the subject. Whenever I found a gap between the data, I searched again for the missing data that I need to fill the gaps, in order to make the research more connected, smooth to read and to understand. So the searching mechanism is simultaneously between searching for data and use the data to make the literature part of the research more homogeneous, until it reach the final shape. Wherever I use information block, I change the font color to blue, this will help me to identify the blocks that I have used from the blocks that I have not use yet. If I zoom out the excel sheet, I could find easily the blocks that I did not use.

While I am managing the data, I write the questions that I used in the interviews. These questions have been modified later in order to maximize the collecting data values from the interviews. First, I thought to send the questions to the companies and wait for them to answer back. That was unsuccessful plan for many reason for example, the questions that I sent was 25 questions, which I tried to minimum as much as possible which still a lot to be answered. Second, I did not know when they will have time to answer questions and send it back to me. Third, it will take them longer time to write the information than say it. So the best set was to do the interview throw phone call, which could take 10-30 minutes. Before I make the call I prepared the questions in word sheet in front of me in the computer, and during the phone call, I am writing down all the necessary information only, but I kept the rest in my mind until I finished the phone call, because I will not be able to write everything in the same time. The most important thing in the interview is to understand the management system deeply so I can manage the answers, in some cases I will eliminate some questions or add other as the need. The phone call interview eliminates all the misunderstanding that could happen throw the questioning part or throw reading the answers.

After I finished the interviews, I started to write them down in scientific way and explorer each company understanding and interpreting for the management system. All the companies I have choose for the interviews are large companies that work internationally. Each company has its own vision about spare parts managing system for some reasons, and I have to understand these reasons to give the best analysis.

The analysis started with holding statistic table to compare the data from the interviews. The table data were classified to the KPIs. The KPIs where chosen depending on the theoretical part and the interviews data.

A percentage table is also holed to shows the usage of the KPIs in the interviewed companies. This table helps to estimate a general view of this KPI.
Final part in writing the research is the analysis, discussion, and recommendations. This part is very important part, because it represents the value of the research, and I have focused on using easy words that can give direct and clear meaning about what I mean so the reader can easily understand the full point.

The research holds depending on theoretical base and seven interviews in seven different production companies from several countries and they produce different products.

The research results represent SPM in general and the result in one region or one country would be differs. This research helps to estimate the SPM potentials and effects, especially in the international companies. The results are also representing 2015 only, where the data were collected from the interviews showed the present situation.

The research results would have more precision if it depends on more companies interviews; this is what the research periods allow to be hold.
3. Theory

3.1. Maintenance Management

3.1.1. Background

Management means the function that coordinates the efforts of people to accomplish goals and objectives using available resources efficiently and effectively.

All equipment is effected to breakdown, and the function to replace or repair the defective unit so the production can be restored, is called maintenance. Maintenance is one of the important branches in the modern production thinking. The reasons are the increasing of complexity of the modern machines and equipment, investment return time, cost of maintenance, and complexity of maintenance functions.

Kalaiarasan and Giliyana (2015) explained that because of the global competition, industrial companies have to develop their productions systems to achieve sustainability. To reach the operational excellence, several companies adopted concepts like Lean and world Class Manufacturing (WCM).

Coetzee (2004) claimed that maintenance is one of the oldest concepts that still be used, the subject area of the maintenance until partial recent time was very basic which need only simple knowledge. Most of who work in industrial organizations they know that the good maintenance function will creates organizations with high level of availability, reliability and operability. By another word the high level organization means bigger production capacity and more profit.

Failure is a dislike fact that companies have to deal with, whenever they produce new equipment or tools to improve the productivity; they have to face new unwanted side effects. Though, considerably efforts are practiced to refine the reliability of equipment. The ever-increasing sophistication and complexity of these modern technological wonders made maintenance one of the fastest growing industries in the world.

Whenever failure arises, the organization will be effected negatively. The negative effects can be anything from losing output, quality, time, costs and threats to the safety of people or the environment. Occasionally the result of the failure is not obvious directly. Dependent on the brutality of the failure in terms of production lost. The organization has to decide if they has to prevent the failure from happening and to what depth they are attending to go to do so, or maybe the failure can be fixed when it happen.

Lycke (2000) explained also that Maintenance has existed when the human started to use tools and equipment. In the Stone Age, human build their equipment by tools and they started to maintain their tools. For thousands of years, tools and equipment have been improved because of maintenance in order to longer the life cycle of them. Lycke (2000) caused the maintenance exist to support and maintain efficient production. Usually maintenance thinking have dedicated on the availability of production organization. Recent maintenance technique has a major impact on improved quality in production organization. Furthermore, maintenance has to be an integral part of business policy.
The costs which may be present in parallel with the maintenance and even the unnecessary cost can be reduced for a higher degree of profitability and efficiency. (Kalaiarasan & Giliyana, 2015)

In addition, Wilson (1999) understood that Maintenance from the manufacturing perspective is to meet the standards rules for safety and to maximize the availability of all equipment and tools. Maintenance concern people, information, materials and money that needed to guaranty that tools, equipment, buildings and plant are need to required, replaced, adjusted, or modified to enable it to operate at a precise availability and performance.

Moreover, Kelly (2006) showed that Perceptive the management authorities and managements philosophies, will help the managements of industrial organization to build internal mechanisms that can operate fine and smooth, considering that the right product must be made at the right time, by the right plant, using the right raw materials and employing the appropriate workforce. The physical resources must be well selected and properly maintained. Effective long-term research and development plans must be implemented and new capital investment generated. By another word, the internal efficiency must be high. From another side, the contact with the outside the company with external influences and constraints, must be made to be supportive and useful, rather than aggressive and harmful, i.e. the overall, externally measured, efficiency must also be high.

Hagberg and Henriksson (2010) stated that most of the companies and their external partners as well as the administration aiming on develop the maintenance process so they can achieve the maintenance operation world class.

The main assignment of the maintenance department to match maintenance resources (men, spares, tools and information) to the maintenance workload, so that the following maintenance department objectives can be attained: sustaining at minimum total cost, organizations that are able of producing the preferred level and quality of output (Kelly, 2006).

Wireman (1994) assumed that the maintenance responsibilities are:

<table>
<thead>
<tr>
<th></th>
<th>Maintenance responsibilities</th>
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<tbody>
<tr>
<td>1</td>
<td>Maintain the existing equipment</td>
</tr>
<tr>
<td>2</td>
<td>Inspection equipment and service</td>
</tr>
<tr>
<td>3</td>
<td>Install equipment</td>
</tr>
<tr>
<td>4</td>
<td>Maintenance storekeeping</td>
</tr>
<tr>
<td>5</td>
<td>Craft administration</td>
</tr>
</tbody>
</table>

Kelly (2006) exclaimed that the maintenance system should be designed to aim at balance between the costs of maintenance, resources and savings in direct and indirect maintenance costs. It’s obvious that maintenance system is designed around the resource formation.

While, Wilson (1999) estimated that Maintenance aims to keep the company competitive in the industrial market, increase the production efficiency, safety at economic costs, and the profitability of quality products, maximize the plant utilization and capability, retain high asset value, decrease the costs, and develop people.
Though, Kelly (2006) thinking that Maintenance is responsible of production, safety and engineering department that specify the plant requirement, and develop the strategy that achieves these requirements at the lowest cost.

In the same time, Coetzee (2004) deduce that Maintenance objectives can be formed to support the production process with sufficient level of availability, reliability, and operability in the minimum cost.

Nevertheless, Wireman (1994) exclaimed that maintenance objects are

1- Reduce the maintenance cost and service as low as possible.
2- Achieve the quality requirements for the production.
3- Convene the availability requirements for important equipment.
4- Maintain the maintenance costs to be as low as possible for non-important equipment.
5- Supply and maintain sufficient facilities for the operation.
6- Supply skillful and qualified supervision.

Even so, Wilson (1999) represented that maintenance plans to be

1- Production life expectation and new product developments.
2- Company policy changes-group, site, financial.
3- Upcoming customer requirements and expectations.
4- Potential acquisitions and sell offs.
5- Process and equipment redundancy and obsolescence.

Maintenance can be improved throw eliminate the losses that can come in combined with maintenance. We can highlight some of the losses.

<table>
<thead>
<tr>
<th>Down time</th>
<th>1- Equipment breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2- Set up and adjustment delay</td>
</tr>
<tr>
<td>Speed or hidden losses</td>
<td>3- Idling and minor stoppages, when the machine is running but no product is processed</td>
</tr>
<tr>
<td></td>
<td>4- Reduce speed, when the actual machine speed is less than the designed speed.</td>
</tr>
<tr>
<td>Defects</td>
<td>5- Process defect (e.g. scrap, defect that needs repair)</td>
</tr>
<tr>
<td></td>
<td>6- Reduce Yield (e.g. from machine start up to stable production)</td>
</tr>
</tbody>
</table>
3.1.2. Maintenance strategies

Maintenance can be divided to major divisions depending on when the machines need to be maintained. Each type of these depends on factors that can decide the maintenance time. Each one also has different advantages and disadvantages. Most of the companies they use all of these kinds, each one in the proper place. Each type needs special scheduling for the maintenance recourses, in order to maximize the advantage.

Wilson (1999) exclaimed that the essential of maintenance is carrying out the right mission at the right time with both speed and skill. Maintenance depends on the progress of strategy which determines the intensity of planned work which is suitable, and on implementing the exact resource structure and systems for organizing and controlling the work.

With the aim of achieve perfect maintenance, the maintenance department need to satisfy the basic needs:

1- Increase the availability.

2- Continuous development for the maintenance strategy.

3- Organize the work to reduce the break down.

4- Measuring, monitoring, reviewing, and improve the service provided.

Moreover, the maintenance department responsible for planning to:

1- Production life expectancy and develop new products

2- Corporate policy changes, group, site, and financial.

3- Future customer needs and forecast.

4- Possible sell and sell off.

5- Equipment and process redundancy and obsolescence.
3.1.3. Corrective Maintenance (CM) “Work to fail”

This is the oldest type of maintenance and it is the origin, where the machines and equipment are used until it fail, breakdown, or its cost be more than profit.

Corrective Maintenance can be refer as the process to maintain and restore an item to original status after it wear out, brake, spoiled etc. (Marquez, 2007).

This type on maintenance still in use in many parts:

1. **Electrical equipment which is unpredictable to decide when and where it will breakdown.**
2. **Unimportant machines and equipment which will not affect the production in case of they break down.**
3. **Parts that do not have any dungarees effect on the environment, worker, and plant.**
4. **Parts that are easy to replace or maintain and there is available resources under the whole working time.**
5. **Parts those are very expensive to replace often.**

Kelly (2006) showed that in CM strategy, no action is taken to detect the inception or to avoid failures. The maintenance work starts with little or no warning. This will be costly in case of:

1. **The failure will lead to loss in production, danger, or damage. Or if the cost of letting the item fails is less than that of using another maintenance strategy.**
2. **The result of the failure is serious but does not take down the production for some time that is enough to do the required maintenance during this time. Such failures have to be identified and planned for in terms of decision guideline. Fault finding and resources is a kind of planning failure maintenance.**

Lycke (2000) explained that in the period (1900-1950), maintenance responsibilities were essential about repair work. Most of the maintenance were based on work to failure, i.e. the equipment were used until it failed then it either replaced or repaired. At that time they knew the importance of maintenance but the trend was to keep the maintenance as low as possible. This period is known as the era of “Break down maintenance”.

Wilson (1999) pointed at that the planned corrective maintenance is planned to hold in not more than one day before. By planned he meant that the job is prepared with tools, drawing, material, and spare parts and delivered also the site of work. It also meant it will take in consideration all the necessary and safety procedures. In the other hand, unplanned corrective maintenance is planned and started on the same day as it is required. Safety and procedures must be followed, the time for gathering the right tools, spare parts, and information will be added. Most of the time, unplanned maintenance is two or three times more costly than planned maintenance, and breakdown is often ten times more expensive than planned maintenance.

This type of maintenance will require spare parts to be ready to use, and fast process time to issue the parts. In most of the cases the company has at least minimum no. of spare parts in the inventory at all the time. This type of maintenance will required more spare parts than other type of maintenance.
3.1.4. Preventive Maintenance (PM)

Lycke (2000) showed that after World War II, there was a lack in manpower. They needed to increase the productivity of production, which lead to establish new type of maintenance that named as Preventive Maintenance. It depends on reduce the maintenance cost by either extensive time-based, or user-based preventive maintenance schedules were set up. Methods to improve the maintenance schedules had improved and developed during the 1960’s.

Wireman (1994) identified Preventive maintenance as a policy decision for each machine or equipment that decides in which maintenance it will be served preventive or corrective. The financial study shows that the more breakdown maintenance is performed, the more costly the maintenance will be.

PM can be referred to as chains of pre-planned performed jobs that aim to neutralize the identified source of potential breakdown of the intended functions of an Asset (Duffuaa et al., 1999), which it makes PM preferable in Asset.

From another angle, Wilson (1999) assumed that there is no technical system that can move the maintenance from reactive to proactive maintenance except that there is an error diagnosis following the correct procedures, allowing planned tasks to be approved to optimize the volume and regularity. By that a phased implementation of proactive approach will bring results that will require some primary investment.

Kelly (2006) uncovered that the level of information is important to establish the level of preventive maintenance, in order to achieve the maintenance goals. And also it would show the type and load of the maintenance, to estimate the required maintenance cost.

Wireman (1994) ensures that the preventive maintenance will be taken only when it will lower the maintenance cost. A check will be hold between the cost of preventive maintenance and breakdown cost. In some parts, it will be more economical to keep them running until they break down. If the cost of preventive maintenance is equal or higher than the cost of break down, then it will be a waste of time and money to hold them.

In order to build strong Preventive maintenance, it needs to depend on essential information, which it can be very useful also. Preventive maintenance schedule and reports can have many of this valuable information.

Kelly (2006) had spoken that the schedule for the preventive maintenance should contain all the necessary information, such plant operation pattern, safety requirements, equipment redundancy, etc.

Preventive maintenance schedule highlight the maintenance workload. Never forget, continuous check are necessary to ensure that the maintenance achieving all its goals.

Wireman (1994) had also spoken about that every equipment report should have the cost of maintenance (materials, man/hour), and history repair record which helps to understand how the equipment behaves and what was done with the equipment.

It also highlights the repetitive problems. This information will help to pinpoint the required preventive maintenance and the emergency maintenance. It also helps to investigate how to reduce the costs, or either the equipment need to be replaced by another one or applying different policy which needs less effort.
Preventive maintenance would reduce the inventory size, where many spare parts will be ordered to come just before of the maintenance time with a safety period. It will also reduce the minimum no. of parts in the inventories, where preventive maintenance reduces the risk of unplanned breakdowns.

### 3.1.5 Condition Based Maintenance (CBM)

Lycke (2000) estimated that the Japanese were first to talk about conditions based maintenance in the 1970's. During the 1980's Condition based maintenance was developed. In the condition monitoring program, the workers continuously update about the condition of equipment in order to forecast and stop failures. Condition based maintenance plays a significant role, because it uses fresh monitor techniques to analyze the condition of equipment in working by identifying signs of deterioration or pending failures.

Ablay (2013) showed that British Standard International (1993) identified CBM as: “the maintenance carried out according to the need indicated by condition monitoring.”

Kelly (2006) has identified condition based maintenance as an attractive idea which shows that the necessary maintenance can be determined throw monitoring the equipment condition and performance. The advantages will reduce the maintenance cost to the minimum through maximize the using of equipment and considering avoid unplanned breakdowns.

Moreover, Wilson (1999) adds that condition based maintenance usually applied to the equipment that do not fail instantaneously, but fail over a period of time and can be alerted throw early signs of an approaching failure.

Kelly (2006) adds that condition based maintenance is important where equipment has random failure or it is hard to predictable or the failure history is missing. It is also important for expensive maintained items.

Condition based maintenance can be hold throw

<table>
<thead>
<tr>
<th></th>
<th>Basic inspection</th>
<th>Generally, checks based on looking, hearing, and feeling.</th>
<th>The cost is almost nothing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Condition inspection</td>
<td>By measuring some parameters which is not recordable and can be used for comparison and control</td>
<td>It can be costly where experience should be involve</td>
</tr>
<tr>
<td>3</td>
<td>Trend inspection</td>
<td>The records and the measurement are plotted as a performance or conditions parameter to detect gradually departure from normal.</td>
<td>It is costly</td>
</tr>
</tbody>
</table>

21
Dennis (2002) stated that the company needs to invest in train the workers in how they can monitor the machines behavior, maintenance procedures, preventive maintenance, and conditions maintenance. This will increase the workers skill to identify the failure before it happen, and this will prevent mostly any coming breakdown. (20-50)% of the maintenance is:

| 1- | Simple maintainability |
| 2- | Cleaning               |
| 3- | Inspection             |
| 4- | Lubrication            |
| 5- | Adjustment             |
3.1.6. Total Productive Maintenance (TPM)

Kodali et al. (2009) considered Total productive maintenance as important concepts in industry that concern as integrated life-cycle approach to maintenance and support.

Ablay (2013) pointed that the Japanese developed TPM in order to improve affectivity, efficiency, and productivity of the maintenance after the use of Just-in-time (JIT) strategy and Total Quality Management (TQM). Any organizations that use JIT and TQM have to use TPM also.

Kelly (2006) showed that one of the TPM inventors said that JIT and TQM cannot be hold without TPM, where TPM highlight the importance of People. The major focus of TPM is continuance improvement throws improving the personal, tools, and prevention of maintenance by eliminating related problem, improve the design and reliability of organization.

Clety (2008) and Ricky (2004) have pointed that TPM use PM and CBM to avoid and expect breakdowns in the future. TPM depending on document all the breakdowns specifications and details (labor (need/hour), spare parts, notes, and other costs). TPM also demand to train the maintenance team to have all the necessary skills that needed to execute the task. TPM focus on continuous improvement of the maintenance process to reduce the maintenance time and resource in each task and to increase the quality of work.

Kilpatrick (2003) have viewed the benefits of TPM in three fields:

<table>
<thead>
<tr>
<th>Operational gains</th>
<th>It is reduce lead time and inventory, it also increase productivity and quality.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative improvements</td>
<td>It is reducing paper work, staffing, process errors, streamlined, customer care, cost reduction, and jog standardization.</td>
</tr>
<tr>
<td>Strategic gains</td>
<td>In achieving all the organization goals.</td>
</tr>
</tbody>
</table>
3.2. Spare parts management

3.2.1. Spare parts

Spare parts are machines changeable parts, tools, equipment and supporting parts which are needed to keep the machines reliability above the desired level. Cedervall & Hilmertz, (2013), showed that old tool can be assembling and some of its part can be used as spare parts. They are named as “reused spare parts”, they will reduce the cost of buying new spare parts.

Mehrotra et al. (2001) claim that the spare parts inventory typically accounts 5-10% of the organization investment. Cardamone (1996) has pointed the main goal of inventory control to maintaining level that can support the demand under various circumstances of the market situation.

According to the well-known Lean philosophy, extra parts material is a waste. Most of the companies who followed Lean philosophy realized disadvantages of having huge parts inventories, where the money that invested in parts inventories, can be invested on more important things. It is also expensive to store a large amount of parts, where these parts need a place, control, handling, etc. which the company can reserved throw having the necessary parts only.

Dennis (2002) explained Lean thinking of inventory throw that inventory is related to keep of necessary raw material and parts. The company required to link to the drumbeat of the market. Inventory should use “push” system instead of “pull”, which will save scores of money and space. Moreover, using the 5S technique will help to identify the unnecessary parts in the storage. Having a good storing system and continuous control will high light the parts that have stored for long time, and prevent any unnecessary orders. It also helps to track the parts usage, which allows modifying the ordering quantity to suit up the need exactly.

Coetzee (2004) explained that spare parts are considered as lifeblood for the maintenance department. It needs to be handled carefully and efficient by purchasing the right quantity with the proper quality at the right time and considering the cost limit. Maintenance organization depends on appropriately managed spare parts inventory.

Maintenance department is depending on well-organized inventories of spare parts. Quantity and time of order considered as one of the importance task in the management. It’s important coming from the changing of price with the quantity, where small quantity purchasing will led to high cost per unit and high quantity purchasing will led to low cost per unit, in the other hand, the cost of inventory will increase when there are many spare parts. The best is to balance between the cost per unit and the cost of storage. From another angle, inventories depend on the investment that the company willing to do to achieve the desired availability, where more types of spare parts led to more insurance and stability of maintenance time. Basically, inventory size depends on the cost, and the cost can come from main sources:

<table>
<thead>
<tr>
<th>1- Acquisition</th>
<th>2- Holding</th>
<th>3- Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>This involves the fixed charge related with place an order.</td>
<td>This involves the interest of the invested capital, storage costs, handling cost and depreciation.</td>
<td>This involves the penalty cost that occurs when the storage is out of spare part that is needed.</td>
</tr>
</tbody>
</table>
Lagercrantz & Wenngren (2013) highlight that Mattson (2004) & Olhager (2000) stated that one of the Inventories advantages is that inventories make the organization dependent form the suppliers and external demand. Inventories can be in many forms: safety stock, cycle stock. Speculation inventories, consignment stock and vendor managed inventory.

3.2.2. Spare parts management

Wireman (1994) showed that maintenance involves shipping, receiving and distribution of spare parts that are necessary for repair, keep up and maintain plant equipment and machines. It is maintenance responsibility to record all the spare parts that are needed, and register all spare parts that inter and leave inventories.

Moreover, it is maintenance responsibility to set the minimum level and the order quantity for each spare part. These two factors are very important where they could result to over cost or delay the production if an equipment breakdown and there are no available spare parts to use.

With the increasing of expertise development in the 21th century, the industrial management system has turn into more complexes, which it leads to increase the critical of spare parts control and availability. Any lack in the spare parts would create unexpected downtime, which leads to lose money (Bailey & Helms, 2007). Eaves & Kingsman (2004) highlighted that a portion of spare parts has slow demand, which leads to unique problems for both forecasting and inventory control. Kennedy et al. (2002), agrees with that inventory has unique relationship with management topics: age based replacement, multi echelon decision, obsolescence, and repairable spare parts.

Aronsson et Al. (2006) have explained that the organizations need inventories to reduce the cost that is not associated within the capital or in the risk of stocks. Inventory reduces cost of parts per order, transportation, administration, error, over stock, etc. A further important reason for the use of stocks is to maintain a high level of service to customers when demand is variable or when providers have poor delivery reliability.

Choosing the right spare parts to be in the inventory with the right quantity is very important decision, where it affects the cost of inventory (Cavlieri et. al., 2008). Inventory management is all about based on certain service demands balancing capital costs against the costs of purchasing, production and transportation (Axsäter, 1991). Holding spare parts to increase the availability can be extremely unwise in the expensive and rarely spare parts issue (Cavalieri et. al., 2008).
Kinnison (2004) divided spare parts management to four departments:

<table>
<thead>
<tr>
<th>1- Inventory control</th>
<th>This is responsible for guaranty that all needed spare parts are available in the right place and the right time. It is also responsible to set the spare parts level in the storages and adjust them if there any changes happen in the usage.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2- Stores</td>
<td>This is responsible for issuing and exchanging parts with the machines. Stores are responsible for delivering parts to work place, and guaranty that the spare parts that need special storage and handling are correctly managed.</td>
</tr>
<tr>
<td>3- Purchasing</td>
<td>They deal with supplier and manufacturers in order to provide all the necessary spare parts under specific costs, delivery time, etc. Normally they have budget, so they are teaming with finance department to set this budget.</td>
</tr>
<tr>
<td>4- Shipping and receiving</td>
<td>They handle all packing and unpacking spare parts that are shipped in or out. They are responsible about quality control inspections that may be required.</td>
</tr>
</tbody>
</table>

Spare parts management includes five responsibilities:

### 3.2.3. Ordering

Ordering includes the timing for make an order and purchase the right quantity of spare parts that reduces the cost. They make order when a specific spare part under the minimum level, where this minimum level depend on many factors which are divers from part to part. The location of the maintenance may affect the stock level, where many maintenance stations will need more parts. Quality, skills and ability of maintenance crew, is another factor that affects the usage of spare parts. A continual perusal of stock usage by the materiel section is necessary to optimize the stock levels on hand. The parts utilization rate is another factor that affects purchasing and reordering time, and we can add the repeatable parts and lead time for repair action as affecting factors. Lastly, varies suppliers policy and offers may be affecting from economic view.

SPM depending in several factors to determine the number of each parts that should be in the order and parts should be hold in the inventory. Most important factors to be considered in spare parts management are:

<table>
<thead>
<tr>
<th>1- Demand</th>
<th>2- Ordering cycle</th>
<th>3- Lead time</th>
</tr>
</thead>
<tbody>
<tr>
<td>This is the rate that the spare parts are required for maintenance work. The demand can be described as being deterministic or probabilistic.</td>
<td>It is the right time to make an order, usually it is decided throw two ways:</td>
<td>It is the time that it takes from placing the order till the delivery.</td>
</tr>
<tr>
<td>Continuous review: the order placed when specific spare parts are under the minimum level.</td>
<td>Periodic review: the order placed every specific period of time</td>
<td></td>
</tr>
</tbody>
</table>

### 3.2.4. Parts storage
Parts storage mainly responsible for store all parts in suitable location where they needed, and storing special parts which it need special condition to be stored. Most of the storage they use the traditional set of storage “shelves and bins”, which is marked by a coordinate system to be locate and found easily. Normally, the shelf and bins numbers are used to register the parts, to simplify the system for the personal to store, locate, register and find the parts. Most of the companies use paper work which is needed to be signed by storage personal and the receiver; in addition, they may use a computer system to show storage level, location, and the availability of parts. A proper storage system will reduce maintenance time throw find and receive the spare parts in a proper time.

Spare parts need to be handle separately, and they should have the characteristic of the environment that the spare parts will be stored and used (e.g. the temperature, humidity, user skill and capability) which found covariates (Ghodrati et al., 2007).

3.2.5. Issuing

Spare parts have varies cost. Parts that have low cost (bolts, nuts, etc.) normally stored in open, accessible bins near to the floor shop, so it would have easy access. Parts that are expensive or need long time to order (black boxes, assemblies, major parts, etc.), stored in place with personal control, who can issue parts to where they needed. When parts are taken the personal, it records throw papers and sometime throw computer program, in order to get a replacements.

3.2.6. Controlling

Parts control are usually done by the maintenance department, suppliers, or outside repair contractors, and warranty holders control spare parts functions.

Ewetz & Fridell (2013) stated that inventory control has developed tools to provide information, including historical consumption, classification, order point and order quantity, and recommendation.

Inventory control of a warehouse with several number of retailer systems is a subject that has concerned major research interest for quite some time (Berling & Marklund, 2013).

3.2.7. Handling parts and supplies

It can be called “shipping and receiving”. It begins when spare parts order issued from suppliers, and in some cases, it includes quality control and inspection to insure the spare parts quality, parts numbers, serial numbers, application, modifications, expire date, and physical conditions are correct. Later they distribute the parts to stores, production lines, shop floors, etc., and register parts throw papers and computers. Spare parts levels are updated occasionally.
3.3. Spare parts classification and techniques

Spare parts are classified by the companies to groups in order to handle them in better way and to avoid losing them by mishandling (parts could be fragile, heavy, small, etc.). In some cases these parts have long ordering time or shipping time and it will be hard to get unplanned replacer. In the other hand there are some parts that can be simply handle and control, where they have low cost relatively to the storage cost, fast shipping time, other parts are easy to be ruined in handling or they have special storing condition. Dividing spare parts to group has many advantages especially in the big storing inventories, where any change in the storing or controlling system will be hard to establish and it could also be costly, in case we apply it to the whole inventory. By dividing the spare parts we can apply better policy on each group without affecting the other groups, this include increasing or decreasing the controlling system according the need. In cases of low cost spare parts, eliminating the inventory control process would reduce the maintenance time. In this case some companies use sub inventory for such parts, and they depend on the maintenance personal to register the used parts, issue, and order more material.

In order to classify the parts in groups, companies use different techniques according to their desires. Some of them use slandered technique like ABC analysis for example.

3.3.1 ABC analysis

The budget resource is a main factor when establishing stock level. Overstocking lead to minimize the maintenance time and eliminate the delay of shipping, but it will cost more than it should too. Having money tied up in parts that could not be used or sometimes expired on the shelf is absolute waste of resources (Kinnison, 2004).

Coetzee (2004) has explained that ABC analysis is famous technique to classify spare parts and reduce the workload. This technique classifies spare parts to three groups (a, b, c, or 1, 2, 3) depending on the value.

Group A has the high value spare parts, and B group has the lower value spare parts, and C has the lowest value spare parts. The value is equal to (unit price * quantity), normally group A has (10-15) % of the inventory quantity and they have cost value about (70-75) %. Group A will need an accurate controlling system and continuous check, because that it have the most value and any fell could happen, it will affect the inventory budget. A special handling and control system is requested, to eliminate any storing or handling loss.

Group B has the middle value parts and they are about (25-32) % of the inventory parts and their cost value are about (15-20) % from the inventory value. A normal handling control system is requested.

Group C has the parts that have low value, where this group items are (50-60) % of the inventory’s items, but their value is about 5% only. A simple handling control system is requested.
<table>
<thead>
<tr>
<th>Quantity ( % of the inventory spare parts)</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-15%</td>
<td>25-32%</td>
<td>50-65%</td>
<td></td>
</tr>
</tbody>
</table>

| Value (unit price * quantity)(% of the inventory value) | 70-75% | 15-20% | 5% |

Handling:

- **Group A**: It will have continuous control to keep the spare parts level as low as possible, where the cost of this group have the biggest effect on the inventory investment.
- **Group B**: It will have normal controlling and handling, with good record for the items.
- **Group C**: It will need simple control and simple record for the items.

![ABC analysis](image)

**Figure 1: ABC Analysis**
3.3.2. Minimum – Maximum control

To make parts order, the company need to know when to make the order and the quantity. Parts have different usage and they can be supplied in different quantities. With the purpose of reduce the cost of inventories; it is wise to keep the maximum level of each part as low as possible. In the same time, it is wise to keep a good safety number of parts in case that the new order is late for normal reasons. With the intention to identify the minimum and maximum number level for each type of parts, companies use different technique. One of the famous technique is “Minimum – Maximum control”.

Coetzee (2004) had aimed this technique to be the most wildly used in inventory control. It depend on establish the minimum and maximum parts level in the inventory from controlling view. The minimum level represent the number of parts that is needed so the last part used just before the new order arrive, and then the order quantity will be the maximum level for this part. A safety cushion should be added to the minimum level to ensure any unplanned changes in the process. The minimum level would be concerning fluctuations in needs, delivery time, parts cost, and storage cost. The minimum level should keep the production hold under normal circumstances. The maximum level then will be the minimum level plus the order quantity. The minimum level represent the safety cushion against increase of parts demand, defective delivery, long shipping time, storage errors, and miss handling. The minimum level increases when the risk of stock out is increasing on particular part. The minimum level should be choosing carefully, where it would be considered as unused potential under normal conditions, and it would reduce the risk of unexpected conditions. From economic view, the minimum level should be as lower as possible. At the same time the minimum should cover any sudden condition that may delay the new parts from arrive at the expected time.

Kinnison (2004) stated that the maintenance activities will determine the parts that in the inventory, maximum and minimum level of each part, order quantity and order time. This will vary from part to part. It is important to have records for the parts usage and a continuous adjustment to satisfy the demand. Moreover, Wilson (1999) stated that some parts like consumable parts for mass production machines and equipment are gladly available from the manufacturer of the planet or stocking agent. For these items, broad stocking is not necessary. It is wise to have small stock to insure immediate supply and to avoid any delay in service. In this case, a continuous control is necessary. A wise choice to be considered is to arrange to exchange parts and components with an organization specialized in refurbishing that can offering a part exchange service. Such organizations are wildly known in automobile manufacturing, where they offer to exchange engines and other components. This exchange will help to avoid high storage cost, and better availability. The disadvantage is that the cost of service will be higher than the cost of normal storage.

After finding the minimum level of parts (safety number), it is important to find the order quantity. The maximum level then will be minimum level plus the order quantity. For identifying the best order quantity, many factors involve (acquisition cost and inventory storing cost). There are different techniques to find order quantity and one of these is Economic order quantity.
3.3.3. Economic order quantity

The cost of spare parts is coming from two shares. First share is the order cost, where each order has a fixed cost that comes from shipping the parts, processing the order, handing the parts in the inventory, etc. Second share is the holding cost, where each part in the inventory need to be controlled, check, cleaned, etc. First share cost per unit is decrease when the order quantity increases, after all its fixed cost and it will be divided by the number of parts in the order. While second share cost per unit is fixed per unit, but it increase with the time that parts stay in the inventory. So increase the order quantity means that the parts will stay longer time in the inventory and this means the inventory holding cost will increase also.

Coetzee (2004) had showed the drawing technique as the best way to find the best quantity order. The technique is easy to understand by drawing the cost curves (storing cost, acquisition cost, and total cost) from the total cost curve, it would be easy to identify the minimum point at the total cost curve which represents the minimum cost.

![Figure 2: Economic order Quantity](image)

From the diagram, the lowest point in the total cost curve is the best order quantity. It shows also how the acquisition cost per unit change with increasing the order quantity, and how the inventory holding cost increase with increasing the order quantity.
3.4. Supply management

The Supply Chain can be defined as all the actions in producing, delivering, and using products or service, that’s includes manufactures, warehouse, distributors, marketing and sales, R&D, finance customer service and costumers. SCM can varies between organizations and companies, but all lead to satisfy the costumers demand. The SCM transport information, products, and money (Chopra & Meindl, 2007).

It is up to the company policy to decide how much they want to involve in supply chain. Where the company control and power over the supply chain, increases with the parts that the company has from the supply chain. This will include more effort that the company will have to put, but it will increase the insurance of delivering the parts in the right time, right place and right quantity.

Coetzee (2004) stated that nowadays, there is realization that the company required to entire supply chain, if they desire to be able to have always the required supply when they need it. This concept shows that there is much natural value implanted in the simple fact that all the activities in the chain must add value to get customer satisfaction.

The advanced maintenance materials supply line should have the following characters:

1- The customer defines the requested quality of the purchased product.
2- The supply chain links do not proceed independently; they are all parts of one large group process to add value to the parts.

The reason of inventory existence is the unmatched between the supply chain and the demand.

In other scenario, there is uncertain demand which the company need to satisfy. Inventory (safety stock) might be a good solution to cover these kind of demand (Fisher, 1997; Hugos, 2006; Chopra & Meindl, 2007). It is highly recommended that all the processes and function of the organization are linked to the supply chain strategy. This will lead the overall supply chain to success (Chopra & Meindl, 2007).

Blecker & Kerstin (2006) have given the factors that cause higher weakness in the SCM:

- Internationally supply chains
- Centralized production and distribution
- Reduced inventory holding
- Outsourcing and reduction of suppliers

Bayer & Bustad (2012) have stated that nowadays business environment has high complexity and insecurity; manufacturing organizations have to manage their supply chain effectively to increase the efficiency and reactivity.

Drüke et al. (2009) have also add that organization aim to be cost efficient as much as they can, in the same time as fast responding to the market demand. In the business field, a general rule is that more complex supply chain lead to the more interfaces present and more vulnerability will exist.
3.4.1. Supplier management

The supplier is a key concern in the organization and as such is at all times treated with care (Ajakaiye, 2012). With the increase of communication between the companies and suppliers, a large number of suppliers appear for every part the company needs. This will create a huge amount of option where every supplier has his own policy of selling his parts. This leads the company to other alternatives that need to be managed.

Coetzee (2004) had identified supplier management as the selection of right supplier, and it is one of the essential aspects effective of purchasing management. Choose the right supplier has the big effect on the price, quality, and time of purchasing. Choosing the right supplier involve preventing the danger of out-of-stock, unwanted parts, extra cost, and long shipping time. From the spare parts management view, the company need answer these questions

<table>
<thead>
<tr>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the characteristics of good supplier?</td>
</tr>
<tr>
<td>Would the company use local supplier only or they can use other supplier?</td>
</tr>
<tr>
<td>Would the company buy from the manufacturer direct or would they buy from distributor?</td>
</tr>
<tr>
<td>How many suppliers for specific parts, will the company have?</td>
</tr>
<tr>
<td>How would the company choose their suppliers?</td>
</tr>
<tr>
<td>If the company could not find a supplier that fits the entire characteristic, how would the company choose the supplier?</td>
</tr>
</tbody>
</table>

Also, the company should keep in mind that the relationship between the maintenance department and the supplier of spare parts should be based on cooperative relationship. The company and the suppliers need to make profits so they can survive and continue the business. Any negotiations should be based on considered the other party view of point. They have to understand each other process, the cost of manufacturing, and the profit margin that each company need. They should also have a joint agreement to improve and to share information.

The organization supply chain strategy could give the indicators to choose the right supplier (An & Fromm, 2005; Chorpa & Meindl, 2007). The organization policy will determine whether responsiveness or efficiency in more important to increase the competitiveness, which will be considered in supplier choosing (Chorpa & Meindl, 2007).

Danielsson & Nilsson (2013) showed that most of the local suppliers are nearby to the markets that demand their spare parts; this will ensure the fast delivery. In common, local spare parts are approximately 30% of the total service business and many request and provide from different regions.

Hajji, et al. (2011) stated that it is permanently more gainful to have more than one supplier, where several suppliers have higher availabilities rate.

Hopkin (2014) has views the importance of consideration Risk Management to the organizations that have internationally suppliers and customers.

Alsharifi (2014) had also added that the supplier should be reported with the desire time for delivery as interval, so in case of any change, the time can be modified to a more suitable, this will increase the efficiency of the logistic.
3.4.2. purchase price management

The price of spare parts and maintenance cost will effects the value and the cost of the products. In order to create a reasonable price for the products, the company needs to achieve a reasonable price for the maintenance cost and fair spare parts price. The spare parts price has large influence on the products price (Coetzee, 2004).

The company should stay updated on the spare parts market, in order to buy with best prices that can improve the production in the lowest price so the company can increase its productivity and to insure its survive.

3.4.3. Storage location

The inventories are related to supply chain efficiency and responsiveness, where large inventory usually have shorter lead-time, higher responsiveness (Chopra & Meindl, 2007)

Storage location is important aspects to be deeply considered to achieve the minimum transportation to all the machines that need spare parts form this storage. The company needs to consider having one or more storing in the site to decrease transportation time.

The best storage location should be on the floor shop to decrease transportation time. The location should involve the location of refurbishments of spare parts if there is (Wilson, 1999).

The number of inventories and their locations is important factor to decide the inventory strategy to be centralized or decentralized, and the trade of the spare parts (Danielson & Nilsson, 2013).

Distribution Centers (DCs) is an effected way to increase the supply chain efficiency, where they choose a suitable place to hold one big inventory that supply few small inventories, this will reduce the number of spare parts in the inventories and free some resources ( Chopra & Meindl, 2007).
3.5. Management Computer Program: Systems, Applications & Products implementation (SAP)

SAP (2015) is one of the world leaders in enterprise applications in terms of software and software-related service revenue. According to market capitalizations, SAP is the world 3rd biggest individual software and software related service benefits.

Knolmayer et al (2002) claimed that engineering calculations can provides the technical information for products, process development, research product planning, product design, development of process plans and programs for numerically controlled machines, and the technical preparations for layout, material flow, and quality assurance.

SAP is providing service in the Supply Chain Management (SCM):

| 1- Business information warehouse |
| 2- materials management |
| 3- production planning |
| 4- sales and distribution |

SAP provides electronics support procurements of goods and services, it integrate the process into overall flow of goods, information, and finances. Business to Business procurements (BtBp) is established particularly for purchasing parts by a staff by purchasing budget. The program provides information about the capability to procure goods, services individually during a session at their own workplace depending on internet technology. The program can support also the choice of suppliers, negotiations terms, shipping, and other agreement.

BtBp provides the following services depending on web support.

| 1- Create, modify, and cancel order requests |
| 2- Approve or reject order requests |
| 3- Conforming the arrival of requested material without the need of involving a central unit. |
| 4- Can derive invoices via extranet from the order data and pass them on to the purchasing department or other parties for approval, invoicing, and payments. |
| 5- Services providers such as consulting or freelancers. |
| 6- Electronic placement of orders |
SAP is also provides a flexible connections service to products catalogs. SAP provides three types of connections:

1. The administration of the company
2. The suppliers
3. Direct access to the suppliers web

In the warehouse management, SAP provides the following services

1. The management of warehouse layout and equipment
2. Overview of warehouse movements
3. The management of activities that combine the goods (receipt, issue, etc.)
4. Maintain the inventory data for storage bins throw continuous stocktaking
5. Put away and picking of dangerous goods and all other materials that need special handling
6. Special services (customized packing, labeling procedures, etc.)

SAP helps to improve and develop the following:

1. Data collections
2. Stocking, picking, and transfers
3. Packing
4. Shipping and loading control
5. Displays of stock data
6. Monitoring functions

### 3.6. Key performance indicators (KPI)

Key performances Indicators are important tool to understand the issue and the result. It is also highlight the essential of the issue, in addition to the goals from the study. Choosing the right KPI’s would lead the researcher to hot spot and improve the result to achieve the highest benefits.

Marr (2012) encouraged the companies to have more knowledge about KPI according to its importance. He also asserts that without properly selected KPI to float management and supervisors blindly over the sea. The problem behind choosing the right KPIs for the business often lies in the line, it is difficult to identify and understand which KPIs that are necessary for their particular operations and instead gathers on him all the values that are easy to measure. A natural result of this is that the management drowning in data and information on different KPIs when they actually lack the data they really need.
4. Case studies

4.1. Case study: Al-Nasser State Company

About the company

General Nasr Company for Mechanical Industries (2015) showed that it is a property of Ministry of Industry and Minerals in Iraq. It was established in the year 1980 in partnership with specialized well known international companies in the mechanical field, and commenced production direct in 1984, and is one of the leading and prestigious in the international market of mechanical industries, companies, and aims to contribute to the national economy. The company locates in the Taji section, it is 35 km to the north of the capital Baghdad, the company is a self-funded financially viable unit and enjoys moral personality and financial. It has individual independent administrative, and it is governed by the Public Companies Act No. 22 of 1997. Al-Nasser state company is one of the giant industrial sectors in the Middle East for its giant capacity and enormous potential, and advanced its position in the national industry companies.

The company consists of four productivity coefficient is

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1- Steel structures plant</td>
<td>It produces structures, industrial double insulation, walls, slabs ceilings and all the parts for caravan’s production, towers, steel doors, poles, etc. The company develops and aims to build the infrastructure in Iraq, and to compete in the international market. The company have encouraged and stimulated to rehabilitate most of the lab sections and adding new and modern machinery for the development of the plant production and quality addition. The company has many partnerships with international companies.</td>
</tr>
<tr>
<td>2- Foundry Special Steel</td>
<td>It is the only specialized foundry in Iraq for the production needs of the cement plants of steel balls and bushings corrosion resistance used in the cement plants of all kinds of hammers and crushers’ corrosion resistance in addition to the fabrication of steel castings and manganese gray cast iron. In other casting multipurpose.</td>
</tr>
<tr>
<td>3- Zulfikar machining</td>
<td>It produces all the necessary formalities and routers for other the other parts of the company. It produces also moldings, spare parts, machining programmed electroplating as the market demands. The company has entered into a partnership with the Jordanian company to produce ornaments seal liquefaction which has produced moderate quantities.</td>
</tr>
<tr>
<td>4- Central laboratory services</td>
<td>It provides the other parts of the company with all the service they need, such as power generators for the projects, different types of water that use in plants, and many other services</td>
</tr>
</tbody>
</table>

The company has a highly trained experienced specialized crew, and run advanced production lines with giant capacities. The company has about 4000 employees and over 1000 machines and equipment.
The Company SPM model

Ali Q. (2015) stated that According to the giant property size of the company, each plant has his individual inventories. Plant’s inventories have connections and they can supply each other with spare parts, but each one has its own budget and its own characteristics management that can fit the plant. The inventories share the following points.

1- Same controlling computer and paper system.
2- They use a standardized controlling and naming system (ISO 9001), so the other inventories can read and know each other spare parts.
3- The spare parts inspectors, who receive spare parts from the suppliers, come from all the inventories, so they can share information and knowledge
4- All the inventories use one exit and entrance with one unify record, in order to avoid any miss delivery for spare parts, where there is large number of spare parts that enter the company.

Foundry Special Steel inventories

There are three inventories in this plant, where they store products and spare parts according to their types and storing conditions.

| 1- Row material inventory | According to the production use, the company use special sands, bricks, and other components to form sands molds. These materials are considered as part of the production line because it reused. All the sands and other components are saved in this inventory because it needs the same storing conditions. This inventory is normal building with big entrance which allows large trucks to enter. It does not have any cooling or heating system. According to its big size of packing and it’s relatively price, the inventories has no personal inside the inventory and there is no security system, where they depend on the company outside security only |
| 2- Equipment spare parts inventory | This inventory stores the iron and electrical parts and equipment. The building normal building with good security system without cooling or heating system. It has small entrance that can fit small truck only to enter. There is personal always at the building to control and record any parts that need to enter or leave the inventory. The parts receive should have authorization paper that is signed from the plant director or heat of department |
| 3- Chemical material inventory | This inventory stores the spare parts that need special condition of storing, especially the parts that can be burn fast or has chemical component. The inventory building is big but has small entrance that can fit small truck only, with the aim of reduce the risk of loading big trucks inside the inventory. The building has |
security system and electronic gate where only authorized personal allowed entering. It is provide also with heating and cooling system to provide the parts with the desired storing temperature. Any parts that needs to be entered or leave the inventory needs to have paper works that have been signed form the plant directory or head of department.

There are sub inventories beside each production line that contain small, cheap, safe, and repeatable break down parts. The sub inventories eliminate the process time to get the parts to fix or maintain breakdown, where the paper work can be done later after fixing the problem. The size and types of parts in the sub inventories are up to the maintenance department to be decided.

4- Sub inventories

Inventories management

1. Control and record

The company use paper and computer system to record and control the parts in the inventories. The personal prefer always use the paper records instead of the electronic system, due to the ease of use (where some workers are uneducated), the computer system is for information network purpose inside the company and the ministry.

2. Storing

According to the variety of parts, there is many storing system. In the raw material inventory, they use containers to store the materials. In the equipment and spare parts inventory, they use shelf and bins system; in some cases they use room to store the large size equipment. In the chemical inventory, they use special containers that especially designed for each part.

3. Order processing time

The parts that were pointed to be delivered from a specific supplier would usually take a week to be processed from the planning department to the supplier, and the parts that are needed in urgent cases (unplanned breakdowns) they usually take two days to be processed. The parts that are not assigned to supplier would take long time to be processed according to financial department policy. It is usually take one month or may be longer time to be processed.

4. Purchasing

Planning department is responsible for making the orders and sends it to financial department, which are responsible to find the best suppliers with the best price and insurance. Planning department interpreters the present working data and the future demand forecast to identify the number of spare parts in the inventories. There are three types of purchasing orders:
1- Yearly order
Some parts are order yearly according the yearly need, where the company aims to minimize the inventories by the end of each year for financial reason and the ministry policy.

2- Monthly order
Parts that are related to monthly demand are order monthly, aiming to avoid over storing and tune the number of spare parts with the changeable demand

3- Urgent demand
This orders are made according the urgent needs (because of unplanned breakdown) and it is made as fast as possible.

After submitting the orders to financial department, they gather the orders from all the inventories, and make bigger orders with larger quantity. They start to contact the suppliers that the company deals with to make offers about the prices, delivery times and guaranty. The company get better offer in larger orders and simple the control and record system.

5. Delivery and shipping

The suppliers are always responsible for the shipping. All the shipping is controlled by a group of inspectors (gathered from all the inventories) check the spare parts work, number, quality, quantity, description and income time. In case of sending the parts between inventories, the receiver inventory is responsible of transporting.

6. Spare parts minimum & maximum level and order size

The minimum level is decided according to the order and shipping time multiplied by the daily usage of this part, plus a safety number in case of delay happens. The maximum level is the usage of parts in the order period (monthly or yearly) plus the safety number. The order size is the maximum level minus the number of parts that there in the inventory at the ordering time.

7. Repeated Problems

Receiving wrong parts are the most repeatable problem we face, in most of the cases the supplier send wrong parts that not fits the demined parts. Because of the specialty of machine that the company use, the supplier should have good knowledge about the parts otherwise it would be hard to identify the right parts. The company is trying to reduce the problem throw choosing the right supplier, modify the control check list, increase the skills of inspectors throw more training and bring them from different inventories, so they can share information and spread information.

The biggest problem that the company faced due to spare parts was a breakdown for 45 days because the replacement part had not the right program, the problem could not be fixed throw internet, and the parts had to be shipped back to the manufactured factory in Turkey to be programmed and sent back to the planet again.
4.2. Case study: Midland Refineries Company (MRC)

About the company

Midland Refineries Company (2015) has showed that the company is a property of Ministry of Oil in Iraq. This was building in 1953 by a group of international company like Foster Wheeler, M. W. Kellogg, and Exxon Research & Engineering. The refinery conversion designed to achieve the maximum of crude oil to sustain the growing nation of Iraq. The company started the production in 1955 with many production types that ranged from simple distillation units to complex fat production. The company had expanded many times and the production capacity reached 110 thousand barrels per day at the end of the last century. Nowadays, the production capacity is reached 210 thousand barrels per day. The Iraqi market for Oil is expanding and there is demand for more production. The company production is supplying the Iraqi and the national market with oil. The company has got the Minister of Oil recommendation for expanding and increase the production rate, also the Ministry of Oil has support the company with the all the needed resources. The company considered to be an important resource for the Iraq economy.

The company locates in the south-eastern suburbs of Baghdad near the Tigris River and an area of nearly 250 hectares. It is also called Daura Refinery according to the name of the area the company locates in.

The main production capacity for the company units is:

<table>
<thead>
<tr>
<th>Production Unit</th>
<th>Production Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>THE CRUDE DISTILLATION UNIT</td>
<td>24,000 BARRELS/DAY</td>
</tr>
<tr>
<td>GASOLINE TREATMENT UNIT</td>
<td>6,200 BARRELS/DAY</td>
</tr>
<tr>
<td>IMPROVED WHITE OIL UNIT</td>
<td>7,000 BARRELS/DAY</td>
</tr>
<tr>
<td>SULFURIC ACID PRODUCTION UNIT</td>
<td>22 TONS/DAY</td>
</tr>
</tbody>
</table>

The company produces:

Gasoline for automobiles
White Oil
Gas Oil (diesel)
Fuel Oil (black oil)
The company has other units that produce complementary materials, which includes:

- **RESERVOIRS TANKS YARD**
- **BLENDING FOURTH ARTICLE OTHILAT LEAD UNIT**
- **ISOLATE OIL MATERIALS AND SEWAGE TREATMENT UNIT**
- **TORCH SYSTEM UNIT**

### The Company SPM model

Al-Bawi H. (2015) has showed that Midland Refinery Company has about 1800 maintenance personals and about 1000 machines to maintain. The working time is 24 hour/day, 7 days/week, 52 weeks/year in 5 shifts.

According to the large number of machines and spare parts that the company has, and regarding the company policy, the maintenance department has classified spare parts to seven types and they use one inventory for each type. Inside each inventory, personal classify the spare parts according to the use and they have special place where they save the high value spare parts. These inventories share the following point:

1. **They use the same managing system.**
2. **Any part that has to be entered or leaved the company has to be registered in the main get check point, and then registered again in the inventory records.**
3. **They use the same technique for naming the parts, which it makes easier to search in all the inventories.**
4. **There is a receiving committee that is formed from one member from each beneficial part, who will do the quality control when any parts order will be received.**
5. **The company uses all three type of maintenance (work to fail, preventive, and base conditions maintenance), it is depending on the importance of the part, the damage that could happen when it break, and the maintenance time.**

### Control and record

They use paper and computer record system. The paper is obligatory for receiving spare parts, and should be signed from an authorize side. The computer program name that is used, ERT (enterprise rescues planning), which is an advanced program that can show the level of parts, when they need to make an order, and connect all inventories that belong to the Ministry of Oil in network, so they can see what each inventory has. Yearly control occurs to rerecord all the spare parts in the inventories and eliminate any miss record. In every receiving spare parts order, a committee of experience personal checks the spare parts quality, quantity, property, and conditions.

In each inventory, there is always personal to hand in spare parts and record them.
Storing

They use the normal storing shelf and bins storing system, and in each inventory, there are special places that are more safety to store the high value parts, to avoid any miss receiving or damage. There are also some parts in the inventories that are designed to store parts in specific conditions as they recommended.

Purchasing

There are many types of order, the orders that is commonly used is ordered by the help of the record program ERT, where it high light all parts level and minimum & maximum levels, it shows notes when any spare parts level is running below the minimum level. It also helps to show the supplier that the company deals with and all the necessary information. This type of order takes a week as processing time, before it reach the supplier.

There is also urgent order, it happens when there is unplanned breakdown. The information is gathered about the needed spare parts and their supplier as fast as possible and order would be send in about one or two days to the suppliers.

There are other type of orders that for long time preventive maintenance, where the spare parts will be received just before the time of maintenance. Where there is no need to store the parts in the inventories.

Shipping and receiving

The suppliers are always responsible for the shipping. In case of transporting parts between the inventories, the beneficiary side is responsible for the shipping. They use pull system to transfer the parts.

Maximum & Minimum level

The company policy is to build stores for 10% percent of each type of parts that would be change due to maintenance issue. So the maximum level for each part is the 10% of the parts that are in process in the company. The minimum level would be 2.5% of the parts in process. This would be the minimum& maximum level for each part in the inventory, in some cases, modifications happens to insure satisfying the maintenance demand.

Order quantity

For the regular parts, order quantity is 7.5% or the parts in process. By other word, order quantity is the difference between the minimum and maximum level of each part. For the parts that have relatively long working time, and high reliability, it is order before short time from when they are needed, so they eliminate storing them in the inventory for long time.
Preparing spare parts time

The needed parts for the maintenance are prepared day before the maintenance or less, depending on where it comes from and storing condition. This is also eliminating the need of sub inventories, where everything is pre organized.

Suppliers

The company dealing with over a thousand suppliers, due to the variety of spare parts and the company policy to ensure finding the right supplier that can satisfy the demand in the right time, right place, right quantity, and best quality.

Repeated problem

Because of the accurate scheduling time the company use, and the bad security situation in Iraq, the company faces shipping problem or shipping delay. To facilitate eliminate this problem; the company improves its relationship with the supplier to be update about any change on the shipping time and to prepare for it.

Improving the spare parts managing system

The company focuses always in improving the system, the company has signed new contract to purchasing new programming system, which will be built especially for Midland Refinery Company. The supplier company is holding meeting with the company departments with the intention of have deep understanding for the company work and to build a computer system which can cover all the need. The new program will have much better security system than the present program, bigger spare parts and suppliers’ data bases, and more advanced options.

The biggest problem that the company faced because of the spare parts

The company had to stop the production in one line for 45 days because the spare parts were ruined in the inventory due to storing conditions. The fault was from the supplier, where the storing condition description was misunderstood due to the bad translation, the manufacturer company had written the instruction in other language than English and the supplier had translated it to English. New parts were ordered and it took 45 days until the production restored.
4.3. Case study: ConAgra Foods

About the Company

ConAgra Foods, Inc. (2015) stated that the company is an American company for packaging the food. The company headquarter is Omaha, Nebraska. It makes products with various brand names, which is available in most of the American supermarket, in addition to restaurants and food services.

The company was founded in 1919 by Alva Kinney and Frank Little in Nebraska. In 1940, the company started to produce flour from its own mills, and in 1942 started into livestock business. In the same year USA president Dickinson opened the company’s new factory in Alabama.

The company changing its name from Nebraska Consolidated Mills to ConAgra in 1971, ConAgra is derived from consolidated agriculture. In 1980, the company expanded its work throw purchased Banquet Foods Company, and moved into the frozen food business and packaged meat industry. Then after, they purchased other brands company like RJR Nabisco, Beatrice Foods and other companies.

In 1993, the company invested 500$ million in the smaller firms, and in 1998, it invested another 480$ million in brands from Nabisco. ConAgra Foods Company is considered from the biggest food companies in North America, the company has over 33,000 personal, and many foods brands that are produced in many factories. These factories are speared in verity cities, most of these factories where purchased from another companies.

ConAgra produces a large number of foods for example frozen food, frozen meat, hot drinks, peanut butter, etc. the company has many brands for example Bertolli ready meals, Choice, Egg Beaters, Healthy, Hebrew National, Hunt’s, Marie Calendars’, Orville Redenbacher, Slim Jim, and P.F. Chang’s.

The company is proud to have its own culture and community. The company had awarded in many occasions and in many fields for example workplace, corporate citizenship, health choice food, research, quality & innovation, and marketing.

The Company SPM model

Naji, S. (2015) has explained that each factory in ConAgra Foods has its own management and personality. The factories flow the company policy but in the same time they have a lot of freedom to choose. The factory that engineer Naji work in has 24 production machines and 30 personal in the maintenance department only. The maintenance personal work in 4 shafts that cover working time of 24 hours/day, 7days/week, and 52 weeks/year. The factory OEE is 78%, the company aiming to increase the OEE to be 85%. The maintenance department has a big role in increase the company productivity.

The company has four inventories, where they classified the parts according to the value. In each inventory, there is a personal at all the time to check the parts and insure that only maintenance personals are allowed to take parts. The maintenance personals do not need to sign papers when they need the regular low value parts where they stored in area that the personal can watch easily.

In the other hand, the personal need to sign papers when they need high and medium values parts
Control and record

The company uses computer programs only to record the parts in the inventories. The computer program name is SAP; it is an advanced program that provides information on parts levels, order times, low-level parts, and other statistical data. The program is linked to the company's headquarters, allowing them to monitor inventory levels and the working process. In each inventory, there is always a personal assistant responsible for spare parts and recording them.

Storing

They use standard storage shelves and bin storage systems, and in each inventory, there are special areas to store high-value parts safely, avoiding any mistakes or damage. There is also a place to store regular, low-value parts, where the maintenance personnel can take them without signing any documents. This system is designed to increase working efficiency by reducing unnecessary steps. Some parts are stored in specific conditions as recommended.

Purchasing

For normal, regular parts, the company signs contracts with suppliers to fill the inventories with parts needed for production. The contract allows suppliers to decide the minimum and maximum levels of parts in the inventories, provided there are always the required parts on time. The supplier has inspectors in the factory to update the parts levels and ensure they are always available for demand. Inspectors decide the order size and amount based on their company policies.

Shipping and Receiving

The suppliers are responsible for shipping. The company does not transport parts between the inventories. The supplier contract reduces maintenance responsibilities, allowing them to focus on improving maintenance.

Maximum & Minimum Level

The suppliers are responsible for deciding the parts levels in the inventories. They have their own policies for large shipments to supply many factories, including their own. The important point is that there is always a safety level for parts.

Order Quantity

The maintenance department orders parts with good reliability and low maintenance, not covered by supplier contracts. The controlling program manages most of the work, giving the date for ordering and suggesting suppliers.
Preparing spare parts time

The parts are prepared according to the parts size and value. Some parts are available 24 hours and other parts are prepared before 1 till 7 days from the maintenance time.

Suppliers

The company dealing with about 20 suppliers, the suppliers responsible for satisfying the maintenance demand. Off course the suppliers has the old parts demand history, to be contact with maintenance demand.

Repeated problem

The most problem that the company faces, is having wrong parts, then we will have to delay the maintenance until we get the right parts if it is possible to delay the maintenance, in some cases we stop the production until we got the correct parts.

Improving the spare parts managing system

The company focus on improve the spare parts management throw improving its relationship with the supplier. The suppliers stay updated about the maintenance status, maintenance problems, and fell parts problems. The company discuses with suppliers how they can increase the efficiency of work and how they can achieve that.

The biggest problem that the company faced because of the spare parts

The company had to stop the production in one line for 7 days because of wrong spare parts until the correct parts had to come.
4.4. Case study: Hilti store house

About the Company

Hilti (2015) is an international company that offers services, products, and systems. Hilti provides professional customers in energy and constructions business filed. Hilti works in over 120 countries around the world. Hilti operate production facilities, R&D centers, and involves in many international technology partnerships. Hilti stands for the best quality and direct customer relationship. The company has 22,000 employees in all over the world. They generate more than 200,000 daily interactions with customers, creating the basis for the ongoing development of new products and services. In Sweden for the second year in row, Hilti awarded for the second place best place to work. The company encourages the employee to improve performance through corporate culture.

The Company SPM model

Gorges (2015) has stated that he work in Hilti planet that are located in Stockholm. The plant is inventory warehouse to store parts and ship them to customers. The plant has the same managing system that is used in spare parts inventories with advanced options. The plant has one parts inventory that contain over a thousand parts and it is run by 17 personal. The plant has also two packing machine to package the parts before they send them to the customers. The plant works one shaft/day, 200 days/year. If any order comes after 15:30, it will delay to the next day.

Control and record

The company use computer program only to record the parts in the inventories. The computer program name is SAP; it is an advanced program where it gives you the level of parts, orders time, low level parts and much other statistic information. The program is linked to the main company headquarter, so they can see the inventory level of parts and the process of working. In each inventory, there is always personal to hand in spare parts and record them.

Storing

They use the normal storing shelf and bins storing system, there is no special places store. They use boxes to save the part, and the boxes are saved in the shelf with bin number. The parts are stored unpacked, and they would be backed just before they will be send to the customers orders. In this ways it will take less storing size.

Purchasing

The plant purchases the parts from Hilti; they receive the parts from the main supply center of Hilti in Arlöv in Sweden.
Shipping and receiving

The main supply center is responsible for shipping the part to the plant inventory, and the plant inventory is sending the parts to the customers. The company has made a contract with shipping company that named DB Schenker. DB Schenker is responsible for deliver the parts to the customers and update the customers about the shipping status.

Maximum & Minimum level

SAP program is helping in decide the maximum& minimum level for parts in the inventory, the program depends on the selling forecast that is estimated from the selling history.

Order quantity

SAP program is also helping in decide the order quantity depending on the available parts in the inventory and the selling forecast during the year season.

Preparing spare parts time

If the order is made before 15:30, then the parts are shipped directly after the order comes. And if the orders come after 15:30, it will delay to be shipped with the next day orders.

Repeated problem

The most problem that the company faces is the inventory running out of parts because of delay from the supplier.

Improving the spare parts managing system

The company focus on improve the spare parts management throw improving the personal training and skills.

The biggest problem that the company faced because of the spare parts

The company had to stop because the supplier did not send the parts for 30 days, because of production problem.
4.5. Case study: Heavy Engineering Equipment State Company

About the Company

Heavy Engineering Equipment state Company “HEESCo.” (2015) stated that HEESCo was established in 1963 as one of the biggest state industry companies in Iraq. HEESCo is specialized at manufacturing and erecting heavy engineering equipment that are required in many industrial fields. The company has 2349 highly trained employees working in various fields (technical, supervision, engineering, etc.). HEESCo has over 50 years of experience in developing the techniques of production process by using advanced machines that are manufactured in international well-known companies. The company use international standards to produce products to satisfy the local demand of oil industry in particular.

HEESCo provide the following production and service to the market:

1. **Cutting techniques:** the company has many modern techniques in cutting metals that are used in the production. The company has the following techniques:

   - *Hot cutting and shearing technique which is used in manual or automatic way.*
   - *Cold cutting by hydraulic machine.*
   - *Shearing razors machine.*
   - *All type of hydraulic and press machines.*

2. **Welding Techniques:** the company has a modern technique that is advanced and can provide the following services:

   - *Classic manual welding.*
   - *Submerged arc welding.*
   - *Column –Boom welding.*
   - *Mig welding.*
   - *Tig welding.*
   - *C.N.C. flame plasma.*

3. **Activity of engineering process:** HEESCo has skilled, professional engineering staff for preparing designs that required for the manufacturing, production, quality, qualitative control and qualitative confirmation for production like pressure vessels, all types of
The Company SPM model

Al-Hachimi (2015) profess that HEESCo has very simple and easy inventory system. It has one inventory for all the spare parts that are need for the machines. There is about 1000 machines and tools in the company and 339 personal in the maintenance department only. There is always personal in the inventory to guide the maintenance personal to the needed spare parts. Inside the inventory, the parts are stored in rows each rows is belong to production line, and each line are spirited to cells, each cell is designed to have the parts for one machine. For each cell there is a card, which has all the machine information, spare parts information, and how many spare parts in the inventory. In some cases, there are spare parts that can be used in more than one machine, and the company depends on the inventory personal expertise to identify these parts and record them in each card in “notes” field.

The company use old production lines and they face many leakages in the spare parts that are not manufactured any more. The company produces these missing parts manually or assigns it to contractor which in both ways misses quality and does not run for long time. HEESCo policy is to reduce the inventory levels for all the spare parts, until they can get the resource to replace all the old production lines with new one. The company is a government property, and they need the resource form the ministry of oil.

Control and record

All the spare parts record is done by paper only, and the parts are classified according to the machines that fits and in which production line they are. For each machine, there is a card of information that contain all the parts information, quantities, suppliers, and any other details. It will be record in the card if there are other machines that use the same type of the spare parts.

The inventory personal keep the planning department update about the parts level, and the planning department is responsible about order spare parts. The planning department has a controlling program that is connected with the ministry to keep them update about the inventory contains.

Storing

The inventory divide the spare parts shelves in rows, each row is for a production line, and each row is divide to cells, each cell is for one machine. In each cell the store all that machine parts. There is also a place where they store the common parts that are in daily need, they store them close to the inventory personal room so it is fast to reach and handle to the maintenance.

The inventory building is isolated and secured and there is no special place for the high value parts, or special conditions storing parts.

Purchasing

According the company policy for reduces the inventory levels, any order will be made only when the parts level is zero in the inventory, and they make the orders to be as lower as possible. It could be costly, but the company still does that.
All the purchasing is done through the financial department, they send a team every week to the market to buy all the needed spare parts. In some cases, one of the maintenance departments will join the financial team to buy the parts that need some skills to identify if they are fitting or not. If the parts do not fit, they take it back to the seller and replace it with the right one. This way of purchasing reduces the paper work time and insures to find the best seller in the market, where many sellers do not want to work with government companies because they have to do all the shipping and a lot of paper work.

**Shipping and receiving**

HEESCo in most of the cases is responsible for the shipping, unless the parts are big or expensive and quality control need to be done before the seller receive his money, the seller have to ship it then.

**Maximum & Minimum level**

According to the company policy, the minimum level is zero, and the maximum level should be as lower as possible. The company will use the managing system which is in use in the Ministry of Oil later, where the maximum number of spare parts will be 10% if the actual parts in use, and the minimum level will be 2.5% of the actual parts in use.

**Order quantity**

The order quantity is up the purchasing team, they can decide which quantity is best according to the company policy for the parts that are in daily demand. The order quantity will be as need for the parts that are not in daily demand, or expensive.

**Preparing spare parts time**

Because of simplicity of the inventory system, the parts can be handled directly when they needed. There is no prepare time.

**Repeated problem**

The most problem that the company faces is the inventory is that there is some parts produce any more. The company either remanufactures them or made them manually which will have then poor quality and will run for short time. The company trying to solve this problem throws searching for new suppliers that able to supply these missing parts. The company expands the searching field for suppliers to be internationally.

**Improving the spare parts managing system**

The company has moved recently from the Ministry of Industry property to the Ministry of Oil property. This movement will make the company to change the record and control system to match the Ministry of Oil system, so they can be linked to gather. The company plan to use SAP inventory managing program as the other Ministry of Oil companies.

**The biggest problem that the company faced because of the spare parts**
The company has few break machines that have no spare parts for more than a year. The company is still looking for supplier who can supply them.
4.6. Case study: DIAB AB Laholm

About the Company

DIAB AB (2015) showed that DIAB is one of the famous companies in composite core material development since more than sixty years. DIAB is supplying a broad range of markets including marine, wind energy, transport, aerospace and industry. DIAB produce complete series of high-performance core materials, with loads of finishing options and kit operations in combinations with engineering services and knowledge. DIAB present widest and most important offering in the sandwich composite market.

DIAB products and services perform according to multi industrial’s standards; DIAB was covering many parts of the market’s demand for many years. The excellent track record shows high quality and performance for DIAB products and services.

DIAB is global company that provides global sales and presents. DIAB tracks their customers to achieve the best results and to be the best support team. DIAB has full materials websites in several countries; in addition DIAB makes local presentations to insure the company strength in security, cost efficiency, flexibility and local support.

History of the Company

The company founder Bertil Diedrichs acquires the Nordic agent for Kleber foam in 1950. The company is established as a company. Divinycell H is launched and production is relocated to Laholm 1969. DIAB set up subsidiaries in the USA and Australia 1983. DIAB Merged with Polimex in 1994. DIAB certified ISO 9001 in 1996 and ISA 14001 in 2000. Ratos and 3i acquire DIAB. Divinycell HP, a high-performance variant of H, is launched. Manufacture in Lithuania and balsa wood processing in Ecuador start in 2005. DIAB starts production in Kunshan, China and expands its production plant in DeSoto, Texas. Divinycell P is launched for the transport market, and Divinycell F for Aerospace. New sales organizations are set up in Poland, Spain, India, Canada and Taiwan in 2008. Ratos becomes principal owner. New sales organization is set up in the UAE in 2009. Divinycell Matrix 7-7 is introduced. Composites Consulting Group, CCG, is launched globally. CCG provides consultancy services in composite technology in 2010. Divinycell F is supplemented with F40, which further reduces the weight of the interiors of commercial aircraft. In material finishes, One Directional Cut (ODC) and Grid Score Thin (GST) are launched, both of which significantly reduce the weight and costs of composite applications in 2011. Divinycell F is supplemented with F130, used as edge fill for both foam and honeycomb panels for the aerospace industry in 2012. Core Selection Guide is introduced on our website, a tool to help you zero in on the types of cores best suited to your application in 2013. New sales organization is set up in Korea and DIAB introduces three new core materials: Divinycell HM, Divinycell PN and Divinycell PX300 in 2014.
The Company SPM model

Johansson (2015) said that there are 12 personal in the maintenance department; they are responsible for about 60 single machines plus peripherals in the form of post-processing machines and lifting devices. The machines availability is 80% in the neck bottle.

The maintenance department is responsible of SPM which includes: inventory, control and record, storing, purchasing. Johansson add that he is working on adding receiving inspections to the maintenance department responsibilities, in order to eliminate any risk of receiving wrong spare parts.

The company has one inventory only which is linked to the supplier only. The company do not use distribution center or sub inventory. The inventory dose not trade spare parts with other inventories.

Control and record

The inventory records are done manually and they use also computer management program (IDUS).

Storing

The inventory uses shelf and bins technique to store the spare parts, in addition to store consumable material also.

Purchasing

The company deals with over 80 suppliers. For the normal spare parts that the company orders repeatedly, it takes about 15 minutes to make an order. And it takes about one day to make an order to rare needed spare parts.

Shipping and receiving

In most of the cases, the suppliers are responsible of shipping the parts to the company.

Maximum & Minimum level and order quantity

The company depends on the historical records to decide the minimum & maximum Levels for spare parts. Subjective assessment is made in prioritized order based on delivery time, quantity installed and historical take out.

Preparing spare parts time

Normally we prepare the parts that are needed in BCM and PM, before 6-10 weeks, and the parts that are needed for CM as soon as possible.
Repeated problem

The most problem that the company faces is

1- Having the wrong parts in the inventory which never will be used.
2- Using parts that have that have stored for long time, will increase the risk of break down and reduce the MTBF, such as belts seals.
3- Having parts more than it is need, to keep the production run at the same availability.

Improving the spare parts managing system

1- Having the right amount of spare parts in the inventory.
2- Improve the historical data system.
3- Increase the PM and BCM to reduce the amount of parts in the inventory.
4- Search for new ways to improve the spare parts management system.

The biggest problem that the company faced because of the spare parts

One motor brakes down and the motor was to not found on the market.
4.7. Volvo Köping GTO

About the Company

Volvo (2015) shows that, Volvo is considered one of the biggest manufacturing companies of buses, trucks, constructions equipment, marine, and industrial engines. The company provides total solutions for financing and service. The company headquarter in Gothenburg Sweden, and it has about 100,000 employees. Its productions facilities are in 19 lands, and it sells in 190 lands. Volvo sells in 2014 reaches 230 billions of SEK.

Volvo (2015) showed that Volvo Group Trucks Operations has 1500 employees that cover all the productions of the Group gearbox and engines, plus the trucks productions of Volvo, Renault, UD and Mack. In Volvo GTO, they supply parts to logistic operation and the Group’s customers.

Volvo Group Logistics solutions, is the logistics centre of excellence inside Volvo within Design, management and logistic optimizations. It covers Volvo Group and other automotive companies. The company uses advanced service according to the world class operational excellence. It have high efficiency and sustainably. It aims to reduce costs, disruption and environmental effect.

Volvo GTO is responsible to ensure material supplying to the production lines in appropriate package for delivering and distribution to the dealers and customers. It also ensures the global availability of aftermarket parts to dealers and end customers at the right time, the right place and the right cost.

To acts in close co-operation with other Group units globally to powerfully grow and transport services and products with the right quality, delivery time and cost inside a proper budget.

Volvo GTO offers the following services

- Packaging
- Outbound
- Inbound
- Parts distribution
- Risk management
- Supplier information

Volvo GTO produces three type of gearbox for trucks, buses and marine. Volvo GTO had win the prize of best gearbox in the world and the best safety company.
The Company SPM model

Wallin (2015) said that there are 200 personal in the maintenance department; they are responsible for approximately 1500 machines, equipments, devices, trucks and robot machines. The machines availability is 93% and the OEEE is 80%.

The maintenance department is responsible of SPM which includes: inventory, control and record, storing, purchasing. The company has distribution center that supply many factories inventories, and Volvo Köping has one inventory which is linked to DC, plus one sub inventory. The DC supply the inventory with all the regular spare parts and the inventory supply the sub inventory. The inventory personal are also authorized to buy parts from suppliers in case they are not found in the DC, in order to reduce the process time and have the parts as fast as possible, then after the DC records these parts and plans to supply the inventory in the future. About 80% from the parts come from the DC, and the company planning to increase the ratio in order to find the best price and supplier. The maintenance personal is also authorized to contact all Volvo inventories in urgent cases, and discuss if there is similar parts that can fit.

Control and record

The company uses computer program that called IFS to control the inventory and to link with DC. The program can give the entire statistic and historical records, plus other functions.

The company also uses paper to deal with the outside suppliers that are not registered in the program, until the registrations is complete and then the orders can be done throw the program.

Storing

The inventory uses different types of storing according the size, use, importance, and usage. Some parts stored in set allows the trucks to pick and go, some in set to be handling picking, and some need special type of storing.

Purchasing

The company deals with over 1000 suppliers. For the normal spare parts that the company orders repeatedly, it takes few minutes to make an order from the DC. And it takes longer time to make an order from outside suppliers; it is depending on the parts importance and the available resources to achieve the purchasing.

Shipping and receiving

In most of the cases, the DC is responsible of shipping the parts to the company. The personal is also authorized to go and bring the parts in case they want to faster the process. The same processes apply with outside supplier.
Maximum & Minimum level and order quantity

The company is aiming to reduce the minimum level to reach zero, where the DC can supply the parts whenever they are needed. Plus, linking the factories inventory will helps to reduce the minimum level, where they can share the same safety amount of parts. In some type of parts that are very fast to be change, they have one spare part only, in order to faster the maintenance process.

The company policy is to have minimum level only on the rare parts which is not available in the DC. The minimum level in this case depends on the importance of the parts and how much difficulty to find them.

Preparing spare parts time

For the parts that comes from DC, the prepare time is zero. And for the parts that come from outside suppliers, it could be several days only. The company policy is reducing the preparing time to zero for all the parts.

Repeated problem

The most repeated problems that the company faces are leak in the parts, when more than one failure happen short time, and the DC is not prepared. This leads to increase the maintenance time.

Improving the spare parts managing system

1- Having the right amount of spare parts in the inventory.
2- Share information and knowledge between the maintenance personal in Volvo factories.
3- Increase the PM and BCM to reduce the amount of parts in the inventory.
4- Reduce the paper work.

The biggest problem that the company faced because of the spare parts

Missing few parts lead to stop the machine for 4 weeks.
4. Analysis

Throw reviewing the case studies, the reader can understand the company policy and goals and how they interpreted these goals in the SPM. Each company follows different policy that suite the company environment, lows, market, and administration.

By comparing these policies according to the most important factors (KPI’s), we can find the weakness and strength of each company. Plus point, we can estimate the loss in each policy and the area of improvement for future development. It also shows, the size of change to resources release or investment that the company can do throw SPM.

From the comparison, we can hold statistic data that helps to build a general understanding about SPM in the manufacturing companies (potential and loss), and how these companies use SPM as active resource to achieve their goals.

Statistic data from the company cases

<table>
<thead>
<tr>
<th></th>
<th>DIAB AB Laholm</th>
<th>Al-Nasser</th>
<th>Midland Refinerie</th>
<th>ConAgra Foods</th>
<th>Hilti</th>
<th>HEESC</th>
<th>Volvo Köping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer registration</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>Yes</td>
</tr>
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<td>Paper registration</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Storing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Classify spare parts</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Use DC's</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Inventories are linked</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Use sub inventories</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>minimum &amp; maximum level of spare parts</td>
<td>how often does the receiving control</td>
<td>who does the ship</td>
<td>how many suppliers</td>
<td>ordering period</td>
<td>ordering time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>--------------------------------------</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>calculating order size</td>
<td>calculating min. level</td>
<td>Only subcontract parts are checked every day</td>
<td>the supplier</td>
<td>&gt;80 historical data &amp; quantity installed</td>
<td>yes &lt; day &lt; day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>historical data &amp; quantity installed</td>
<td>historical data &amp; quantity installed</td>
<td>every order</td>
<td>the supplier</td>
<td>7-10 the company make orders every (year, month, and urgent)</td>
<td>no 2 days 7 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(order period* daily usage)</td>
<td>(order time * daily usage) + safety</td>
<td>every order</td>
<td>the supplier</td>
<td>&gt; 1000 When the parts reach the mini. Level</td>
<td>yes 2 days 7 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5% of each changeable part</td>
<td>7.5% of each changeable part</td>
<td>every order</td>
<td>the supplier</td>
<td>&gt; 20 supplier has to fill the inventory every day</td>
<td>yes daily day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>the contractor responsibility</td>
<td>the contractor responsibility</td>
<td>none</td>
<td>the supplier</td>
<td>&gt; 20</td>
<td>yes &lt; day &lt; day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAP</td>
<td>SAP</td>
<td>none</td>
<td>shipping contractor</td>
<td>1</td>
<td>yes &lt; day &lt; day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>up to personal expertise</td>
<td>zero</td>
<td>every order</td>
<td>the company</td>
<td>&gt; 100 when the parts no. reach zero</td>
<td>no &lt; 5 days day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>As mini. As possible</td>
<td>zero</td>
<td>Every order</td>
<td>The supplier and the personal</td>
<td>&gt;1000</td>
<td>Few minutes yes &lt;4 days Few minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improving the system</td>
<td>The biggest problem breakdown</td>
<td>Most repeated problem</td>
<td>Preparing spare parts time</td>
<td></td>
<td></td>
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<td>the biggest problem breakdown</td>
<td>most repeated problem</td>
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<td>most repeated problem</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>the biggest problem breakdown</td>
<td>most repeated problem</td>
<td>preparing spare parts time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reducing the level parts in the inventory</td>
<td>120 days</td>
<td>reduce the spare parts level in the inventory and increase the availability</td>
<td>6-10 weeks</td>
<td>6-10 weeks</td>
<td>as soon as possible</td>
<td>mini. level + order size</td>
<td></td>
</tr>
<tr>
<td>Increase the personal skills</td>
<td>45 days delay</td>
<td>Receiving wrong spare parts from the suppliers</td>
<td>2-7 days</td>
<td>1 day</td>
<td>as soon as possible</td>
<td>mini. level + order size</td>
<td></td>
</tr>
<tr>
<td>New computer program SAP</td>
<td>45 days delay</td>
<td>shipping delay</td>
<td>2 days</td>
<td>1 day</td>
<td>as soon as possible</td>
<td>10% of each changeable part</td>
<td></td>
</tr>
<tr>
<td>Improve the relationship with supplier</td>
<td>7 days</td>
<td>Receiving wrong spare parts from the suppliers</td>
<td>1-7 days</td>
<td>1 day</td>
<td>always ready</td>
<td>the contractor responsibility</td>
<td></td>
</tr>
<tr>
<td>Increase the personal skills</td>
<td>30 days</td>
<td>supplier delay</td>
<td>always ready</td>
<td>always ready</td>
<td>always ready</td>
<td>SAP</td>
<td></td>
</tr>
<tr>
<td>New computer program SAP</td>
<td>year</td>
<td>poor quality</td>
<td>same day</td>
<td>same day</td>
<td>as soon as possible</td>
<td>order size</td>
<td></td>
</tr>
<tr>
<td>Share information and knowledge</td>
<td>4 weeks</td>
<td>Leak in parts</td>
<td>zero</td>
<td>zero</td>
<td>zero</td>
<td>zero</td>
<td></td>
</tr>
</tbody>
</table>

Calculating max. level

Min. Level + order size

Preventive maintenance

Corrective maintenance

Calculating max. level

Improve the system

Search for improvement & increase the PM to reduce the level parts in the inventory

Reduce the spare parts level in the inventory and increase the availability

6-10 weeks

6-10 weeks

As soon as possible

Mini. Level + order size

Increase the personal skills

45 days delay

Receiving wrong spare parts from the suppliers.

2-7 days

1 day

As soon as possible

Mini. Level + order size

New computer program SAP

45 days delay

Shipping delay

2 days

1 day

As soon as possible

10% of each changeable part

Improve the relationship with supplier

7 days

Receiving wrong spare parts from the suppliers.

1-7 days

1 day

Always ready

The contractor responsibility

Increase the personal skills

30 days

Supplier delay

Always ready

Always ready

Always ready

SAP

New computer program SAP

Year

Poor quality

Same day

Same day

As soon as possible

Order size

Share information and knowledge

4 weeks

Leak in parts

Zero

Zero

Zero

Zero
From analysis the statistic data that we have collected from the companies that we interviewed, we can estimate the losses in the SPM according to the KPIs.

1- Computer management program

We can see that all the company are using computer management program in the inventories. This shows that all the companies know the importance of using computer management program and the benefits. From another side of view, half of the companies we interviewed still use paper work on the inventories. The paper work takes time, and we can consider it as a waste that the companies should removed throw improve the management system to have more accuracy and increase all the personal skills to be able to use and depend on the computer management program.

2. Spare parts classification

We can see that two of seven companies do not classify the spare parts in the inventories. Keeping all the parts in normal storing conditions would ruin the parts the need special storing condition. The spare parts classification would give more focus to the personal on how to distribute their time, where some spare parts do not worth continues control.

Use DCs and link between the inventories have potential to find better price, shipping time, chance to find the missing parts, and to share information.

One company only from the sex companies uses sub-inventory. Sub inventory would reduce the process and the maintenance time to have the parts.

3. Maintenance type

Pm and BCM required less spare parts level in the inventories than CM. So increase the PM and BCM would have a positive effect that lowers the spare part level. All the companies use all of the three types of maintenances. It would be excellent choice to improve throw finding more PM and BCM.

4. Number of suppliers

Increasing the number of suppliers would give more stability and flexibility to the company to avoid any outside problem. It is also gives better prices and productivity. Even though, still some companies use few suppliers only, which be considered risky.

5. Order time

Order time is one of the factors that reflex the management strength and responds speeds. The longer time would reflex over process that does not add any value to the customers which the management needs to avoid. Urgent order time would reflex the respond time of the system to restore the production in the shortest time. Many companies take more than a day to make an urgent order, which is a waste.
6. Ordering period

Ordering period reflexes the flexibility of the system to tune up with the demand of the market. Depending on fixed time to make an order would have unnecessary spare parts on the shelf, and how long the period is how long the west will be.

Calculating the order size can be done throw different methods. Historical data and mathematical methods would be the best choice, where the order size will be change in every order to fit the market demand and to avoid unnecessary parts on the shelf.

It is also recommended to update the shipping and ordering time from the suppliers before makes any order to fits the market conditions in each order.

8. Spare parts quality control

Some consider spare parts quality control is a waste and some companies do not do it, in fact it would be as insurance cost the company pays to avoid the risk of having wrong parts or defective parts. Quality control would reduce the minimum level after reducing the error percentage. It is highly recommended to make a quality control for each spare parts order the company receives.

10. The biggest problem that the company face because of spare parts & repeated problems

Avoiding the long time breakdown would be an achievement by itself, and comparing other companies’ biggest problem would improve the management view to avoid similar problems.

As we can see from interviews, small problems could cause long breakdown, and some of the problem could not solved yet, where the problem needs also time and resources from the personals to solve the problem.

11. Future planning for SPM improving

Future planning would be very important to give the company management new improvement to consider and connect with other department, suppliers, and customers.

Sharing information about the future plans would lights the thoughts and gives the management more sharpness to build the system after comparing and share information of the company policy and planning with other companies.
By making a static data table, we can estimate the use of each KPI as a percentage. This will help the reader to get a better view on the loss of SPM.

<table>
<thead>
<tr>
<th>Kpi</th>
<th>In Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use computer to control</td>
<td>100%</td>
</tr>
<tr>
<td>Stopped use papers in the process</td>
<td>43%</td>
</tr>
<tr>
<td>Classify parts in the inventory</td>
<td>71%</td>
</tr>
<tr>
<td>Use DC’s</td>
<td>29%</td>
</tr>
<tr>
<td>Link inventories</td>
<td>71%</td>
</tr>
<tr>
<td>Use sub-inventories</td>
<td>29%</td>
</tr>
<tr>
<td>Average of normal order time</td>
<td>2,6 days</td>
</tr>
<tr>
<td>Average of urgent order time</td>
<td>2,6 days</td>
</tr>
<tr>
<td>Make orders online</td>
<td>71%</td>
</tr>
<tr>
<td>Average no of suppliers</td>
<td>315 suppliers</td>
</tr>
<tr>
<td>They are responsible of the shipping</td>
<td>29%</td>
</tr>
<tr>
<td>Check the spare parts fitness and quality</td>
<td>71%</td>
</tr>
<tr>
<td>Average preparing time for part before the PM</td>
<td>5 days</td>
</tr>
<tr>
<td>Average preparing time for part before the BCM</td>
<td>6 days</td>
</tr>
<tr>
<td>Average of the longest stop time because of the SPM</td>
<td>70 days</td>
</tr>
</tbody>
</table>
5. Conclusion

Spare parts are important section of the maintenance, and any leakage in parts could lead to breakdown that is unplanned cost. From another angel of view, having over spare parts will means bad using resources, spare parts cost money, and store them cost money and time. The best set is find the right number or spares for each parts in the right place and right time.

Nowadays, with the internet revolution companies can contacts thousands of sellers in all over the world, and manage purchasing orders from over the sea to reduce cost and have better quality. Moreover, maintenance techniques have developed where the advanced maintenance (based conditions maintenance) equipment and tools are developed, which allows the maintenance personal to estimate in more accurate way, the failure time and the best time to do the maintenance.

Companies can use all the potentials in using technology to increase the company productivity in the market. Otherwise, it would be hard for them to compete in the future. To survive they need to develop, learn, and practice. Maintenance is a major sector to develop, and spare parts are an important branch in the maintenance. Spare parts management is a good sector for the companies to increase the efficiency where there is a lot of potential in it.

Increase the responsibility of spare parts contractors will free the company form some of the working load but it will cost extra money. Companies are using this technique when they have short of personal or when they to develop the company to have better efficient.

Sub inventories technique would reduce maintenance time throw eliminate the process time of receive the parts from the inventories especially in the cheap parts case, where the time gain would be in low cost. This technique helps also when the stopping time is very expensive, or the spare parts inventory would be far from the production line. In case of having small spare parts inventory and other consumable material inventory, merge the inventories would reduce the cost, and personal effort.

Design the inventory to fit the company needs of spare parts and the processing time, extra inventory area would be unnecessary cost. Using one inventory would reduce the personal effort to control and store but it will increase the process time, where all the needed parts will have to run throw the same personal. Using number of inventories will need more personal to control and store, and would reduce the process time.

Using management computer program would faster the flow of information, where it can reduce the order time to minutes, and give much information about the inventory statues in seconds. Using computer program does not mean to eliminate the paper system, many companies using both systems. Build up a management program to fits the company need will maximize the benefits.

Having few reliable suppliers lead to reduce the safety size of spare parts, and short the time for searching for the best offers for spare parts, and its disadvantages is waste the probability of finding better supplier with better price or quality. Dealing with large number of supplier, would eliminate any risk that can come from suppliers breakdown, where then there are other alternatives. It also increases the chance of finding new supplier with better qualifications. Many suppliers would means also more efforts to manage.
Spare parts minimum level in the inventory, represent the safety zone for any unexpected delay, it would be wise to have it, but it would cost money also. The best spare parts level should be balanced between the cost of spare parts leakage cost and cost of having spare parts waiting in the shelves. Involving the supplier could be an option to concern, where the supplier can guaranty the availability of spare parts with extra cost; this will reduce the cost of waiting spare parts in the shelves.

From the cases study, every company has its own management system to run the spare parts according to the type of maintenance, usage, breakdown losses, and breakdown dangers, importance of each machine, company policy, the country regulars and laws, security, availability, capability of using resources, and company future plans for improve and development.
6. Discussion

- The maintenance is essential part of the production, it has influence in the company productivity, this influence increases with company expansion. Maintenance costs money and time. Unwise maintenance management could lead the company to Bankruptcy, on the other hand the right maintenance could be the reason for leading the company to survive and succeed.

- The maintenance includes properties and actions. The properties are spare parts and equipment that used in the process of maintenance, the actions are the process to prevent breakdowns and restore the production as fast as possible when any fail happen. Having parts more than it need will be a waste of money, time, and resources and having less then it need would increase the main time of maintenance.

- Preventive maintenance and based conditions maintenance reduce the spare parts level in the inventories due to reduce the risk of unplanned breakdowns, this not mean that PM and BCM is always better than CM. the maintenance department needs to make study for most repeatable problem to find out the best type of maintenance that would satisfy the company needs and resources.

- Management computer program would give status information in seconds and will boost the process time. It would also connect the inventory to the admiration or other inventories. It is always wise to use computer program in the inventory and invest on increase the personal skills to use and depend only on the program, where the programs has a mass of potential that could reduce the resources in the inventory management.

- Join the inventories in cooperative relationship would reduce the spare parts level and save money, time, and efforts. It will give more option to consider in any order. It could also reduce the spare parts cost when one order will be made for several inventories in the same time, where in general, when the order quantity go up, the unit price go down, and the vice versa.

- Sub inventories are good choice to reduce the process time in some cases where the inventory is far or big inventory cases.

- Analysis technique and history statistic would sharper the management decision, it would the work load and improve the resources distribution.

- Reliable suppliers reduce the risk of order delay, and dealing with several suppliers would eliminate the risk of leakage spare parts in the market. The minimum levels of spare parts in the inventory represent the dependability and reliability of the suppliers under the factory city place policy.

- More involvement to the suppliers in the company process would reduce orders efforts, and more involvement to the company in the suppliers’ process would save money. It is up to the company to decide how much they want to have from the supply chain. Where more involvement means more efforts, reliability and less unit price, in the other hand increase the supplier’s involvement would reduce the workload on the company and release some resources that could the company needs in more important areas.

- Merge inventories would reduce the personal effort, and split inventories would reduce the process time.
• Changing the inventory design to fit the spare parts and reduce the effort of storing.
• It always up the management to decide the improvement area, after finding the neck bottle. The neck bottle decides the department productivity and any efforts in other branches would be a waste. In more technical thinking, the company could release some resources from high effective sections and use them in the neck bottle section. Having all the department regions in the same level of productivity would reduce the resources and keep the department productivity at the same level.
7. General Recommendations

Spare parts management is an important branch of the management, which can lead the company to succeed or failure. All the companies should manage the inventories wisely in order to reduce the cost and to ensure having the right spare parts in the right time and the right place, plus having a well-counted safety number of spare parts for unexpected delays, or breakdowns.

Each company has unique production lines, system, management, maintenance, location, policy, limitation, resource, prices, etc. which lead to that every company should have its own SPM system that can fit for every part of the company, and reduce the cost of each part.

The company can start with estimation for the number of spare parts in the inventories, which can be done through the calculation of shipping time in days multiplied by the usage of spare parts per day, plus a safety number that can be a guess from expertise. After the start with these numbers, the company can decide to:

3- Improve availability of the spare parts and reduce the personal effort.
4- Reduce the inventory cost to minimize the revenue.

I have prepared a list of the potential area for each choice.

**Improve availability of the spare parts and reduce the personal effort.**

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<tbody>
<tr>
<td>1</td>
<td>Buy spare parts from only reliable suppliers that have accurate delivering date and less risk of delay</td>
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<tr>
<td>2</td>
<td>Maintain the relationship with the suppliers through involve them to satisfy the company needs</td>
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<tr>
<td>3</td>
<td>Increase safety level to increase the risk of leakage in spare parts</td>
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<td>4</td>
<td>Increase inventory efficiency through reduce inventory process time and considering having sub inventories</td>
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<tr>
<td>5</td>
<td>Invest in preventive maintenance and based conditions maintenance to reduce the risk of breakdowns</td>
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<tr>
<td>6</td>
<td>Invest in using better technology in managing inventories, for example better management computer program, electronic scanning system, etc.</td>
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<tr>
<td>7</td>
<td>Merge spare parts inventories with other inventories to reduce the personal efforts</td>
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<tr>
<td>8</td>
<td>Split inventory to parts to reduce process time</td>
</tr>
<tr>
<td>9</td>
<td>Improve the inventory design to fit the needs and reduce the process time</td>
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</table>
Reduce the inventory cost to minimize the revenue.

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<tbody>
<tr>
<td>1</td>
<td>Search for new suppliers that have better quality of better prices</td>
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<tr>
<td>2</td>
<td>Accept the suppliers terms to reduce the prices</td>
</tr>
<tr>
<td>3</td>
<td>Reduce safety level to increase the risk of leakage in spare parts</td>
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<tr>
<td>4</td>
<td>Minimize the number of inventories to reduce cost</td>
</tr>
<tr>
<td>5</td>
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<td>8</td>
<td>Improve the inventory design to fit the needs and reduce cost</td>
</tr>
</tbody>
</table>

If the company decision is to improve inventory efficiency and reduce personal effort, this will lead to increase the inventory cost, and vice versa. The best decision is balance between the two sides, the company can choose to improve in one alternative and when it reach the satisfaction, the company start to improve in the other alternative. In this way, the company can keep improve the management system.

Continuous improvements are the success key to survive and increase the productivity of the company to face the changes in the industry market.

We can see also that preventive maintenance and based conditions maintenance are help in both improvement alternatives. So it is strongly recommended that the company invest in them and in train the worker and personal to achieve them.
7.1. KPI

I have chosen several KPIs to show the leak and the strength of the companies SPM system. These indicators will give explanation in general and it would not take in consideration the company goals and situation. In all the cases the KPIs would show the strength and weakness and give the companies and the readers a bigger view to understand the SPM regardless the company condition.

1. Computer management program

This can give the company very fast static information to estimate the current situation of the past and present conditions of inventory. The computer program can link the inventory to other inventories, so they can share the available parts in order to reduce cost and fast the process. Advanced computer program can give more options, for example: make order on line, give indicators about the right time and quantity to make an order, supply the supplier with information to forecast the demand, etc.

Using computer program to manage spare parts inventory would boost the management to new level especially in the big companies. Its effect will be reduces in the small companies.

2. Spare parts classification

Classify spare parts would distribute the personal effort in the right way, where some parts are highly cost or fragile, and other parts are low and hard to be ruined. By classifying the parts and put a policy for each group of parts, the personal effort could be well managed. The low cost parts could have lower process to be delivered to the maintenance personal. This would free some resources and short form the process time.

3. Maintenance type

Maintenance type would increase the parts safety level in the inventory, where PM and BCM required lower parts as the minimum level then the CM. subsequently increase the effort on increase the PM and BCM would improve the inventory as well when it release some resources and reduce the unplanned breakdown that could cause urgent needs of spare parts.

4. Number of suppliers

The number of suppliers that the company deals with is important factor, when the number is bigger this means more chance at have the spare parts. Dealing with one supplier would expose the company to leak when the supplier has any production problem. Having several suppliers would give the management more alternatives to choose from according to their policy.

In short period view management, some companies decided that many suppliers would consume more time and money and they would rather use these resources on other things. But in long period view, where increase the number of suppliers would give the company more stability and more potential to expand in case of increase the market demand.
5. **Order time**

Order time reflex the process complexity to make an order. Reduce the order time would give the company many advantages. Online orders are a very excellent choice, where it reduces the order time to a few minutes instead of days, and the possibility to find many suppliers in a very short time. Make order online would require more experience from the personal to avoid the wrong parts, in all the cases, increase the personal skill to be able to make order online would be a very wise choice to improve the SPM system.

6. **Ordering period**

Some companies make orders in specific time periods; other companies make orders when the spare parts reach the minimum level. The best way is depend on the historical data, the demand forecast, minimum level, and continuous adjustment to fit the required demand. This would keep the right amount of spare parts depending on the current circumstances.

7. **Spare parts quality control**

The best time to do spare parts quality control is at the receiving time, this would minimize the lost process time until they find the problem. It would be better chance for fixing the problem with lower costs then finding out it is wrong parts when they need them.

8. **The biggest problem that the company face because of spare parts & repeated problems**

This indicator will show the SPM response time to fix unexpected situations. The lower response time reflexes the strength of management system. In the same time, it reminds the company with the importance of SPM.

9. **Future planning for SPM improving**

It would give the reader a farther sight for improvement and it links the companies thinking of SPM.
8. Recommendations

8.1. Al-Nasser State Company

- The company has great classification system for the parts which give more flexibility and security. Using sub inventories increase the efficiency throw reduce the maintenance time.

- The company should invest in train all the maintenance personal on how to use the computer program for record the parts, in order to eliminate all the paper work, where they take longer time that increases the maintenance time. Computer programs could give more information in shorter time.

- The ordering time could be lower through discuss the financial department policy, the ordering time in the urgent cases is high relatively comparing to other companies. The company needs to modify the process to reduce the order time.

- Finding the best seller in the company system, focuses on the economic side only, where the financial department is responsible for that. Maintenance personal should involve in finding the seller, to insure finding the right quality also beside the best price. Buying cheap parts and reject them later for poor quality, would take time that is important factor.

- Calculating the minimum& maximum level throw the daily usage of parts, would be ineffective when it is used for long time orders, where the market demand can be changed and the daily usage would be changed also, so forecasting the demand for long time is unwise thing, reduce the order quantity that is depend on daily usage forecast would increase the efficiency of the system.
8.2. Midland Refineries Company

- Building a management computer program is very wise, where any computer program would not fit the companies direct, it will take few modification to optimize the program.
- Having the paper system as obligatory to receive the parts from the inventories would increase the maintenance time. The company should modify the process or finds new faster technique.
- All three types of maintenance is used in the company, and they use the same policy for calculate the minimum & maximum levels, the parts that are used in the preventive and based conditions maintenance should be lower than the other parts, after all the reliability of the machines that having these types of maintenance are more than the other type, so they parts level should be effected by the reliability also.
- The parts minimum level should be updated with the change of the security issues, where the minimum level should be higher for the parts that have more risk to be late.
- Considering hire a contractor to fill the regular needed parts would have many advantages, which off course will have extra cost. Hiring a contractor would be very good choice in some cases.
- Using sub inventory is very effective to reduce the maintenance time when the needed parts are cheap and could be stored without the need of personal.

8.3. ConAgra Foods

- ConAgra Foods has a very good OEE 78% and planning to increase it is indeed will be a tough goal to make. The OEE reflects the availability, quality, and performance, but it does not reflect the economy side. Producing the products in lower cost would increase the recourses that could be used in improve the production system.
- Having contractors who is in charge of filling the parts inventory would reduce the company work on spare parts, but it would costly too. The contractors will have personal on the inventory to control the level, ship the parts, and supply the part, which will lead to extra cost.
- Controlling bigger part of the supply chain will increase the control of chain and reduce the cost. Having contractors means that the company giving up some of the supply chain.
- The buying group should always have at least one member from the maintenance, who can insure that the purchased parts are right and it have the necessary quality.
- Connect the company inventory, could be useful to reduce the cost throw ordering the parts from other inventory than order it form the suppliers.
8.4. Hilti

- Hilti using very modern technique management in warehouse, where all the functions are done electronically by SAP program. Electronic orders take no time comparing with the paper work.

- Depending on one supplier is unwise decision, where any break out for the supplier means a break out for the inventory also. Considering have more than one supplier would be wise modification to do.

- Depending on one shipping company means that any delay on the shipping company would be a delay for the Hilti also. Considering have more than one shipping company would be wise modification to do.

- Most of the small companies do not realize the potential of spare parts management, when they are dealing with small amount of parts. The case is different in large companies or medium companies that have large size of inventories, where the inventory investment could be expensive, slow, or not efficient because of possible break downs and leakage of parts.

8.5. Heavy Engineering Equipment State Company

- The company using very poor managing system due to the change of the production line in the future. Because of unknown the date of change the production lines, the policy of the company would cost more than having the normal policy. Break downs would cost more than having spare parts in the inventory. The company can reduce the minimum & maximum level of spare parts instead of buying the minimum order quantity.

- Computer management program would have many advantages, and the program could be used regardless changing the production line or not. Training the inventory personal on the computer program would have many benefits when the production reset.

- Sending a group of employees to buy spare parts every week is wise according the large number of machines in the company. The group would take long time to find right spare parts and sending more than one group would be unwise too. Sending the employees to the market would not increase their expertise and they would waste their time in order to find a better price only.

- Using scientific methods to calculate the best order quantity would save money and time.

- Instead of reusing the missing parts, the machines should be modified with the purpose of having new parts that are available in the market.
8.6. DIAB AB Laholm

- The company uses very good technique in SPM, and in order to improve the system, it is wise to work on increasing the personal skills to avoid any error that can lead to keeping wrong spare parts on the shelf.
- Manual counting is easy to ensure the records, but at the same time, it takes time that could be used in other places. Improving the controlling system would be a good choice to eliminate the manual counting.
- Sub inventory is recommended to think about, where sub inventory could be very useful when used in the right way.
- Using Order Quantity Technique in addition to the historical data could improve the purchasing system.
- DIAB has more than one factory around the world, and linking between the inventories of these factories, would give more options to consider when related to search for specific spare parts that is missing in one region and available on other region.

8.7. Volvo Köping

- The company has very advanced SPM system, where the personal have a lot of authorities in order to faster the process. This system is the best system in all the interviewed companies.
- The company can invest in increasing the PM to reduce the unexpected failures which lead to most of the problems.
- Increase the personal skills to increase BCM to eliminate the visible failure before the happen.
9. Proposals for further work

Spare parts management is a potential area that could increase the company productivity. Many companies have built up their own managing system, which is successful relatively because they did not compare their system with the other system that is used in other companies. The goal is to highlight the potential benefits that can come from using optimum system.

Building a management system model could be an interesting area also, it does not have to be advanced, it could be fundamental and the beneficial side could evaluate it to maximize the functions. Applying this module to large, medium, and small companies, and evaluate them, could be helpful and increase the value of the research.

Highlight the potential of the spare parts management throw simulation program that can show the difference between the current and the suggested model would have a better effect and understanding to the companies to see the points from another angel.
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9.2. List of the web sites references


9.3. List of the companies representatives that have been interviewed


APPENDICES

This is the list of equations that have been used in the interviews.

Spare parts management

General information about the interviewed person

Name:

Job position:

Place of work:

Date of the answers:

General information about the company

How many employees in the maintenance department?

How many machines are there in the company?

What is the availability of the production lines?

What is the OEE of the production lines?

What is the OEE that the company aiming to?

Spare parts management

Most of the companies mean four responsibilities when they say spare parts management (inventory control, stores, purchasing, and shipping and receiving). How many categories are there in the spare parts management in your company?

Inventory control means that the management is responsible for ensuring that the necessary parts are available in the right time and right place.

What methods do you use in managing the spare parts inventories? (Paper, computer program, or both)

Before how long time from the maintenance, do you prepare the spare parts?

Stores are responsible for issuing parts and store them.

How many spare parts inventory storages are in the company?

Do these stores work in combination with other stores in the company?

How do you classify spare parts? (Value, cost, importance, etc.)

Do you use sub inventories to reduce transportation time?
How do you calculate the minimum level of spare parts in the inventories?

How do you calculate the order quantity?

How do you store spare parts? (Shelves and bins or other way)

**Purchasing and shipping**

Which method do you use to calculate order size and time?

How many suppliers do the company has?

How long time takes to order spare part? (From taking the order form the maintenance personal to sending the order to the suppliers)

Who is responsible for the shipping? (Supplier or the company)

Do you order spare parts from other company inventories?

Do you do quality control for spare parts for first time only or for every order?

**Problems that you face with spare parts**

What are the most repeatable problems that happen with the spare parts?

How do you fix these problems?

Does your company work on improve spare parts management system? And how do they do that?

What is the biggest problem that your company faced in the past with the spare parts?