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1. INTRODUCTION

The Overall Equipment Efficiency (OEE) was originally coming from Japan in 1971. In 1988, when Nakajima introduced TPM in US, this was also including OEE. Since then OEE has been used as a performance indicator of equipment. Overall Equipments Effectiveness (OEE) is a performance measurement system for an equipment, that clearly defines the losses in manufacturing with a continious monitoring system.

OEE is becoming very popular in operations. It is a key performance indicator (KPI) in TPM. OEE is probably the most important tool in the TPM improvement program

The aim of this thesis is using one of the most reliable performance analyzing methods and evaluate the bottlenecks in a dynamic manufacturing system.

In this paper the benefits of using overall equipment efficiency as a manufacturing improvement tool is explained. To do so a thorough the implementation steps and the results of the methodology are discussed with a case study.

Literature study performed including Lean Manufacturing, Total Quality Management (TQM), Total Productive Maintenance (TPM), Preventive Maintenance (PM), 5S, Single Minute Exchange of Die (SMED), Overall Equipment Effectiveness (OEE) and Toyota Production System (TPS).

In chapter two is being mentioned about TPM, the history of TPM and describing asset care and the maintenance types. Also discussed implementation principals of TPM and the difficulties of TPM implementation.

In chapter three is being mentioned about OEE, the history of OEE, OEE's indicators, the way of calculating OEE, six big losses and the definition of the types of losses. The reason of using OEE is also mentioned in this chapter.

In chapter four we tried to explain the benefits of using overall equipment efficiency (OEE) as a manufacturing improvement tool. Now we will discuss about the implementation steps and the results of the methodology. The case study is done in **AREVA TD**, Gebze, Turkey

2. TOTAL PRODUCTIVE MAINTENANCE (TPM)

Total Productive Maintenance's (TPM) goal is zero breakdown and zero defects. Off course this improves the productivity and reduces cost.

According to G. Brar it is "Maintaining and improving the integrity of our production systems through the machines, equipments, processes and employees that add value" (G.S. Brar; Keeping the Wheels turning, 2006)
Preventive maintenance was imported from United States in the 1950s to Japan. It is based on periodic servicing and controlling, and replaced by predictive maintenance in the 1980s. TPM should be implemented on a company wide basis, but usually most of the organizations misunderstood the aim, and thought only shop floor people should be involved in it.

TPM is a very efficient way of doing maintenance by the staff of the organization, it is a improvement way in OEE, autonomous maintenance, and formation of maintenance activities. (Brar, 2006)
TPM aims to establish good maintenance practice through the pursuit of "the five goals of TPM" : (www.superfactory.com, 2008)

a. **Improve equipment effectiveness:** Defining the losses, which are downtime losses, speed losses and defect losses.
b. **Achieve autonomous maintenance:** Given at least the maintenance responsibilities to the people who is operating the equipment.
c. **Plan maintenance:** Defining the preventive maintenance stages for all equipments and create the standarts of the maintenance conditions.
d. **Train all staff in relevant maintenance skills:** Define the responsible people of operating and maintaning and train them. TPM focuces on continuous training for the people.

e. **<u>Achieve early equipment management</u>:** Eliminating the failures by focusing on the root cause of failures of the equipment, and attact as early as possible.

TPM eliminates the losses;

i. Downtime from breakdown and changeover times
ii. Speed losses
iii. Idle times
iv. Quality defects and scrap

The aim must be to measure and monitor all the losses, and try to reduce them. Reducing those losses will be a benefit of organization’s profitability. (Willmott , McCarthy, 2000)

“Unexpected breakdown losses, speed losses, quality defect losses, in which defects lead to reworking or scrapping; and equipment losses from wear and tear on equipment, reducing its durability and productive lifespan. When it comes to equipment, on the shop floor and beyond, organizations typically pursue four techniques for total productive maintenance (TPM): efficient equipment, efective maintenance, mistake proofing (known as poke yoke in lean contexts), and safety management.” (David R Butcher, 2007)

2.1 ASSET CARE

“The means to increase returns on investment are to decrease the operating costs or to increase the turnover of capital. From the physical assets' point of view, these requirements mean a need for dynamic and continual life cycle management, optimal capacity development, higher overall equipment effectiveness, higher reliability and flexibility of physical assets, and lower maintenance costs of production equipment.”
(Komonen, Kortelainen and Räikkonen, 2006)

Asset care is about autonomous maintenance and planned preventive maintetance.

The equipment's users which are the operators should be trained very well for preventive maintenance. They should maintain the asset on daily basis, check, lubricate, replace parts, perform basic repairs and detect the abnormal behouviour of the equipment. (Butcher, 2007)

2.2 MAINTENANCE

SFS-EN 13306 standard defines maintenance as below:

"*Maintenance consists of every technical, administrative and management action during the target's lifecycle the purpose of which is to maintain or improve the target's ability to perform its task*" (SFS-EN 13306, 2001)

2.2.1 TYPES OF MAINTENANCE

There are some types of maintenance as listed below;

1. Corrective: Done as quickly as possible when a failure occurs

2. Preventive: Regular maintenance perform to prevent failures occur.

3. Predictive – With a good analyse of 'vital signs', we should take the necessary actions before a failure comes up.

4. Detective – Performed on the devices like fire alarm, smoke detector etc. They just see need a periodic control to see if they are working or not.

Ia Williamsson catogories the maintenance types as perfective, adaptive, corrective and preventive and showed the work load on those types as in Fig 2.1. (Ia Williamsson, 2006).

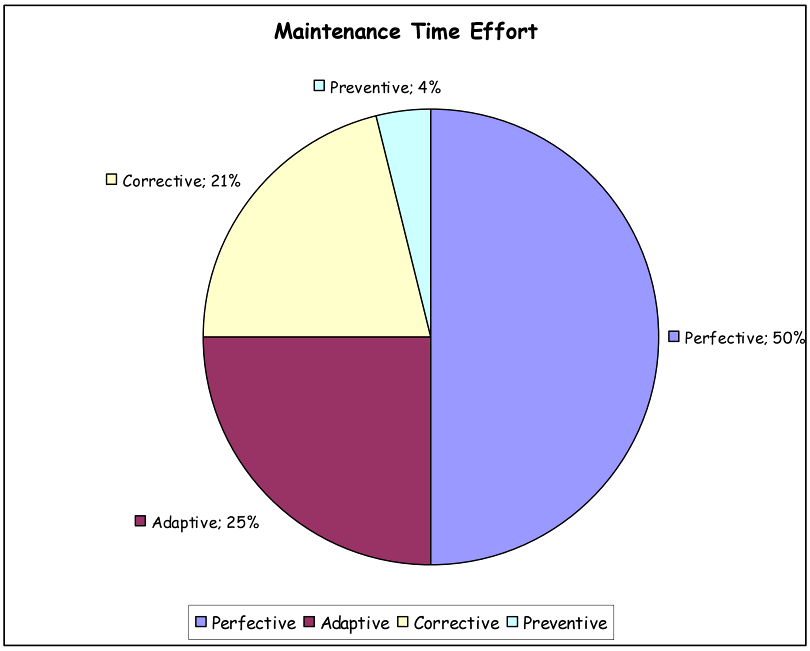


Fig 2.1 Workload of types of the maintenance; approved by I. Williamsson, 2006

2.2.2 PREVENTIVE MAINTENANCE (PM)

Maintenance of an equipment is recognized as a mandatory action. However, pressures arise from production can result in delaying the scheduled preventive maintenance. Sometimes delay in doing this maintenance is infinite then the equipment breaks down and the maintenance becomes corrective instead of preventive.

The planning should determine how often PM is necessary, what form it should take and which sub-processes should be audited to be sure that PM programming is followed. Maintenance plans are sometimes obliged to be verified based on the data of the Cost of Poor Quality (CoPQ) and high costs incurre due to new investments. Without being in the need of proofing the necessity of PM, the concept total productive maintenance (TPM) is aimed to use equipment at its maximum effectiveness by eliminating waste and losses caused by equipment malfunctions. (Besterfield, 2003, Juran 1979)

Preventive maintenance must be pointed out for controlling the reliability of machines in a process. (Honkanen, 2004)

2.3 TYPES OF FAILURES

Tuomo Honkanen (2004) defined two types of failures in TPM, which are "function-loss breakdowns and function-reduction breakdowns. Function - loss breakdown is a state in which the equipment functioning stops. The function–reduction breakdown is a state in which the machine still operates but causes speed losses and defects". (Honkanen, 2004)

There is a clear distinction between chronic failures and sudden failures as Nakajima defined (1989). Sudden failures are the ones which are easy to detect and happens randomly, but chronic failures are hidden in production system and happens frequently. Usually the chronic failures happen because of bad conditions such as dirt etc. And TPM's aim is standardizing the conditions by cleaning and preventing them and keeping operating environment clean and organized by inspecting them. (Honkanen, 2004)

2.4 MEAN TIME BETWEEN FAILURES (MTBF):

Mean Time Between Failures (MTBF) is showing us the equipments reliability. Reliable equipments' MTBF measurement is high. Usually measured in hours, it can help to quantify the suitability of an equipment for a potential application.

2.5 MEAN TIME TO REPAIRS (MTTR):

"MTTR, or Mean Time to Repairs, is the typical time that a certain device will take to recover from any breakdown." (http://www.articlewisdom.com Robert Thomson, 2008)

It is the typical time essential to carry out corrective maintenance on all of the removable items in a product or system.

2.6 5S PHILOSOPHY

5S is applied for effective work place organization, reduces waste, simplifies work environment while improving quality and safety.

The five **S** stand for the five first letters of these Japanese words:

1. "Seiri" means "Sorting out"

2. "Seiton" means "Set in order and Arrange"

3. "Seiso" means "Shine and Sweep"

4. "Seiketsu" means "Standardizing"

5. "Shitsuke" means "Sustain and Self discipline"

One of the important things to do for asset care comes from applying the 5S philosophy**.**

The aim of applying 5S is getting rid of unnecessary things, putting everything in its right place, keeping the work place clean and organized; and giving the same discipline to everybody. (Willmott , McCarthy 2000)

The advantages of implementing 5S in the shop floor are as below;

a. Saving Time,
b. Reduction on the failure ratio,
c. Preventing the working accidents,
d. Improvement on productivity and quality,
e. Increasing motivation on the employees,
f. Improving the employees' self confidence,
g. Increasing competiveness for the company.

Basically 5S process would increase the moral of the employees, increase efficiency. Company becomes competitive in the market with better quality, reaches to faster lead time and less waste, and also it will create positive impressions on customers.

2.7 SINGLE MINUTE EXCHANGE OF DIES (SMED)

"SMED is the term used to represent the Single Minute Exchange of Die or setup time that can be counted in a single digit of minutes. SMED is often used interchangeably with "quick changeover"" (www.superfactory.com, 2008)

SMED and quick changeover should be used for reducing the time for changing a machine from one product to another.

By applying SMED, we should eliminate non-value added operations, perform external set-up, simplify internal set-up and measure.

2.8 IMPLEMENTING TPM PRINCIPALS

The key of TPM is making it easy to do things right, and difficult to do things wrong.

The successful implementation of TPM needs mainly the below stages. (Willmott , McCarthy 2000) (Fig 2.2)

1. Continuous improvement in OEE
2. Operator asset care (autonomous maintenance)
3. Maintainer asset care
4. Quality maintenance
5. Continuous skill development
6. Early equipment management

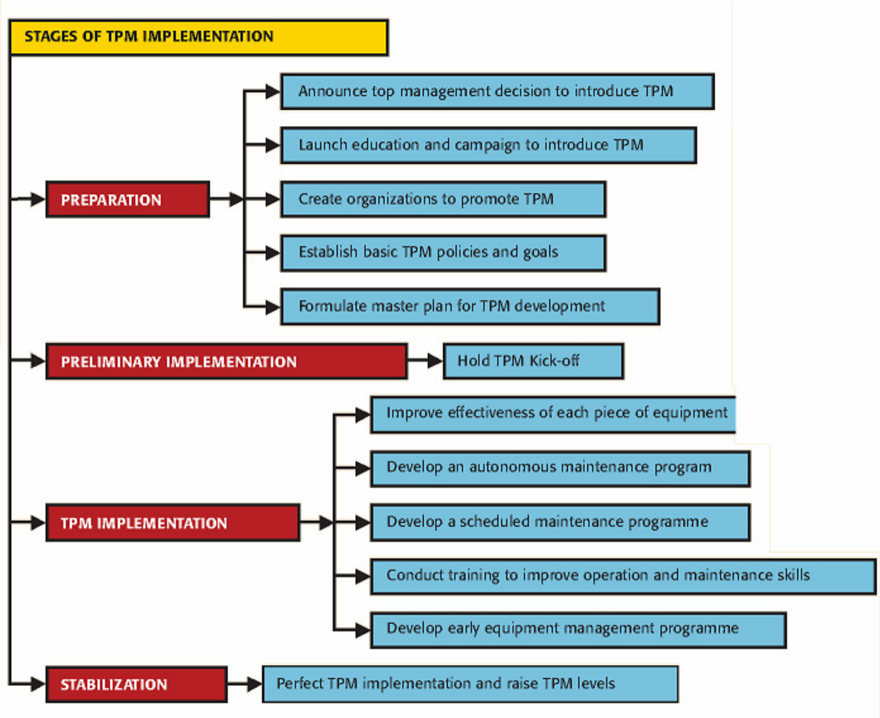


Fig 2.2 The stages of TPM Implementation; approved by G. S. Brar, 2006

TPM has lots of benefits for the companies. One of the most important benefits is that maintenance expenses are planned and controlled. (Park, Hane; 2001)

In order to develop skills continuously we need to improve people competences to establish the goal of training for sharing ideas, values and behaviors. With this approach the objectives of the training must be linked to business goals, set up a training framework, build capability systematically, design a training and awareness program which encourages practical application to secure skills and future competences.

The supervisors of the company play an important role for implementing TPM. And when the operators involves into the program and knowing their own equipment well, that would help for improvement in the productivity. (Brar, 2006) The concerned people of the program are the operators, team members and managers. It will be structured to maximize the contribution of each individual and to develop their skills to the limit of their capability.

For a successful TPM implementation, companies should setup their strategy first. Understanding TPM philosophy is very important for all level of management. (Fig 2.3) That is a positive culture change in the company, because of that reason communication becomes very important and also HR department’s role is very important for communication.

Decision-making responsibility must be from to the bottom level of the organization up to the top management for a succesful TPM. Everyday a little bit improvement is one of the TPM’s aim.

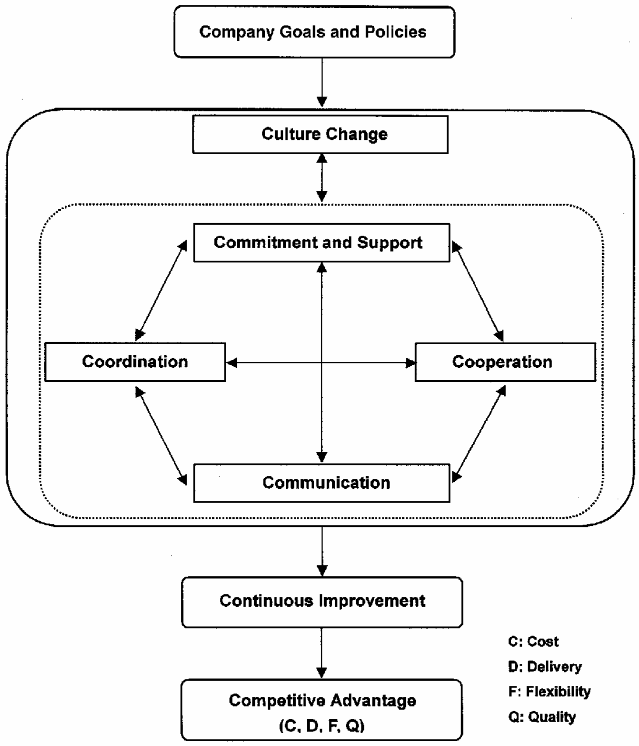


Fig 2.3 A framework for succesful TPM implementation; approved by K.S. Park, S.W. Hane (2001).

The goal of TPM is improving on operability, maintainability, reliability, product development and service, life cycle cost prediction, feedback and control.

K.S. Park, S.W. Hane (2001) summaries the roles of implementation TPM in a table very well. (Fig 2.4)

Phase	Top Management	Midlevel Management	Maintenance Technicians	Operators
Phase 1: Preparation	Educate and create a management structure	Educate and establish TPM groups		
Phase 2: Preliminary Implementation	Serve on TPM committee and conduct management diagnosis	Assist in training and development, assessment and certification programs	Prepare assessment and certification programs	Begin training and certification
Phase 3: TPM Implementation	Serve on TPM committee and conduct management diagnosis	Support training and certification programs; conduct diagnosis of chronic losses	Continue certification programs and attack chronic losses	Continue training and perform maintenance tasks
Phase 4: Stabilization	Serve on TPM committee and conduct management diagnosis; incorporate maintenance goals into the business strategy	Support training and certification programs; conduct diagnosis of chronic losses	Conduct standardized maintenance	Improve autonomous maintenance

Fig 2.4 The roles during TPM implementation; approved by K.S. Park, S.W. Hane.(2001)

2.9 DIFFICULTIES OF TPM IMPLEMENTATION

We can summaries the difficulties of TPM implementation as following;

a. People’s resistance for changings,
b. Not given enough attention, resource etc,
c. Not understanding the philosophy and the methodology well,
d. Not being patient enough to see the results, and given up early.

2.10 TPM ACHIEVEMENTS

TPM lets us to improve the progresses in some areas. These are better understanding the equipments performance, equipment importance where it is worth to do improvements on it in order to the potential benefits. TPM improves the teamwork and supports good relationship between production and maintenance. The aim of this work is reducing cost and given better service by improving processes and reducing loss times for example changeovers and setups with trained operators and maintainers. (Brar 2006)

"TPM is one of the world class lean manufacturing strategies that is well structured with eight fundamental development activities and data based approach (OEE) to improve both the effectiveness and efficiency of any production system/process involving everyone". (ChoyDS; 2003)

TPM adresses excellent manufacturing processes by optimizing the effective use of all manufacturing resources, equipments, people and processes. (Pomorski 1997)

In summary TPM is concerned of improvements in cost, quality and speed and rethinking of business processes.

3. OVERALL EQUIPMENT EFFECTIVENESS (OEE)

OEE is coming from the philosophy of lean manufacturing, which is based on the work has done by TOYOTA to improve the production system. The aim of lean manufacturing principles are, pull processing, perfect first time quality, zero defects, waste elimination, continious improvement, flexibility and maintaining long term relationship with suppliers. Lean is basicly getting all things right, in right place, in right time, and in right quantity while elimininating waste. (Dransfeld, 2007)

The Overall Equipment Efficiency (OEE) was originally coming from Japan in 1971. In 1988, when Nakajima introduced TPM in US he also introduced OEE. Since then OEE is using as a performance indicator of an equipment. (Sheu, 2006). Now OEE is accepted as a main performance indicator. (Muthiah, Huang, 2006)

There are eight pillars of TPM as shown in the Fig 3.1: (Brar, 2006). We will focus the first one which is overall equipment efficiency.

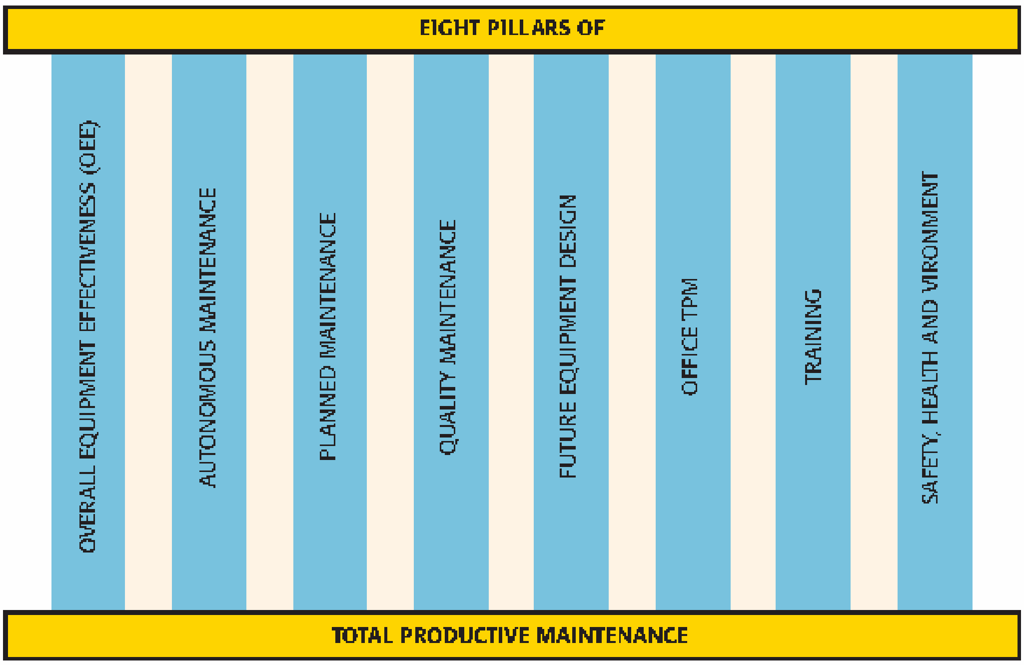


Fig 3.1 TPM's pillars; approved by Gurinder Singh Brar

“Overall, the TPM implementation leads to an increase in overall equipment effectiveness or availability of machines, increase in productivity, improvement in quality, reduction in inventories, reduction in numbers of accidents, reduced burden on maintenance department and implementation of scheduled preventive maintenance.” (Brar, 2006)

OEE is probably the most important tool in the TPM improvement program. When the equipment’s productivity is calculated, the time the machine is producing is taking into account, not the amount of the output or the quality. With OEE, those three criteria is taken into consideration, and indicate the all picture of the machine. (Brandt, Tjärning, 2006)

It is very important to focus on the botlenecks in production for increasing the factory’s capacity and productivity. Once all the bottlenecks and losses are defined, then management can focus on the improvements for the impact of efficiency, output and the cost effects of those bottlenecks. (Konopka, Trybula, 1996)

“The best way to increase equipment efficiency is to identify losses that are hindering performance. Moreover OEE is a tool for continous improvement and lean manufacturing initiatives.” (D. R. Butcher; 2007)

For any improvement strategy there must be a way to define and measure how are we doing and how do we compare with the others. (ChoyDS, 2003)

Measure of total equipments performance is defined as OEE, which shows us what the equipment is doing and what it is supposed to do. The measurement is based on availability, performance and quality rate of the output. It is based on defining the related equipments losses, which reduce the equipments effectiveness, and improves the assets performance and reliability.

Overall Equipment Efficiency (OEE) measurement can be applied at different levels in manufacturing systems. (Mahadevan, 2004)

a. Measuring initial of manufacturing system and compare with the future values.
b. Points out the bad performances and identify the needs for improvement.
c. The studied and performed line can be used as a benchmark for the other similar facility in the factory.

The methodology categorizes the losses and provides the main areas for improvements priorities and starts with root cause analysis, with this approach it will highlight the hidden capacity. (Muchiri, Pintelon 2007)

OEE's industrial applications are different from one company to another. OEE is customized for the manufacturer's industrial requirements.

OEE is a key performance indicator (KPI) in TPM and Lean Manufacturing and it is the best way for monitoring the manufacturing process.

3.1 OEE CALCULATION

Overall Equiment Efficiency is the metric, which Nakajima (1988) used in TPM. It is basically a multiplication of availability efficiency, performance efficiency and quality efficiency. (Giegling *et al* 1997)

$$A = (T / P) \times 100 = [(P - D) / P] \times 100$$

A= Availability

T= Total Operating time = (P- D)

P= Planned operating time

D= Downtime due to equipment failures, setups and adjustment

$$E = [(C \times N) / (P - D)] \times 100$$

E= Perpormance efficiency,

C= Therotical cycle time

N= Production amount

R = [(N- Q) / N] X 100

R= rate of quality products

Q= Number of nonconformities

OEE = Availability (A) X Performance (E) X Quality (R) (Besterfield 2004) (Fig 3.2)

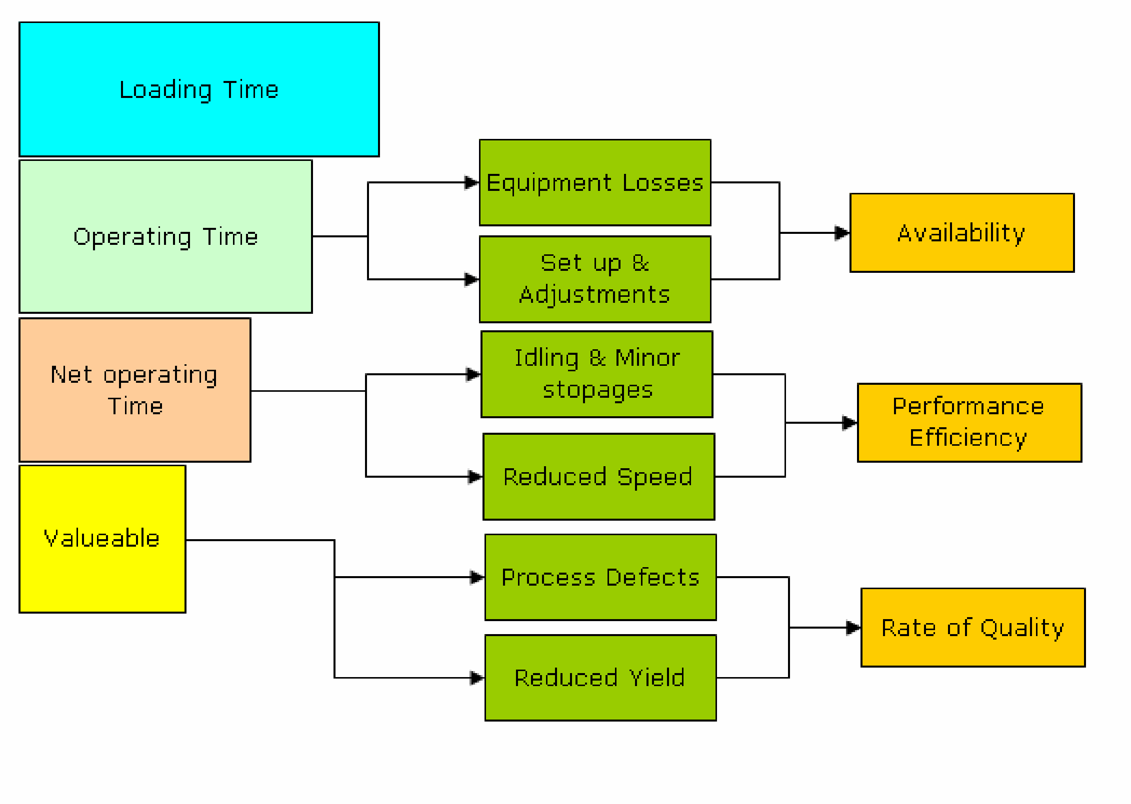


Fig 3.2 OEE Indicators related six big losses and operation times; approved by D.H. Besterfield & M. Besterfield, "TQM" 3e, Pearson Prentice Hall, 2003, New Jersey

3.2 OEE INDICATORS

3.2.1 **Availability:** The equipment's available time for production, which was scheduled for. That is the time the equipment is creating value. When it is not doing any value added work due to the failures, breakdowns etc, it is still creating cost. Availability is the ratio of operating time to planned production time.

3.2.2 **Performance:** Performance is calculated by comparing the actual cycle time against ideal cycle time. Performance is the ratio of net operating time to operating time.

3.2.3 **Quality:** When the production is wasted and not meet to the defined quality standarts. It is calculated by comparing the good and reject parts. Quality is the ratio of fully productive time to net operating time.

"The availability rate is determined by three factors, namely reliability, maintainability, and maintenance readiness. The reliability factor is the length of time equipment is able to run without failure and is measured by MTBF. Maintainability is the length of time for which an equipment can be brought back to an operating condition after it has failed, and is measured by MTTR. Since it is the responsibility of maintenance function to ensure the availability of production equipment, the availability rate is related to maintenance effectiveness. The other important time loss is due to changeovers and replacement of routine wear parts." (P. Muchiri, L Pintelon, 2007)

For TPM implementation Toyota became one of the first company to eliminate the waste (Nakajima, 1988). Toyota defined six categories of equipment losses in its production system, which were equipment failures, setup and adjustments, idling and minor stoppages, reduced speed, defects in the process, and reduced yield (Nakajima, 1986). These six losses are combined into one measure of overall equipment effectiveness (OEE). (Chakravarthy *et al* 2007)

Even the equipment's availability is 100 percent, it's OEE could be extremely low due to the equipment's performance or to the equipment's quality of output. (Konopka, Trybula 1996)

There are so many applications in the literature about improving productivity and OEE.

3.3 SIX BIG LOSSES

Nakajima (1988) defines six large equipment losses; (Fig 3.3)

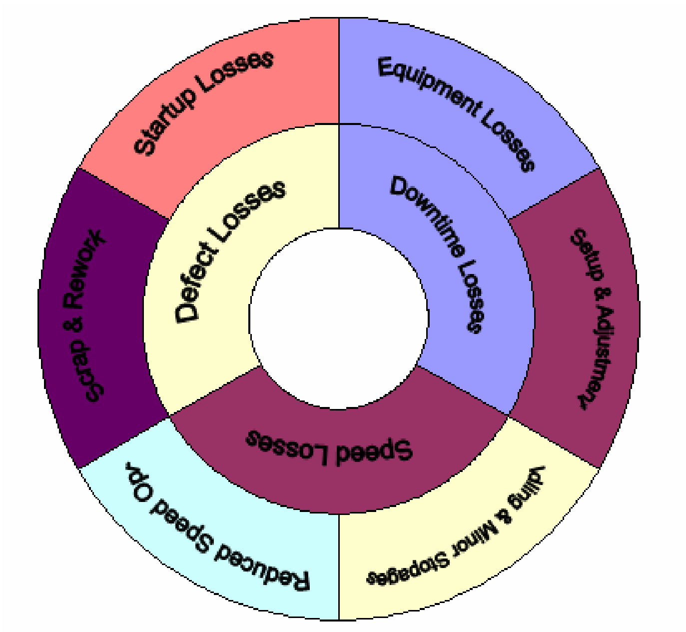


Fig 3.3 The types of the losses

When these six big losses are known then the aim will be focus on these losses, monitor and correct them. That information gives the management and the shop floor people a chance to fix the problem quickly. The aim must be being fast for data collection and categorizing those data. Root Cause Analyzes can be applied for categorizing the data collected. (Korhonen 2007)

3.3.1 DEFINITION OF THE LOSSES TYPES; (Rona, Rooda 2005 and www.oee.com)

3.3.1.1 **Downtime Losses:** These are the loss times when machine was planned to run, but it stands still. There is two main types of downtime losses: equipment failures, and setup and adjustments.

3.3.1.2 **Equipment Failures:** These are the unexpected and sudden equipment failures, breakdowns. That is the time that the machine is not producing any output. Those losses are categorized as downtime losses when productivity is less.

3.3.1.3 **Setup and Adjustments:** This is the time that some machines requires some adjustments (exp: tool changing) between changeovers. That is the time between last good part and the next good part. This is the time that the equipment meet the next requirement of the production, which is time till to the first undefected part.

3.3.1.4 **Speed Losses :** Speed losses are when the equipment's running speed is not at its maximum speed as it is designed. There is two types of speed losses: idling and minor stoppages, and reduced speed operation**.**

3.3.1.5 **Idling and Minor Stoppages :** These are not technical stopages, usually small problems, which the operator can see and correct. But they could reduce the productivity of the equipment very much.

3.3.1.6 **Reduced Speed Operation:** This is difference between the equipments designed speed and it's actual operating speed. The aim is to reduce the difference between actual and designed speed**.**

3.3.1.7 **Defect Losses:** Defect losses mean the equipment's output is not meeting the required quality. There is two types of defect losses: scrap and rework, and startup losses.

3.3.1.8 **Scrap and Rework:** When the equipment's output is not meeting the specified quality and needs rework to correct the defect. The aim is zero defects and good production at first time.

3.3.1.9 **Startup Losses:** This is the loss when equipment need time to start-up. Sometimes it can be at an acceptable level, but it could take so much time for stabilization.

Equipment failures and setup and adjustments losses are known as downtime losses and are used to calculate the availability of a machine. The speed losses and idling-minor stoppages are speed losses, which called performance efficiency of a machine. The start up losses and scrap and rework losses are considered to be losses due to defects; the larger the number of defects, the lower the quality rate.

In the below table the losses are very good explained with the examples, table is from www.oee.com (Table 3.1)

Six Big Loss	OEE Loss	Event	Examples
Breakdowns	**Down Time Loss**	Tooling Failures	There is flexibility on where to set the threshold between a Breakdown (Down Time Loss) and a Small Stop (Speed Loss).
		Unplanned Maintenance	
		General Breakdowns	
		Equipment Failure	
Setup and Adjustments		Setup/Changeover	This loss is often addressed through setup time reduction programs.
		Material Shortages	
		Operator Shortages	
		Major Adjustments	
		Warm-Up Time	
Small Stops	**Speed Loss**	Obstructed Product Flow	Typically only includes stops that are under five minutes and that do not require maintenance personnel.
		Component Jams	
		Misfeeds	
		Sensor Blocked	
		Delivery Blocked	
		Cleaning/Checking	
Reduced Speed		Rough Running	Anything that keeps the process from running at its theoretical maximum speed (a.k.a. Ideal Run Rate or Nameplate Capacity).
		Under Nameplate Capacity	
		Under Design Capacity	
		Equipment Wear	
		Operator Inefficiency	
Startup Rejects	**Quality Loss**	Scrap	Rejects during warm-up, startup or other early production. May be due to improper setup, warm-up period, etc.
		Rework	
		In-Process Damage	
		In-Process Expiration	
		Incorrect Assembly	
Production Rejects		Scrap	Rejects during steady-state production.
		Rework	
		In-Process Damage	
		In-Process Expiration	
		Incorrect Assembly	

Table 3.1 : Table of six big losses, approved by Rona, Rooda (2005)

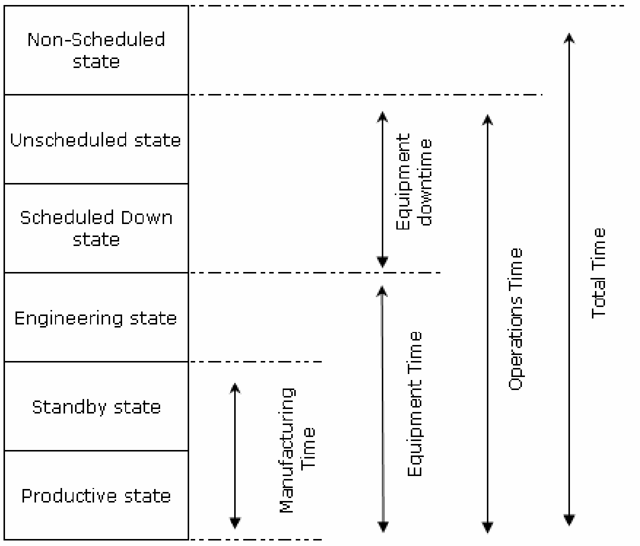


Fig 3.4: OEE Equipment states, approved by De Ron and Rooda

In the Fig 3.4 Rona and Rooda showed the defined six main states of manufacturing equipment. (Rona and Rooda 2005)

3.4 WHY USE OEE?

It is defined by Kaydos as stated in Rona and Rooda (2006) there are five major reasons for companies to measure performance.

1. Improved control, since feedback is essential for any system.
2. Clear responsibilities and objectives. Because good performance measures to clarify who is responsible for specific results or problems.
3. Strategic alignment of objectives. Because performance measures have proven to be a good means of communicating of a company's strategy through out of the organization.
4. Understanding business processes. Because data measurements require an understanding of the manufacturing process.
5. Determining process capability. Because understanding a process also means knowing it's capacity.

Overall Equipment Effectiveness (OEE) makes companies to focus improving their equipment's performance they already own, instead of makes new investments, that means OEE will provide the biggest return on asset (ROA). (www.downtimecentral.com 2008)

There can be a big improvement on the profitability with small improvements on OEE, 10 percent improvement in OEE can result in a 50 percent improvement in ROA, with OEE is 10 times cost effective than purchasing a new or additional equipment. (Hansen, 2001)

OEE is only given data about the manufacturing processes. The benefit would become obvious, when using OEE with lean manufacturing programms and also as a part of TPM

"An 85 percent OEE is considered as being a world class and a benchmark to be established for a typical manufacturing capability". (F.K Wang, W. Lee, 2001)

3.5 HOW TO MEASURE OEE?

The most importing thing about measuring OEE is data collection methods.
It is the most important state of performance measurement and continious improvement. Data collection can be made manually or automated.
With manuel data collection small stopages and downtimes can be forgotten. Also manuel data collection can demotivate the people, there can be reactions against this measurements. (Muchiri, Pintelon, 2007)

Firstly a data collection plan must be defined and some tools must be created to make the data collection easier for the people, who will be responsible of collection datas. Shop floor meetings must be launch periodicaly. The good ideas are mostly coming from the shop floor people, obviously they are in the middle of the operation and can give good ideas. With this way shop floor meetings will make everybody to involve into the subject. That makes the people to do things about it, because they are also a part of the decisions which is taken during the meetings.

The below table is approved by P. Willmott, D. McCarthy (2000) and shows us the myth and the reality about OEE metric. (Table 3.2)

Myth	**Reality**
OEE is a management tool to use as a benchmark	This misses the benefit of OEE as a shop floor problem-solving tool
OEE should be calculated automatically by computer	The computation approach is far less important than the interpretation. While calculating manually, you can be asking why?
OEE on non-bottleneck equipment is unimportant	OEE provides a route to guide problem solving. The main requirement is for an objective measure of hidden losses even on equipment elsewhere in the chain.
OEE is not useful because it does not consider planned utilization losses	OEE is one measure, but not the only one used by TPM. Others include productivity, cost, quality, delivery, safety, morale and environment.
We don't need any more output, so why raise OEE.	Management's job is to maximize the value generated from the company's assets. This includes business development. Accepting a low OEE defies commercial common sense.

Table 3.2: Myths and realities of OEE, approved by P. Willmott, D. McCarthy, (2000) A Route to World Class Performance

OEE enables the companies to increase their outputs and to discrease the number of defects. There are also some software tools that can be used for measuring, optimizing and implementing OEE for increasing the companies productivity. (Ziemerink, Bodenstein 1998)

4. CASE STUDY

In this paper we tried to explain the benefits of using overall equipment efficiency (OEE) as a manufacturing improvement tool. Now we will discuss about the implementation steps and the results of the methodology.
The case study is done in **AREVA TD**, Gebze, Turkey.

4.1 INTRODUCTION OF AREVA TD

AREVA GROUP, world energy expert, offers its customers technological solutions for highly reliable nuclear power generation and electricity transmission and distribution.

65,000 employees are committed to continuous improvement on a daily basis, making sustainable development the focal point of the group's industrial strategy.

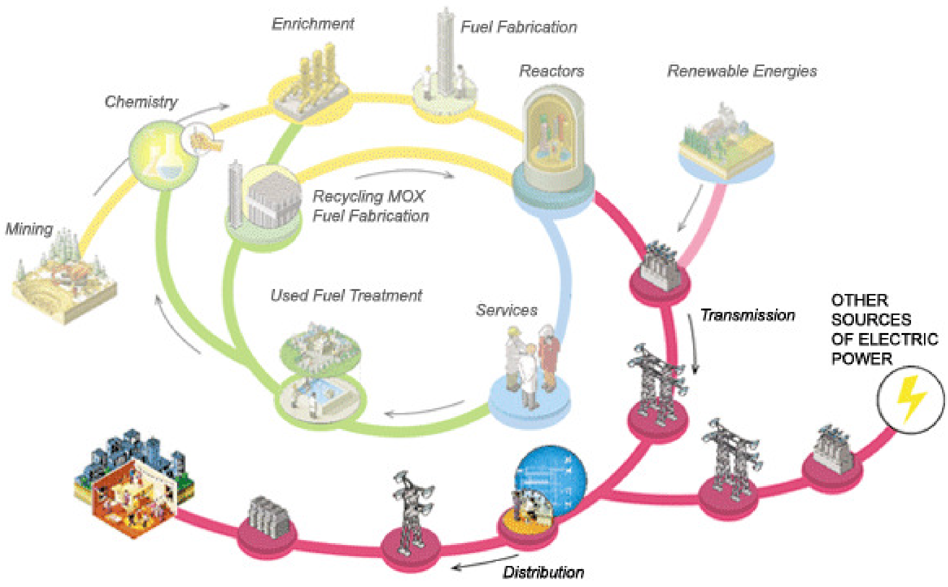
AREVA T&D's leading position in today's energy market follows over 125 years of pioneering innovation, technological expertise and an unwavering commitment to quality and customer service.

AREVA T&D offers solutions to bring electricity from the source onto the power network.

AREVA T&D builds high- and medium-voltage substations and develop technologies to manage power grids worldwide.

AREVA T&D's technologies and expertise ensure higher safety, reliability and capacity of power grids around the world.

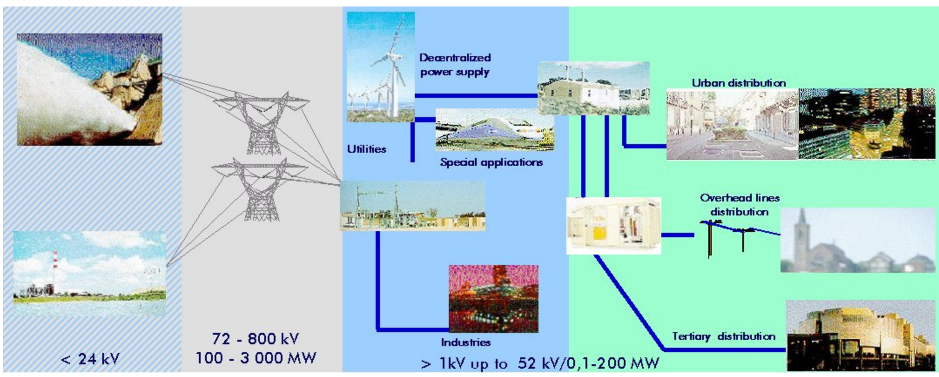
AREVA T&D provides a wealth of solutions for the transmission and distribution of electricity worldwide.



With 68 industrial sites and a presence in more than 100 countries, **AREVA T&D** provides full-fledged solutions to over 30,000 customers in 160 countries around the world. (www.areva.com 2008)

PRIMARY DISTRIBUTION SWITCHGEAR

The Primary distribution network makes the link between High voltage/Medium voltage substations and Secondary Distribution networks, as well as electro-intensive industries and infrastructures**.**



The case study with OEE has been done with the CNC punching machine which is belongs to AREVA TD, Areva Turkey Medium Voltage Switchgear (ATM) factory, in Gebze, Turkey and produces medium voltage switchgear cabinets. Those cabinet's sheet metal parts are produced in mechanical workshop. The mechanical workshop will be called as MWS in this paper. ATM produce PIX cubicles in the assembly line and the sheet metal parts of PIX cubicle are produce by MWS, which is ATM's sheet metal factory. (Fig: 4.1 and Fig 4.2)

Fig 4.1: Picture of PIX Cubicle

Fig 4.2: Sheet Metal Trolley

4.2 Process Flow:

Firstly the process was defined in the workshop; (Fig.4.3).

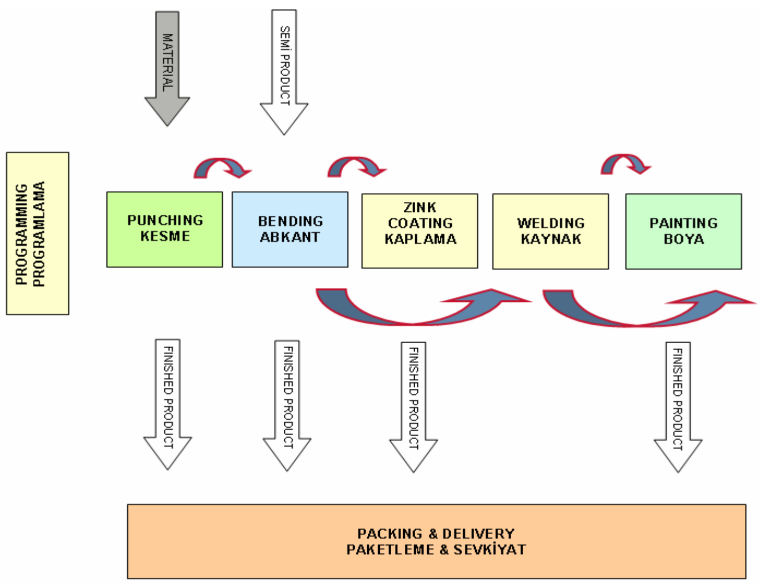


Fig 4.3: Process Flow

That was a very simple process map, and should be detailed, and the hidden processes between workstations should be pointed out, also define some necessary processes. In Fig 4.4 is the detailed process map.

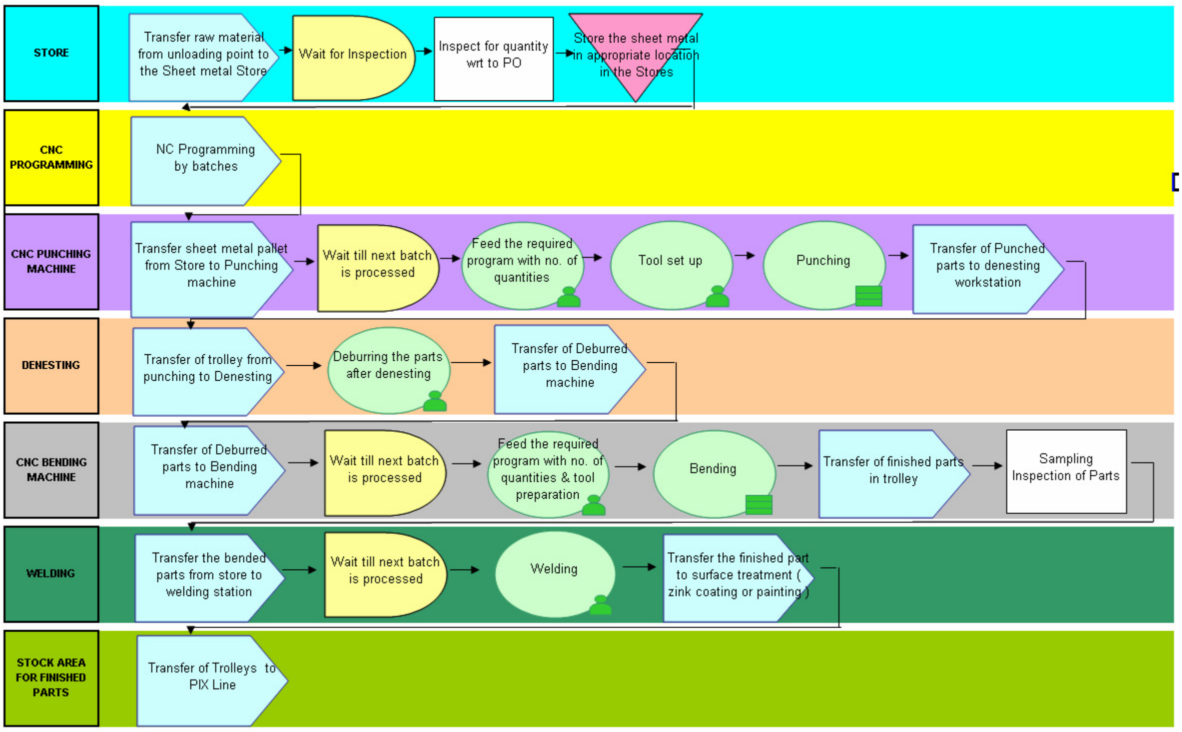
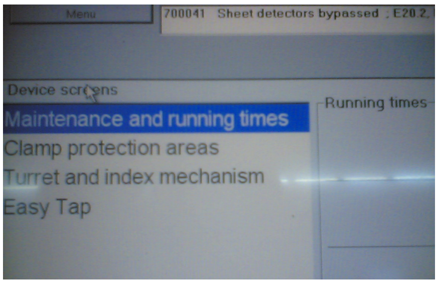


Fig 4.4: Detailed Process Flow with additional processes defined.

The study is done on CNC punching machine. The machine was planned to work three shifts a day and six days a week. One shift is 7,5 hours. There is three tea breaks, 10 minutes each and half an hour for lunch break. The time between the shifts is fifteen minutes and the employees are having fifteen minutes for cleaning at end of their shift. The machine is running with a NC program, which is a special software for the machine. Two programmers are working in the programming center.

Some data collection forms were defined at the beginning and see how the machine's behavior was. Firstly we have defined the time of the machine was having power and the time it was producing physically, which is the time of NC program's running time. We collect that data directly from the machine. The software which machine uses is able to measure and give us the exact time. (Fig. 4-5). Machine's operators should get trained for data collection and they should get understand the importance of those measurement. They had to understand the benefits of this monitoring system, because it is obvious they wouldn't be pleased to be monitored. If they don't believe on the benefits of this study, the datas which they would enter would not be very realistic. Each operator were resetting the times before starting their shift, and at end of the shift they were writing down the times on the Data Collection Form 1, (Table 4.1), which was on the screen.



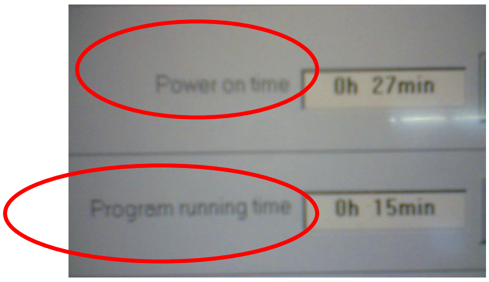


Fig 4.5: "Power on Time" & "Program Running Time" data from the machine

DATA COLLECTION FORM 1									
DATE	**SHIFT**	**OPR**	**HR**	**MIN**	**POWER ON TIME (MIN)**	**HR**	**MIN**	**PROGRAM RUNNING TIME**	**USAGE %**
03.12.07	07:45-15:45	BV	7	56	476	3	10	190	40%
03.12.07	15:45-23:45	AA	7	43	463	3	22	202	44%
04.12.07	23:45-07:45	İK	7	57	477	2	50	170	36%
04.12.07	07:45-15:45	BV	7	35	455	3	7	187	41%
04.12.07	15:45-23:45	AA	7	35	455	3	10	190	42%
05.12.07	23:45-07:45	İK	7	48	468	4	22	262	56%
05.12.07	07:45-15:45	BV	7	40	460	3	0	180	39%
05.12.07	15:45-23:45	AA	6	6	366	2	40	160	44%
06.12.07	23:45-07:45	İK	7	43	463	3	15	195	42%
06.12.07	07:45-15:45	BV	7	41	461	3	21	201	44%
06.12.07	15:45-23:45	AA	7	42	462	4	10	250	54%
07.12.07	23:45-07:45	İK	7	43	463	3	22	202	44%
07.12.07	07:45-15:45	BV	7	56	476	2	55	175	37%
07.12.07	15:45-23:45	AA	7	45	465	3	3	183	39%
08.12.07	23:45-07:45	İK	7	48	468	2	38	158	34%
08.12.07	07:45-15:45	BV	7	40	460	2	51	171	37%
08.12.07	15:45-23:45	AA	7	45	465	3	1	181	39%
09.12.07	23:45-07:45	AA	7	52	472	2	55	175	37%

Table 4.1: Data Collection Form of "Power on Time" & "Program Running Time"

"Power on Time" & "Program Running Time" datas show us the machine was just running 42 percent of the time it was supposed to run, which was not a good result. We had to find the reasons of this big gap.

4.3 MAINTENANCE PLANNING

The operators were responsible of their machines maintenance, we have realised it was not doing with a controlled system and there was some differences between the operators with the way of doing maintenance. We had to define an exact and proper way for preventive maintetance with the maintenance department.

Firstly we defined all the maintenance steps which operators would be responsible for preventive maintenance which are daily and weekly maintenance tasks. (Fig 4.6). We clocked each task and defined exact rules to do and exact time for them to spend for the maintetance.

A visual management tool was also created to see the breakdowns, electricity cut outs, down air pressure problems and all the planned maintenance on the machine. (Fig 4.7)

4.4 STRUCTURAL LOSSES

There are also some structural losses, which are the tea breaks, lunch breaks, shift changes and cleaning time, which is 20 percent of the time. Those times are certain and we will not work on those.

4.5 CAUSE AND EFFECT DIAGRAM

The next step was defining the hidden losses. We monitored the machine, also make some meetings with the operators about the time they were spending on mostly and the interuptions they were facing during their shifts. With the team members we have defined the cause and effect diagram to see the effects and find out the way of improving the performance of the machine. (Fig. 4.8)

OPERATÖR SERVİS KARTI		YIL 2008	FORM KOD ....
DEM. NO	TZG.ADI:	FINN POWER SAC DELME TEZGAHI	

Mad. No.	GÜNLÜK YAPILACAK İŞLEMLER	SÜRE/sn.
	BAKIMA HAZIRLIK	
1.	ÇALIŞMA MASASININ TEMİZLİĞİ	300
2.	HAVA ŞARTLANDIRICISININ KONTROLU	30
3.	TARET VE TAKIM TUTUCU KONTROLÜ	60
4.	MULTİ TOOL VİDALARIN SIKILIĞININ KONTROLÜ	60
5.	ATIK METAL KONVEYOR BANDININ GERGİNLİK KONTROLÜ VE TEMİZLİĞİ	20
6.	PARÇA METAL KONVEYOR BANDININ GERGİNLİK KONTROLÜ VE TEMİZLİĞİ	20
7.	X EKSENİNDEKİ KLAVUZUN TEMIZLIĞI	150
8.	MAKİNA EMERGENCY(GÜVENLİK) SİSTEMLERİNİN KONTROL EDİLMESİ	10
9.	Y EKSEN KILAVUZUNUN TEMIZLIĞI	100
10.	ALT TARET VE PUNCH PRESS ALT ÇERÇEVE TEMIZLIĞI	30
11.	ELEKTRIK PANO KLIMASININ ÇALIŞIP ÇALIŞMADIĞINI KONTROL EDİNİZ.	10
Mad. No.	HAFTALIK YAPILACAK İŞLEMLER	Peryot
12.	PUNCH MOTOR SOĞUTUCU KONTROLÜ VE FİLTRESİNİN TEMİZLİĞİ	60
13.	İNDEX TAKIM TUTUCULARIN YAĞLANMASI	600
14.	ALT FORM TUTUCULARIN YAĞLANMASI	600
15.	TAKIMLARIN TEMIZLIGI mlt:4320+nrm:2880=	7200

AYLAR	Mad. No.	GÜNLÜK																													OPERATÖR	KISIM AMİRİ
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31		
MART	1																																	
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Fig 4.6: Daily and weekly maintenance sheet.

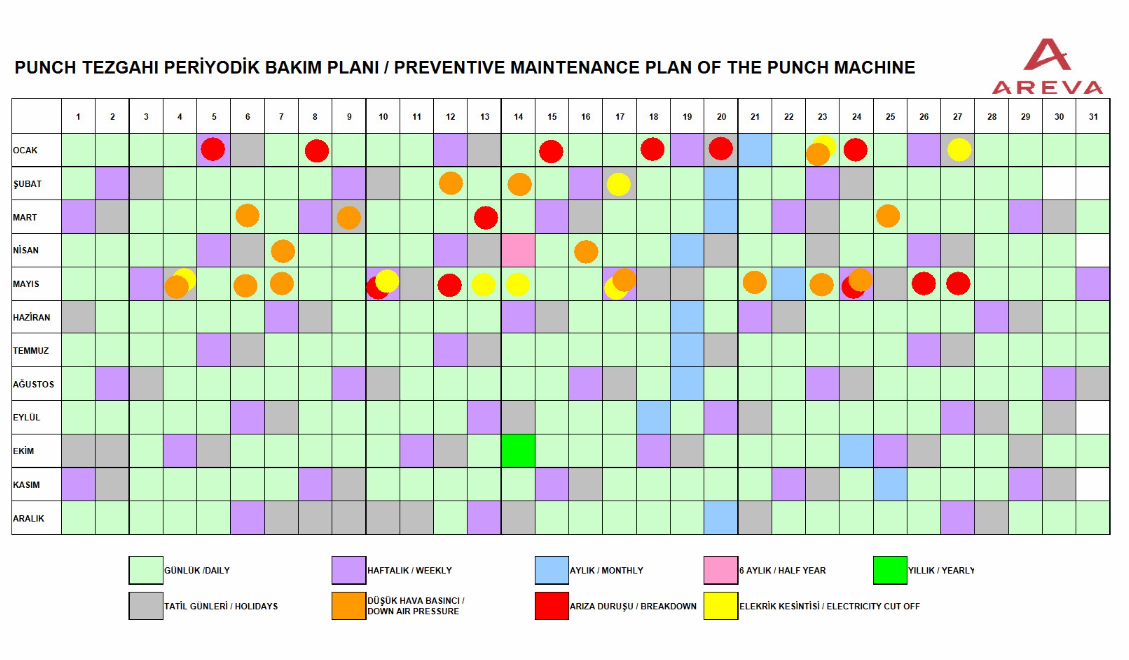

Fig 4.7: Maintenance Plan, Visual management tool for MTBF

4.6 IMPROVEMENT ON PROGRAMMING SIDE

For improvement we need everyone to work on this issue. With this approach we ask to use microjoints on the sheet plate, which is a joint between the parts and the parts are not seperating from the plate while the machine was working. That help us not to stop the machine for collecting the parts on the plate, and the operator were able to do the next job's preparation, because he was not going and picking up the parts, for every and each time. That helped saving so much time on the machine and the operator's time. There was other tips we have done on the programming stage which were common punching on the same length edges, nesting in nestings etc. (Fig.4.9) That would make time savings on the machine.

We have done big improvement on the programming side. Now we were ready to work on the operating side.

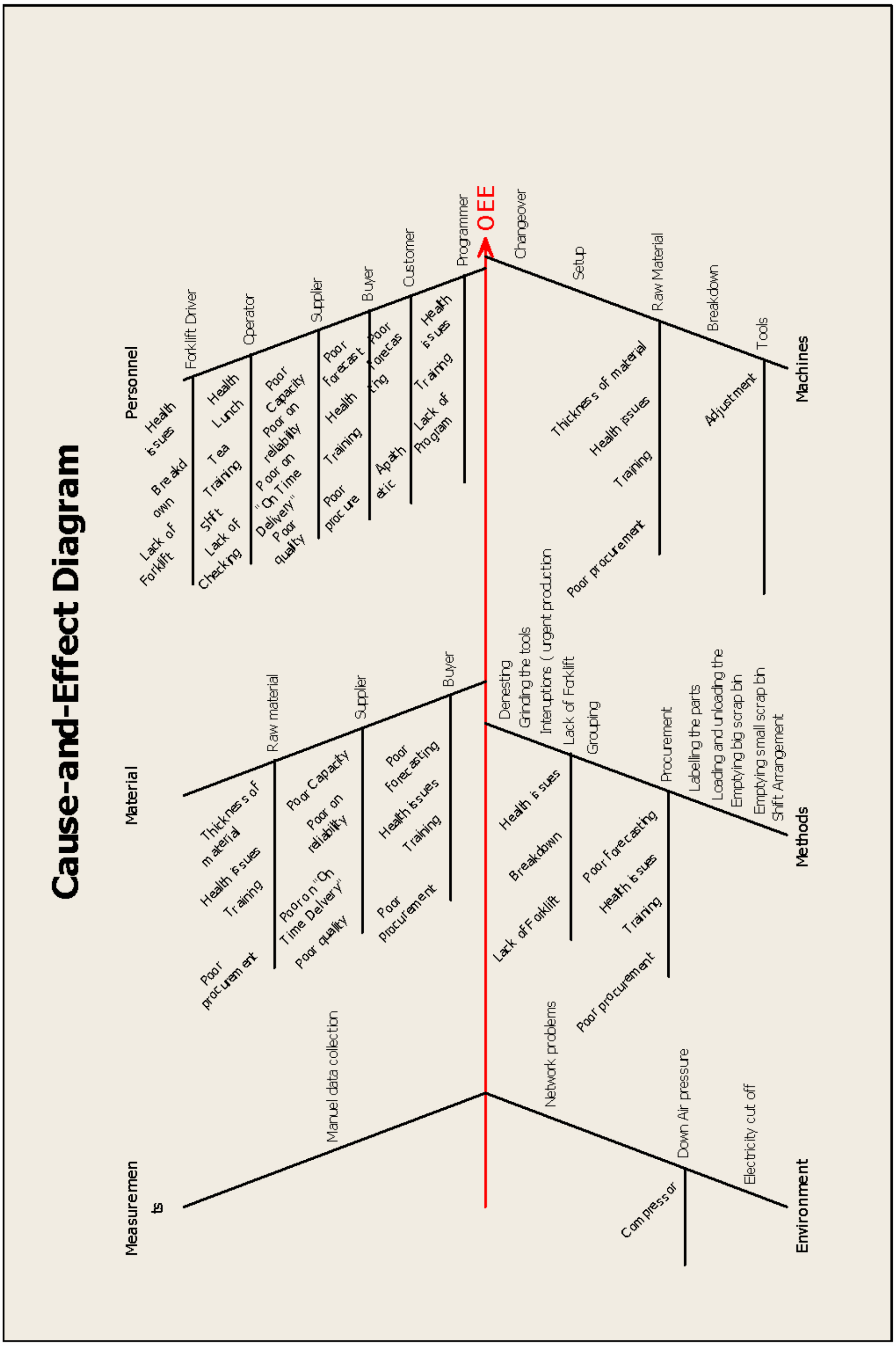

Fig 4.8: Cause & Effect Diagram

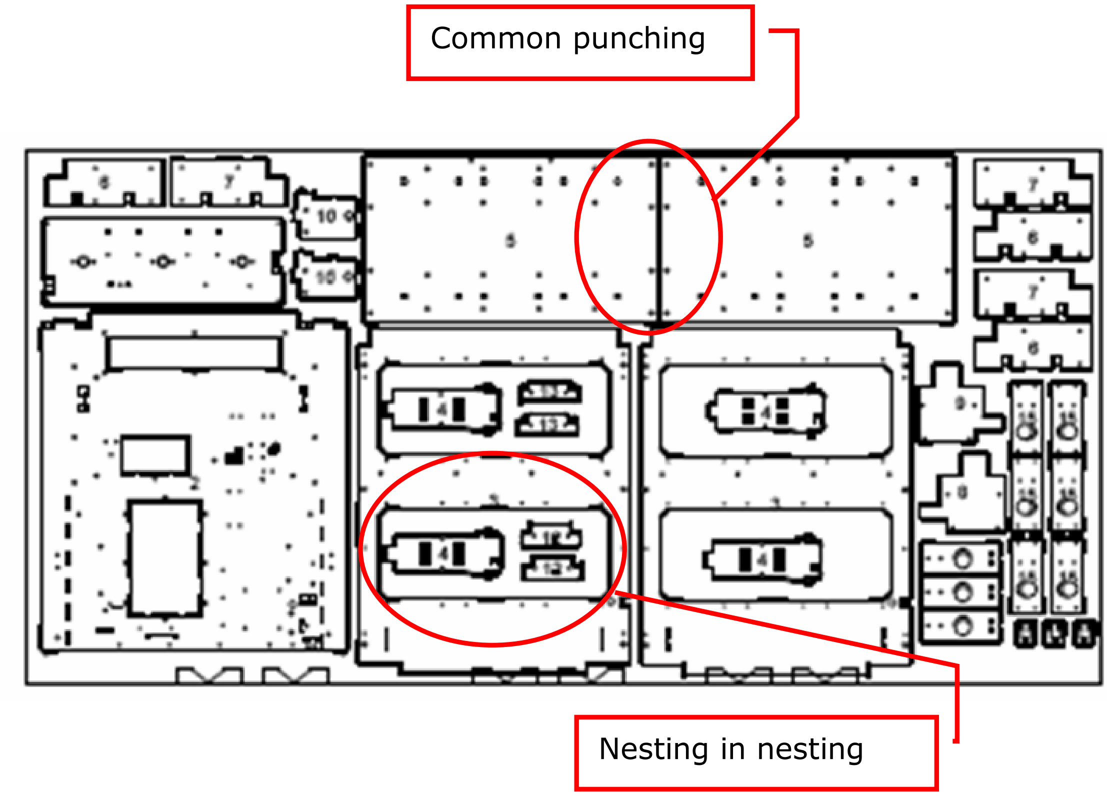

Fig 4.9: Nesting example

Microjoints were very useful but we have seen the operators was spending so much time on denesting process (breaking the microjoints and collecting the parts from the sheet) , the program was running about 6-7 minutes but denesting was taking about 10-15 minutes, they were also labelling the parts, and this denesting process was done on the machine at that time. It is seen if a seperated denesting table was defined then the operators would run the machine while they were doing denesting on a seperate table. That worked well, and made big improvement on the output.

4.7 5S ON THE SHOP FLOOR

On the punch machines the tool dies are changing between thicknesses, we made a tool cabinet for all the punch and dies, and catagories them. We have put labels on each tool and die, all the tools had identification by this way. That help the operators a lot. They were not spending much time for finding the correct tool, and we saved time. Also with this way we have stopped quality defect of using wrong tool and saved also our tools for getting damaged, because wrong tool usage damages the tools, might also breaks them. (Fig. 4.10)

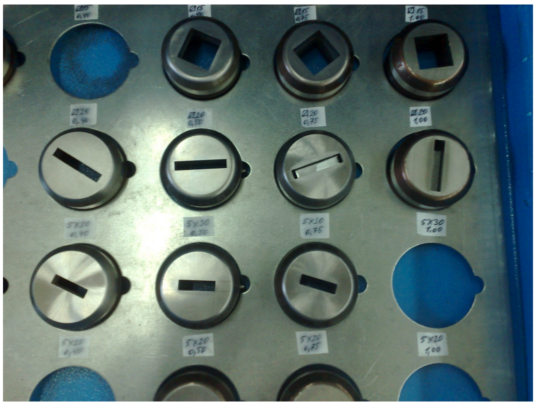

Fig 4.10 Tool drawer.

Damaged tool would produce bad products, which will effect the product quality rate. (Amer 2007)

During the study we have measured the noise level of the punch machine while working, the measurement results were 97 db , which is against the health and safety conditions of the employees even though they are using ear protections. Because of that reason we discussed with the machines producers and found out a way to reduce the noice by reducing the ram speed of the machine. The solution was reducing the cutting force, which reduce the process performance efficiency, but EHS (Employee Health and Safety) is more important then anything else for AREVA TD. After implementing this solution the noise level became below 85 db, which is suitable for the work environment.

The data collection team informed and trained about the importance of this data collection and the way of collecting and entering the datas. (Table 4.2)

Item	Data Collection Description	Responsible Person	How measured?	Related Form to record	Related Factors to Record	Period
1	Number of sheets punched	All punching Operators	End of the shift they must enter the quantity of sheet they have punched	Target sheets	# of sheets	Every shift
2	Power on Time & Program Running Time	All punching Operators	Data is coming from the machine	Power on Time & Program Running Time Entering Form	Minutes	Every shift
3	DownTime Losses	All punching Operators	Manually measured	DownTime Entering Form	Minutes	Every shift
4	Defected parts	Process Quality People	Quality control measurements	KKHR (Quality Control Failure Entering Form) Form	# of parts defected	Every shift
5	Number of cubicles produced	Programmers	Projects worked related week	None	# of cubicles	Weekly

Table 4.2: Data Collection Plan

We have done several shop floor meetings and defined another data collection form and asked them to fill all the losses they are facing. There was 15 tasks, which usually interups the operators while working. The goal of that defining the biggest loss and making improvent on it. (Table 4.3 and Table 4.4)

FinnPower E5 makina duruş dataları /
FinnPower E5 machine downtime datas

Hafta / Week	:	

No	Tarih / Date	Vardiya / Shift	Duruş Kodu / Failure Code	Başlama / Start	Bitiş / Finish	Süre (dak/min)	Açıklama / Description
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Duruş tanımı:		Duruş Kodu:
Takımların hazırlanması (Setup)	:	1001
Acil araya girilen işler	:	1002
Hammadde bekleme (forklift şöförü için)	:	1003
Küçük hurda kazanının boşaltılması	:	1004
Büyük hurda kazanının boşaltılması	:	1005
Paletlerin üzerinde parça sac aramak	:	1006
Malzemelerin etiketlerinin yazılması	:	1007
Vardiya devralındığında takımların kontrolü	:	1008
Stok malzemelerinin yerleştirilmesi	:	1009
Punchtan çıkan malzemelere uygun yer bulunması	:	1010
Elektrik kesilmesi	:	1011
Makina arızası	:	1012
Hava düşüşü	:	1013
Program bekleme	:	1014
Diğer	:	1015

Table 4.3: Downtime losses data collection form

4.8 DATA COLLECTION PLAN

The most important thing with data collection was actually making everybody to understand the reason of collecting data, otherwise it would not be possible to get reliable datas. Nobody would like to be monitored while working.

4.9 DOWNTIME LOSSES ON THE MACHINE

DT Code	DT Description
1001	Tool Setup
1002	Training
1003	Lack of Forklift Driver
1004	Emptying small scrap bin
1005	Emptying big scrap bin
1006	Looking for right size of small plate
1007	Labelling
1008	Checking the tools (takeover the shift)
1009	Looking for a place for the stock parts
1010	Lack of place or trolley for punched parts
1011	Electricity
1012	Breakdown
1013	Air pressure
1014	Lack of program or programming mistakes
1015	Others

Table 4.4: Main interuptions

Table 4.5 is an example for the operators output and target sheet, during the study the target revised 6 times after and each improvement. We used the number of sheets output for calculating the loading and unloading downtime. Obviously as much as the output increase the productivity will get higher. But we have to consider the time of loading and unloading the machine with the raw material.

For calculation we have monitored and take one min for each sheet's loading and unloading time. This is important to see the time that the operators are spending on the task.

Week 20'08 Output (by plate)

Shifts	Hours	WEEK 20	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Shifts total	Opr
1.Shift	23:45	Target	21	21	21	21	21	21	0	126	AA
	07:45	Output	16	12	25	21	28	26	0	128	
2.Shift	07:45	Target	23	23	23	23	23	23	23	161	BV
	15:45	Output	20	24	32	27	41	19	25	187	
3.Shift	15:45	Target	25	25	25	25	25	18	0	143	İK
	23:45	Output	33	32	25	32	30	27	0	180	
Total Target			69	69	69	69	69	62	23	430	115%
Total Output			70	68	82	80	99	72	25	495	

Table 4.5: MWS Output of number of sheets produced.

With this "Failure Data Collection Form" we have defined most of the losses. There was about 40 percent of the lost time was not defined but it went down to 1 percent. (Table 4.6). Which was a big improvent for the beginning but the big issue was making improvements on those losses.

Table 4.7 and table 4.8 is shows all the data collected and ready to use for OEE calculation. Table 4.7 is monitored daily datas, and Table 4.8 is monitored weekly summarized data.

Week	Power on time (min)	Program Running Time (min)	Identified DownTime (min)	Unindentified DownTime (min)	Program Running Time (%)	Identified DownTime (%)	Unindentified DownTime (%)
49	8735	3600	2441	2694	41%	28%	31%
50	8804	2521	2905	3378	29%	33%	38%
51	4635	1749	1177	1709	38%	25%	37%
52	5561	2076	1399	2086	37%	25%	38%
1	4582	1714	1614	1254	37%	35%	27%
2	9201	3163	2733	3305	34%	30%	36%
3	9280	3123	3099	3058	34%	33%	33%
4	8749	2999	2797	2953	34%	32%	34%
5	3728	1237	1265	1226	33%	34%	33%
6	6019	1916	1775	2328	32%	29%	39%
7	5045	1544	2434	1067	31%	48%	21%
8	6022	2153	1721	2148	36%	29%	36%
9	6959	2562	1856	2541	37%	27%	37%
10	8851	3364	2573	2914	38%	29%	33%
11	7431	2416	3156	1859	33%	42%	25%
12	8426	3114	2210	3102	37%	26%	37%
13	8300	3015	2335	2950	36%	28%	36%
14	7981	2799	2587	2595	35%	32%	33%
15	6027	2644	1761	1622	44%	29%	27%
16	8301	3856	2705	1740	46%	33%	21%
17	6936	3519	2662	755	51%	38%	11%
18	8762	4263	3658	841	49%	42%	10%
19	8833	3907	4674	252	44%	53%	3%
20	8840	3882	4912	46	44%	56%	1%
21	7899	3534	4322	43	45%	55%	1%

Table 4.6: Comparing Identified and unidentified times

Date	Shift	Month	Year	Week	Tea Break & Lunch	Cleaning	Hr	Min	POWER ON TIME (MIN) (Planned operating time) - P -	Hr	Min	PROGRAM RUNNING TIME (Total Operating Time)	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	Service	Weekday	Preventive Maintenance	Shift Change
1.5	23:45-07:45	5	2008	18	60	15	7	47	467	3	39	219	33							10									4	4,38	15
1.5	07:45-15:45	5	2008	18	60	15	7	45	465	4	25	265	35		10							15							4	4,38	15
1.5	15:45-23:45	5	2008	18	60	15	7	42	462	3	44	224	70		5	10				10									4	4,38	15
2.5	23:45-07:45	5	2008	18	60	15	7	44	464	3	53	233	15		17	11				14		20							5	4,38	15
2.5	07:45-15:45	5	2008	18	60	15	7	45	465	4	50	290	27		20					10		10					35		5	4,38	15
2.5	15:45-23:45	5	2008	18	60	15	7	39	459	3	41	221	40																5	4,38	15
3.5	23:45-07:45	5	2008	18	60	15	7	47	467	3	48	228	7		16	12				15	18								6	47	15
3.5	07:45-15:45	5	2008	18	60	15	7	43	463	2	38	158	32							10									6	47	15
3.5	15:45-23:45	5	2008	18	60	15	7	45	465	3	16	196	52		8					10		10							6	47	15
4.5	07:45-15:45	5	2008	18	60	15	6	50	410	3	10	190	40							10			60		15				7	4,38	15
5.5	23:45-07:45	5	2008	19	60	15	7	45	465	3	28	208																	1	4,38	15
5.5	07:45-15:45	5	2008	19	60	15	7	40	460	3	37	217	50							8							40		1	4,38	15
5.5	15:45-23:45	5	2008	19	60	15	7	48	468	3	59	239	33		12	10				18		10				16			1	4,38	15
6.5	23:45-07:45	5	2008	19	60	15	7	45	465	4	46	286	22		15					10									2	4,38	15
6.5	07:45-15:45	5	2008	19	60	15	7	43	463	3	24	204	103		20	10									8				2	4,38	15
6.5	15:45-23:45	5	2008	19	60	15	7	44	464	2	57	177	100							18									2	4,38	15
7.5	23:45-07:45	5	2008	19	60	15	7	45	465	4	10	250	35		25					30					35	15			3	4,38	15
7.5	07:45-15:45	5	2008	19	60	15	7	44	464	3	20	200	103		10	10		20		7							30		3	4,38	15
7.5	15:45-23:45	5	2008	19	60	15	7	45	465	3	26	206	87		15	10				15									3	4,38	15
8.5	23:45-07:45	5	2008	19	60	15	7	44	464	3	18	198	30							10							40		4	4,38	15
8.5	07:45-15:45	5	2008	19	60	15	7	45	465	4	20	260	31		7					10		10							4	4,38	15
8.5	15:45-23:45	5	2008	19	60	15	7	47	467	4	5	245	47		55	23				18									4	4,38	15
9.5	23:45-07:45	5	2008	19	60	15	7	45	465	3	56	236								10							30		5	4,38	15
9.5	07:45-15:45	5	2008	19	60	15	7	43	463	2	55	175	77		35					10									5	4,38	15
9.5	15:45-23:45	5	2008	19	60	15	7	48	468	3	49	229	39			10				24									5	4,38	15

Table4.7: Daily Monitoring

Week	Month	Power on time (min)	Program Running Time (min)	Tea Break (min)	Cleaning (min)	Preventive Maintenance (min)	Shift Change (min)	Loading & Unloading Time (min)	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	Service	Identified DownTime (min)	Unindentified DownTime (min)	# of cubs produced	# of sheet punched
49	12	8735	3600	1140	285	211,08	285	460	0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2441	2694	35	460
50	12	8804	2521	1140	285	211,08	285	369	0	0	0	0	0	0	0	0	0	0	0	465	0	150	0	0	2905	3378	32	369
51	12	4635	1749	600	150	129,04	150	148	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1177	1709	0	148
52	12	5561	2076	720	180	95,18	180	224	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1399	2086	34	224
1	1	4582	1714	600	150	129,04	150	225	0	0	0	0	0	0	0	0	0	0	0	360	0	0	0	0	1614	1254	20	225
2	1	9201	3163	1200	300	215,46	300	358	0	0	0	0	0	0	0	0	0	0	0	360	0	0	0	0	2733	3305	35	358
3	1	9280	3123	1200	300	215,46	300	364	0	0	0	0	0	0	0	0	0	0	0	720	0	0	0	0	3099	3058	17	364
4	1	8749	2999	1140	285	211,08	285	351	0	0	0	0	0	0	0	0	0	0	255	240	30	0	0	120	2797	2953	47	351
5	1	3728	1237	480	120	35,04	120	315	0	0	0	0	0	0	0	0	0	0	0	195	0	0	0	0	1265	1226	16	315
6	2	6019	1916	780	195	142,18	195	313	0	0	60	0	0	0	0	0	0	0	0	0	0	90	0	0	1775	2328	22	313
7	2	5045	1544	660	165	133,42	165	246	0	675	0	0	0	0	0	0	0	0	315	0	75	0	0	0	2434	1067	26	246
8	2	6022	2153	780	195	142,18	195	289	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	0	1721	2148	17	289
9	2	6959	2562	900	225	150,94	225	325	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	1856	2541	28	325
10	3	8851	3364	1140	285	211,08	285	406	0	0	0	0	0	0	0	0	0	0	0	0	80	166	0	0	2573	2914	38	406
11	3	7431	2416	960	240	197,94	240	358	0	120	0	0	0	0	0	0	0	0	0	1010	0	30	0	0	3156	1859	38	358
12	3	8426	3114	1080	270	206,7	270	383	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2210	3102	26	383
13	3	8300	3015	1080	270	206,7	270	388	0	0	0	0	0	0	0	0	0	0	0	0	120	0	0	0	2335	2950	35	388
14	4	7981	2799	1020	255	242,94	255	364	0	0	0	0	0	0	0	0	0	0	0	0	0	450	0	45	2587	2595	39	364
15	4	6027	2644	780	195	142,18	195	359	0	45	0	0	0	0	0	0	0	0	0	0	45	0	0	0	1761	1622	43	359
16	4	8301	3856	1080	270	206,7	270	413	233	0	52	50	0	7	0	10	0	0	0	0	75	0	38	0	2705	1740	40	413
17	4	6936	3519	900	225	193,56	225	340	475	70	93	36	0	5	0	32	0	10	0	0	0	0	57	0	2662	755	48	340
18	4	8762	4263	1140	285	211,08	285	441	668	0	126	70	5	0	0	174	18	85	60	0	15	0	75	0	3658	841	41	441
19	5	8833	3907	1140	285	70,08	285	483	757	0	204	73	0	20	0	198	0	20	0	905	63	31	140	0	4674	252	48	483

Table 4.83: Weekly Monitoring

4.10 ANALYSING THE COLLECTED DATAS

We realised some petty losses and those were making big changes on the output, for example the operators were downloading the NC programs from the network while machine was stoped, which they can also do while the machine was running. Also they were preparing the tools for the next job when the machine was not working and machine was waiting until the tools get ready and to installing into the machine. We have pushed the operators to do the machine’s adjustment and preparations for the next program while the machine was running. Also some spare cassettes supplied to have the dies ready for different die clearances of the multistations. And more multistations for reducing the time loss on setup. Even those little changes maked improvements and also program running time increased significantly. (Fig: 4.11; Fig: 4.12)

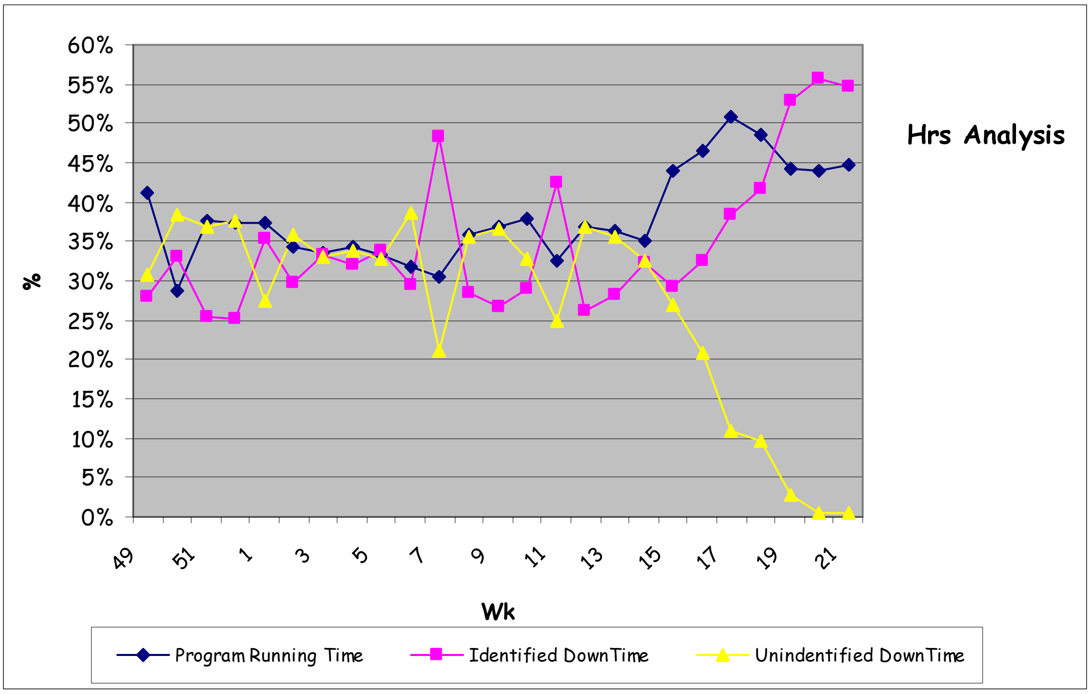

Fig 4.11: Identified - Unidentified Losses and program running time graph

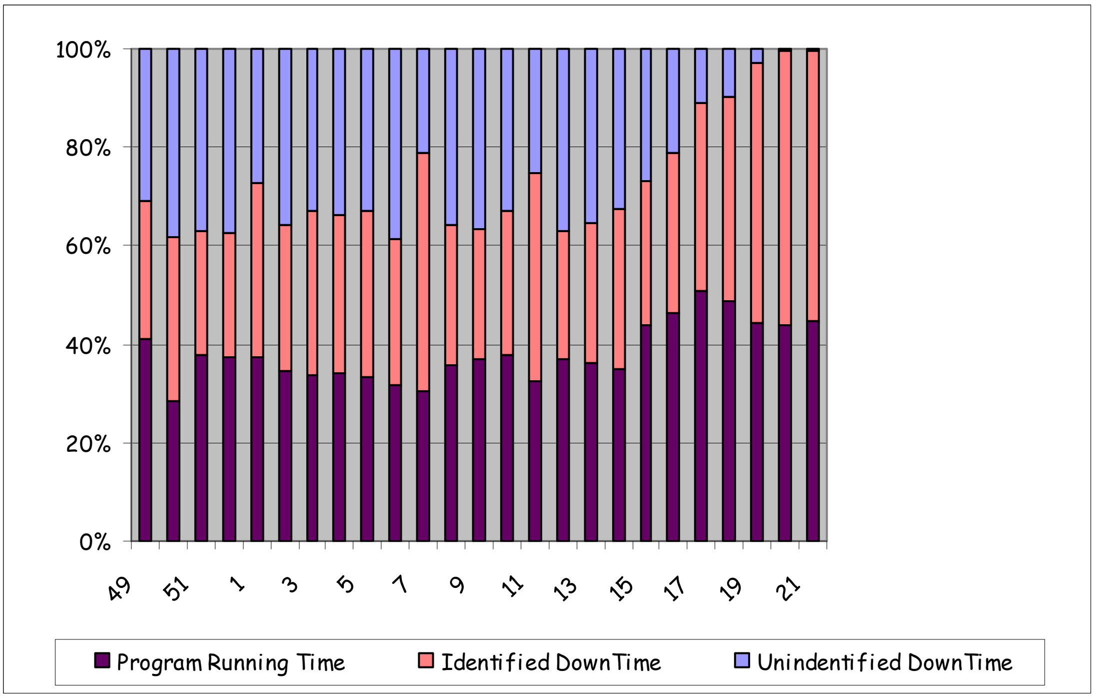

Fig 4.12: Chart of program running time, identified and unidenfied down time.

During the study there was two big breakdowns happened on the machine, both breakdowns cause was the same, which were the stopage of the conveyer that carries the slugs (small scrap parts) of the sheet. We have put andon lights for the operators, if there is any stopage happens it warns the operator also the rest of the people in the workshop with a red flushing light, if everything is normal and the conveyor works properly it just turn into green light, which was very usefull as a visual management tool. We were confident that there will not be any breakdown because of the same reason. Fig: 4.13 shows us the losses of the machine we have defined during this work.

The main downtime list of the machine is as below;

1. Breaks (tea breaks and lunch time)
2. Cleaning
3. Shift Change
4. Preventive Maintenance
5. Service
6. Sheet loading and unloading time
7. Tool setup
8. Training
9. Lack of Forklift Driver
10. Emptying big scrap bin
11. Emptying small scrap bin
12. Looking for right size of small plate (cut outs)
13. Labelling the parts
14. Checking the tools (takeover the shift)
15. Looking for place or trolley for the stock (double bin) parts
16. Looking for place or trolley for the punched parts
17. Electricity
18. Machine breakdown
19. Air pressure
20. Lack of program or programming mistakes
21. Network connection
22. Others

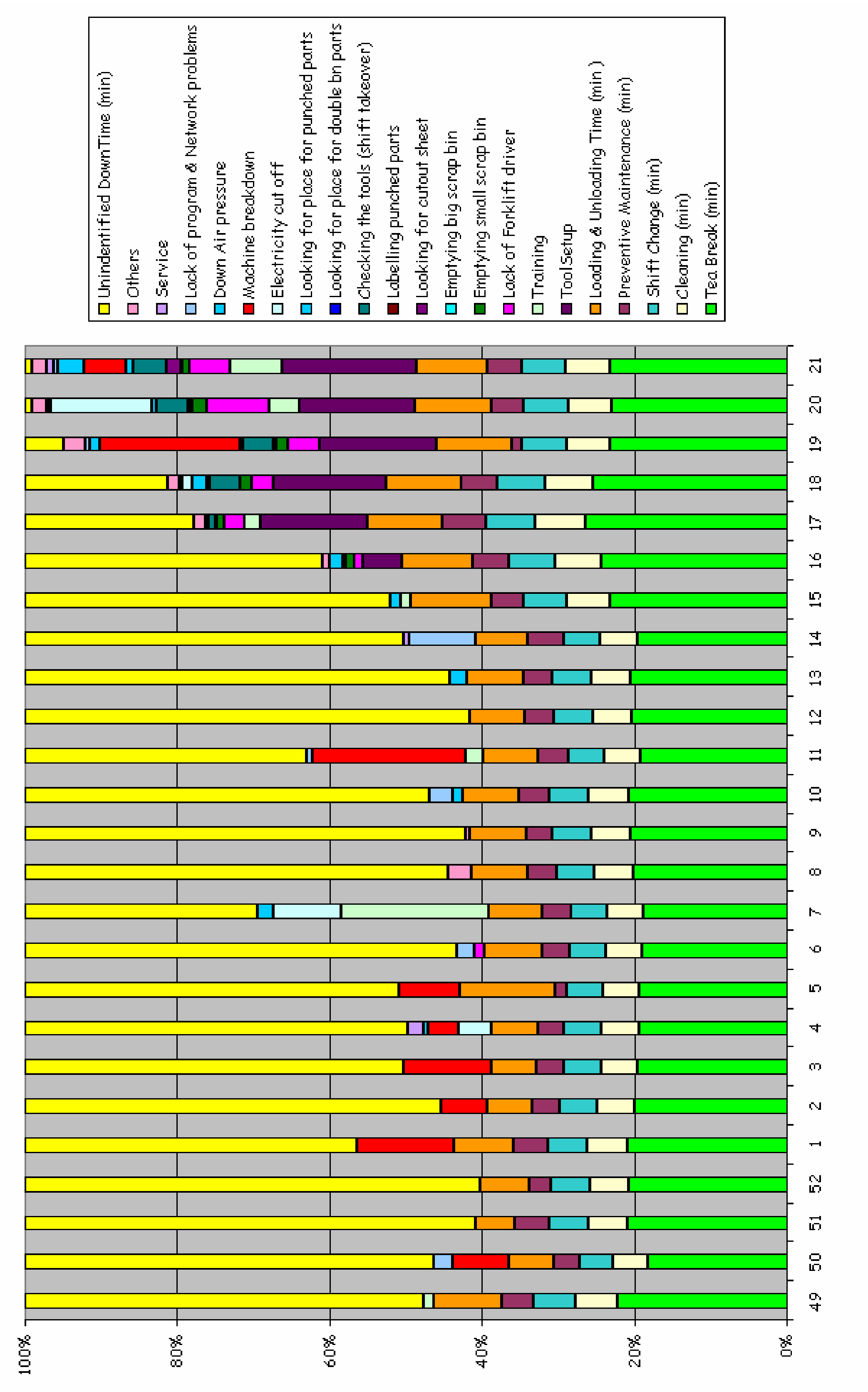

Fig 4.13: Downtime losses

4.11 PARETO DIAGRAM OF THE DOWNTIME LOSSES

Minitab15 is used for the pareto diagram of the losses. In Fig 4.14 all the losses are seen and Fig 4.15 all the losses without structural leakages are seen, those structural leakages are tea breaks, luch times, cleaning times, shift changes and the time for preventive maintenance. Those times are not planned for any output, those losses are effecting the availability of the machine.

MWS is a supplier of the assembly line and the capacity of the assembly line is about 72 cabinets in a week. At the beginning the machine was producing about 25 cubicles in a week. That shows MWS is just able to produce 34 percent of the line's capacity, the rest of the sheet metal parts was subcontracting. Because of that reason the improvement of the mechanical workshops capacity was very important for the management, it would also make cost benefits.

The aim was not supplying all the sheet metal work from MWS, it was producing at least 70 percent in house (MWS) and 30 percent outsourced. 70 percent in house makes around 50 cubicle per week. MWS's weekly target is 50 cubicles. That means 100 percent improvement is accepted from MWS.

After defining all the downtimes, which the operators entered. We have analysed the datas and made a pareto diagram of the losses. Pareto diagrams pointed out the areas we should focus on, from the highest downtime to the lowest one. It seems we should work on loading and unloading time, breakdowns, tool setup and electricity cut offs first.

It was known where to focus with that pareto analysis. And made some changes after defining all the losses, which were some tools, some spare cassets for the dies, a booster for the down air pressure etc. After all those study the output increased significantly. There is still lots of things to do for improvement.

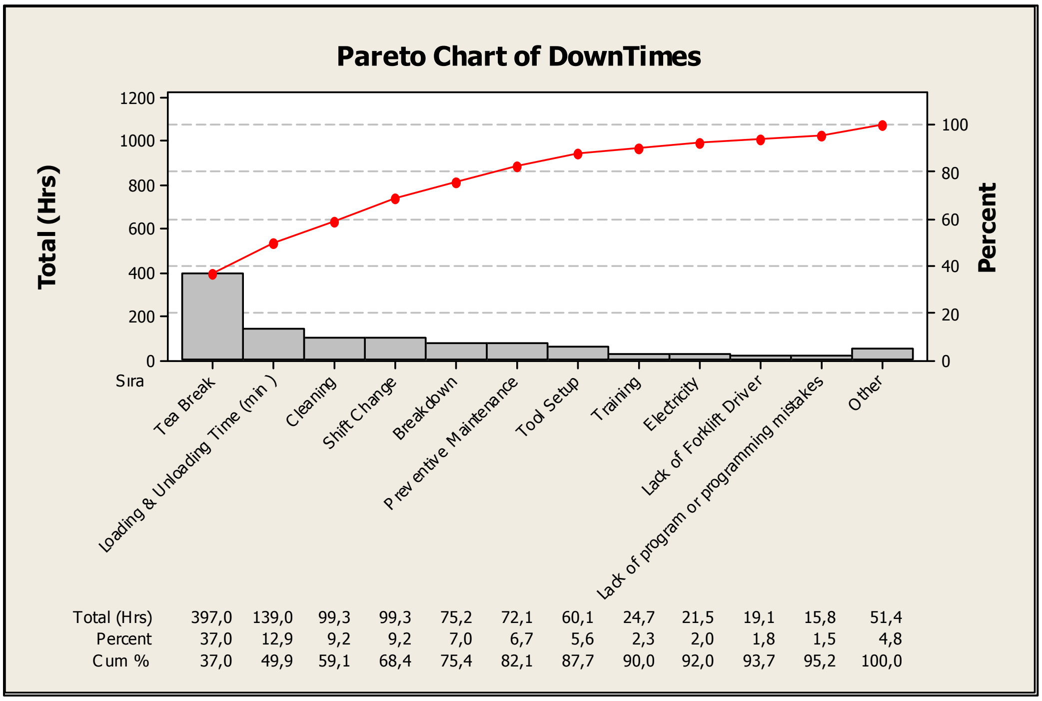

Fig 4.14: Pareto Diagram of all downtime losses

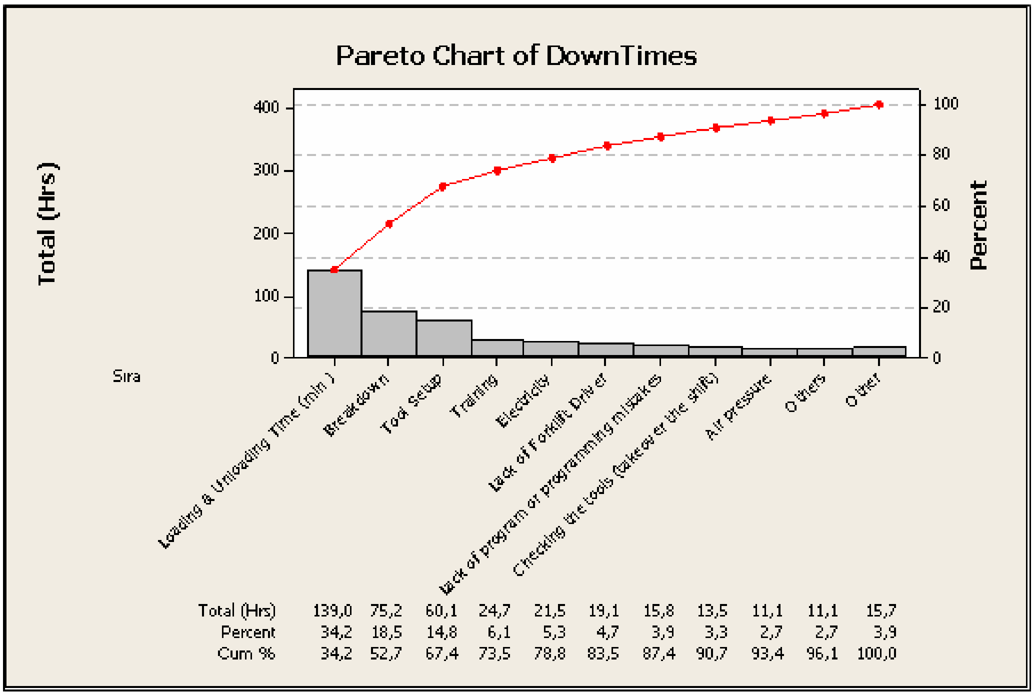

Fig 4.15: Pareto Diagram of downtime losses without structural leakages.

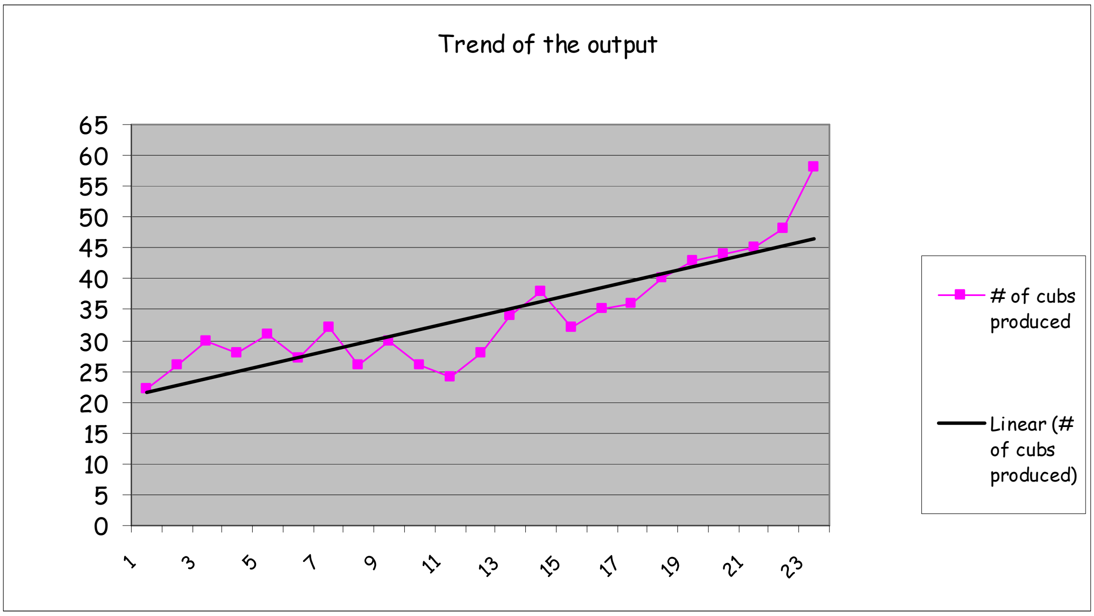

Fig 4.16: Trend of output

The benefit of this study is seen obviously in the Fig 4.16. The productivity increased more then 100 percent. MWS's capacity became above its targets.

4.12 STATISTICAL ANALYSIS

Minitab15 was used for statistical analysis. The below graphs are some statistical analysis of the collected data.

First histogram graph covers all the datas collected during this study, the mean of this period is 182,5 mins, second histogram was made with the data after a few improvements in the process has been done, and the mean of this period is 193,5 mins. And the standart deviation went down from 42,94 mins to 37,99 mins. (Fig 4.17 and Fig 4.18)

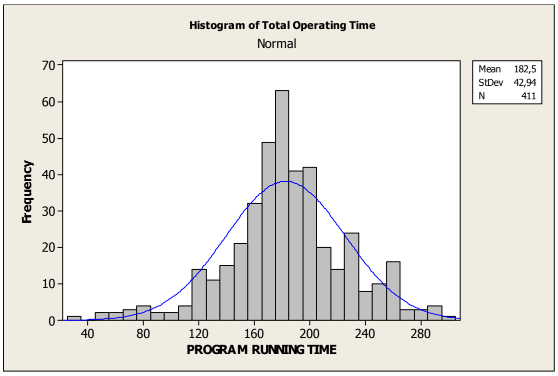

Fig 4.17 Histogram of all the **datas** collected during the study

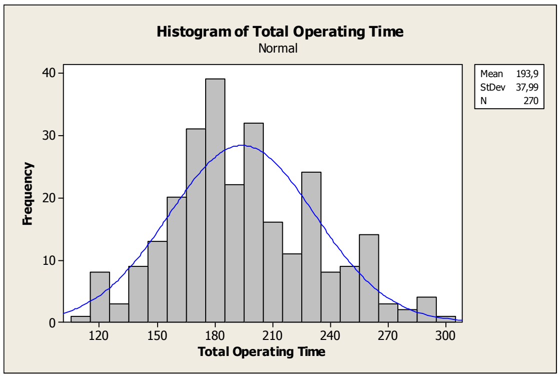

Fig 4.18 Histogram of the datas collected after a few improvements in the process during the study

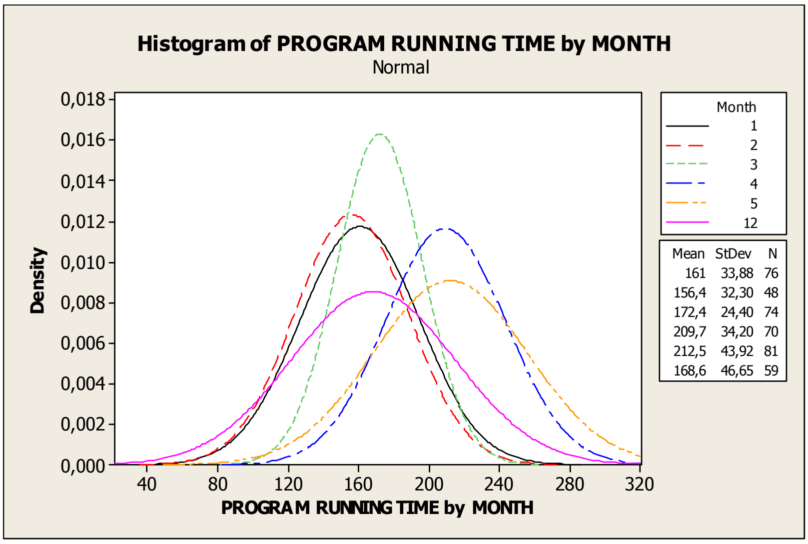

Fig 4.19 Program Running Time by Month

We have started to work in December 2007 and in six months time all the statistical analysis proves the improvements. On the Fig 4.19 we see the month of May has the maximum mean then the other months. On the right hand side of the Fig 4.20 are probability plot of the total operating time, right–top probability plot is for all the datas since December Right–bottom probability plot is showing us the difference between the years of 2007 and 2008. In December 2007 datas are very disfuse at the beginning, which is the time we were just started monitoring and didn't make many changes on the process. In the Fig 4.21 datas analysed by shifts.

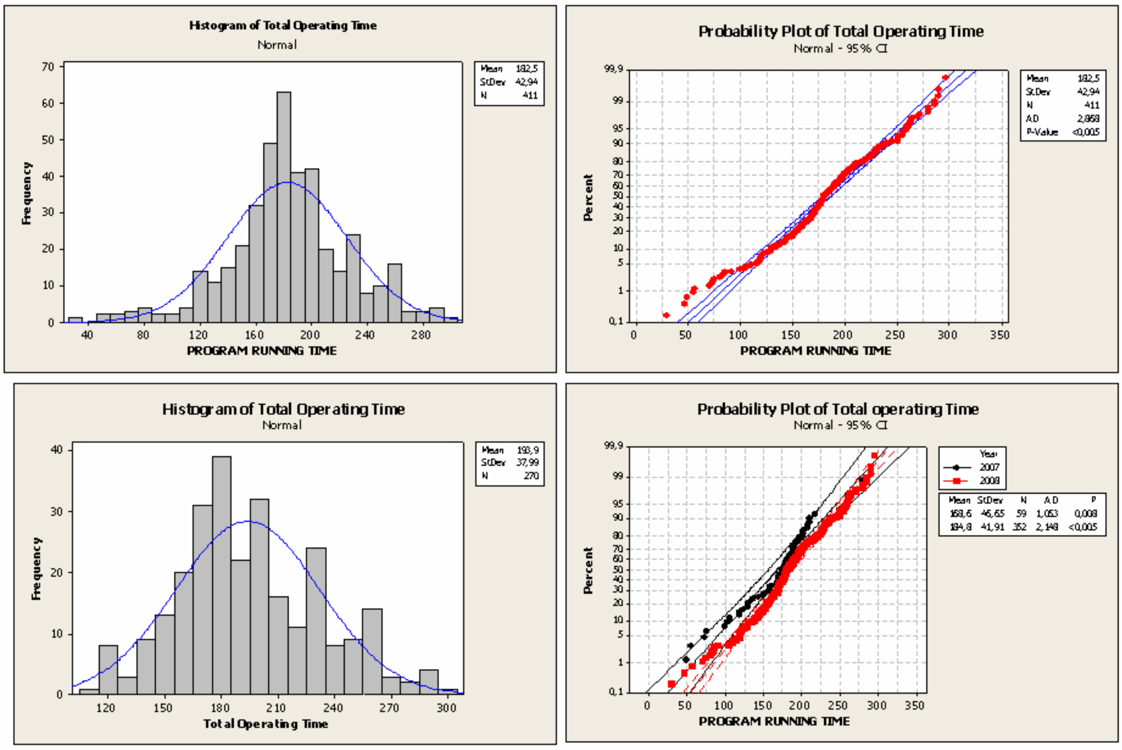

Fig 4.20: Histogram and Probability plot of the process by year

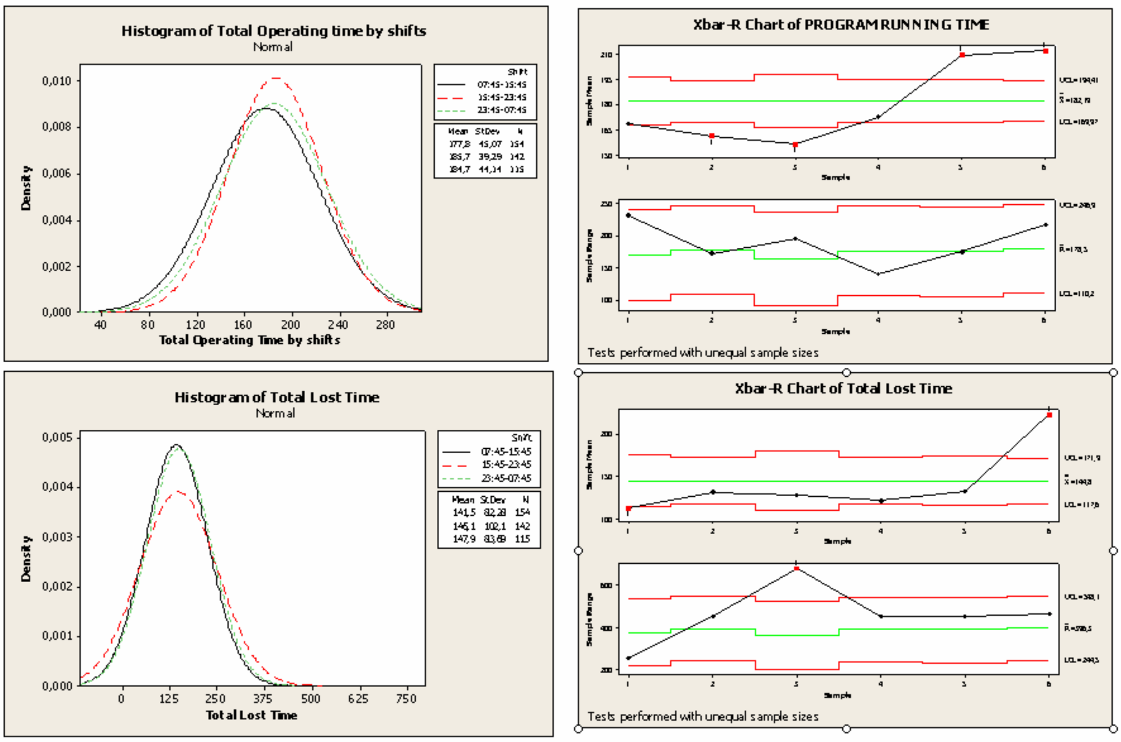

Fig 4.21: Histogram of Total Operating Time and Total Lost Time by shift and Xbar-R Chart of Total Operating Time and Total Lost Time by shift

4.13 OEE CALCULATION

	Equipment Losses				Speed Losses																
Month	Preventive Maintenance (min)	Breakdown	Electricity	Air Pressure	Shift Change (min)	Loading & Unloading Time (min)	Tea Break (min)	Cleaning (min)	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1014	1015	Service
12	646	0	465	0	900	1201	3600	900	0	60	0	0	0	0	0	0	0	0	150	0	0
1	806	255	1875	30	1155	1613	4620	1155	0	0	0	0	0	0	0	0	0	0	0	0	120
2	569	315	0	75	780	1173	3120	780	0	675	60	0	0	0	0	0	0	0	90	150	0
3	822	0	1010	200	1065	1535	4260	1065	0	120	0	0	0	0	0	0	0	0	196	0	0
4	996	60	0	135	1230	1917	4920	1230	1376	115	271	156	5	12	0	216	18	95	450	170	45
5	699	1490	228	62	1125	1970	4500	1125	3018	510	1056	296	30	119	0	778	0	195	62	1015	270

Month	Power on time (min)	Program Running Time (min)	# of cubs produced	# of sheet punched	# of cubs targeted	Availability -A-	Performance efficiency -E-	Rate of quality products - R -	OEE	Target
12	27735	9946	101	1201	200	**96%**	**51%**	**100,00%**	**48%**	85%
1	35540	12236	135	1613	250	**92%**	**54%**	**100,00%**	**49%**	85%
2	24045	8175	93	1173	200	**96%**	**47%**	**100,00%**	**45%**	85%
3	33008	11909	137	1535	200	**94%**	**69%**	**100,00%**	**64%**	85%
4	38007	17081	210	1917	242	**97%**	**87%**	**100,00%**	**84%**	85%
5	34873	15445	207	1970	200	**93%**	**103%**	**100,00%**	**96%**	85%

Table 4.94: OEE Calculation

Calculating OEE for MWS; (Table 4.9)

1. Preventive Maintenance, Breakdown, electricity cut outs, lack of air pressure times effects the availability of the machine. Which are equipment losses.

For April if we calculate the availability;

A = (T/ P) X 100 = [(P- D) / P] X 100

P = Planned operating time = **38007 min**

D = Downtime due to equipment failures, setups and adjustment =
= 996min+60min+0 min+135 min= **1191 min**

T = Total Operating time = (P- D) =38007 min – 1191 min = **36816 min**

A = (T/ P) X 100 = [(P- D) / P] X 100

A = (36816 min / 38007 min) X100 = 97%

A = 97%

2. Performance efficiency is calculated by # of cubicles that produced into the related week. It is the ratio of produced cubicles and targeted cubicles.

E= Performance efficiency,

C= Therotical cycle time = **242 cubicles** was targeted

N= Production amount = **210 cubicles** was produced

E = (210 cub / 242 cub) X 100 = 87%

E = 87%

3. We didn't take into account the rate of quality, because the detected part percentage was about 0,01% level.

R = [(N- Q) / N] X 100

R= rate of quality products
Q= Number of nonconformities
Defected parts were not taken into account, because the level of defected parts was 0,001 %.
R = 100 %

OEE for April;

OEE = A x E x R = 97% x 87% x 100% = 84%

In the Fig 4-22 shows us the OEE trend by month.

Fig 4-22 OEE Trend by month

5. SUMMARY

In this study Overall Equipment Efficiency (OEE) implementation wasn't the only way used for increasing the productivity, firstly applying 5S principles on the shop floor minimized the idle time at each process, people had cleaned their workstations and organized work shop. And the motivation effect on the employees was impressive. Implementation 5S helped us to organize the work environment, and give a clear process flow to the employees, also helped the increase the productivity. During the study we share all the information related the company performance, the workshop's performance with control chart and graphs on visual display boards. The improvement they see also made them to do better and motivate the people.

The important thing for implementing any improvement method in companies is to understand the need of total participation of all employees.

MWS had more then 100 percent improvement on the output and choosen as a benchmark sheet metal factory between the Primary Distribution Swithgear (PDS) sheet metal factories in AREVA TD.

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