CHAPTER – 4 INTEGRATING LEAN TOOLS AND TECHNIQUES IN PLANT MAINTENANCE FUNCTION

Chapter Summary

The “Integrating Lean tools and techniques in Plant Maintenance function” explains the identification of lean tools and techniques related to Plant maintenance function and development of lean maintenance model.

4.0 Lean Philosophy:

Womack and Jones (1996) describe the business environment within which they saw Lean techniques being successful. Five key principles are

- Value
- Value Stream
- Flow
- Pull
- Perfection

4.1 Value

Business focus is on market and market is of customers, without them business cannot be exist. Understanding the requirements of customer through the needs is the key element and the strategy of business. In the first principle of Lean, Value defines from the customer needs and then the same will be deployed across the business organization. The value adding activities are the activities where customer is willing to pay for and it can be recognized through enlightening the customer.
A general ballpark figure shows that in a typical manufacturing industry the value-adding accounts is less than 5% of the total time a manufacturing time. It is terrible to believe that 95% of the time is spent adding costs to the manufacturing process. Even more alarming thing is such wastes are present in every activity of the manufacturing process starting from supplier; to distribution point till the product reaches. These wastes are unavoidable in both internal and external process flow.

The traditional Lean seven types of Muda are:

- Overproduction
- Inventory
- Over Processing
- Motion
- Defects
- Waiting
- Transportation

The key lean tools and techniques for understanding the value is

- **Listening to the customer (Voice of the Customer)**

### 4.2 Value Stream

Once value is identified, identifying the value stream is the next step. The process steps of the value stream are to identify each and every steps of the specific product flow. The key technique and methodology used in the value stream is process activity mapping. The process activity mapping at a strategic level defines what has to be done. Value stream mapping is uses at a more tactical level for identifying Muda present in a particular process and show a way to improve the operational efficiency.
The value stream map is used to both illustrate the “current state” and the desired “future state” of the process. The map highlights the seven types of Muda mentioned above and is used to provide a basis for developing plans to implement lean tools and techniques.

The key lean tools and techniques used in Lean principle practicing organization for implementation are

- **Value Stream Map**
- **Waste Elimination**

### 4.3 Flow

Lean organizations are concerned with systematic material flow with higher inventory turns by eliminating the material idling, queuing and stagnating in the process. They ensure proper material flow in the process by reducing / eliminating all wastes in the process. Flow ensures the processes from raw material to finish product completes without any type of obstructions, delays and waste. Flow also ensures single piece flow in each and every process with smooth work flow between processes by increased flexibility. Flow focus on product First time right. It ensures the process alignment with customer needs.

The key lean tools and techniques used in Lean principle practicing organization for implementing Flow are:

- **Heijunka**
- **Standardized Work**

### 4.4 Pull

The strategic level Pull system identifies the needs of the customer and helps to improve on-time delivery of the product. Kanban helps to derive the pull system. The Kanban is a tool that gives the visual indication of production / withdrawal of material informations to the upstream process. The Kanban is the heart of Flow, without which materials cannot move in between the processes. The necessity of the Pull system is to have materials available whenever required. The inventory
of the material is maintained internally and externally with the suppliers as buffer stock to replenish whenever there is a trigger for replenishment.

The key objective of Pull system is to pull the material and process as per customer required date. The tool used in Lean principle practicing organization for implementation is

- **Material Control – “KANBAN”**

### 4.5 Perfection

Once the processes are set improvements are made, it is mandate that the processes set and improvements made in the processes are to be maintained with the standards. Adherence to this standard will ensure the sustenance of the improved processes and bring improvement for the future. The organization must understand the importance for understanding the transformation to Lean through a continuous improvement process.

The Key tool used in Lean principle practicing organization for implementation is

- **Jidoka**
- **Visual Control System**
- **Kaizen**
- **TPM**
4.6 **Lean principle / Philosophy with applicable Lean tools and techniques**

As per the study of Lean principle, some of the commonly practiced lean tools and techniques were identified from Lean principle practicing organization, expert through the research survey and shown in the table – 4.1

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<tr>
<th>S. No</th>
<th>Lean Principles / Philosophy</th>
<th>Applicable tools &amp; techniques (Data collected from research survey)</th>
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<td>6. Material Control – Kanban</td>
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<td>10. Total Productive Maintenance</td>
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*Table – 4.1 Lean principle / Philosophy with applicable Lean tools and techniques*
Value stream mapping (VSM) is considered as the basic tool for management for starting the lean operation along with 5S methodology which is absolutely necessary for the organization as a foundation for improvements. Recently 5S has taken an update with an addition of safety to refer it as 6S. Safety should be at the frontline of the organizational activities to keep the work place disciplined spic & span and to create a safe working ambiance.

Discipline and safe working ambiance is the greatest benefit from a 6S program. Standardization work areas will give the benefit of reducing cycle times with cost efficiency and reduced motion which has a direct impact on wastes reduction towards transportation and inventory. An ideal plant layout other with single piece flow including the raw material in and finished goods out of the plant in-line with pull system.
4.7 Lean Tools and Techniques in Plant Maintenance function for improving Internal Customer Satisfaction

Identified lean tools & techniques from the lean principles are plotted with common maintenance practices for improving the internal customer satisfaction shown in figure – 4.2

Figure – 4.2 Lean Tools and Techniques in Plant Maintenance function for improving Internal Customer Satisfaction
4.8 Lean Tools and Techniques

4.8.1 Voice of the customer:

Listening to the customer will give an opportunity to fulfill the customer requirement. Working close to the customer will make the needs loud and clear and brings the culture of working together. It will also create a direct relationship resulting in customer relationship which also improves the customer satisfaction. Hence,

*Voice of the customer has a direct effect on internal customer satisfaction*

4.8.2 Kaizen:

**Kaizen** is a Japanese term that means continuous improvement, it is derived from the words 'Kai', which means continuous and 'zen' which means improvement. Some translate 'Kai' to mean change and 'zen' to mean good, or for the better. So, Kaizen is defined a “Continuous Improvement” or “Change for better”.

In an organization employees’ perform their work with the given standards which is imposed by management team. Improving the standard for benefits is defined as Improvement. The process of improvement has to be continuous in the organization for establishing the higher level of standards. Management’s core responsibility is to review and maintain the revised standards. The management has to motivate the employees for involving in the continuous improvement for achieving the organization’s higher level of standards.

In most of the organization these improvement are executed by the supervisory and manager level people and the bottom level employee who will be unskilled will be working the machinery will spend his time only in machine operation and follow the instructions of the supervisor without adding value for the organizational standards. The higher up the manager is, the more he is concerned with improvement. As he become more skilled and proficient in his work he will start think on need based improvement for improving the process through small improvements by involving themselves in suggestions and kaizens. Most of these suggestions and kaizen will
reflect in the improvement of quality and productivity. When the employees start involving in kaizen based activities they eventually identify more opportunities for improvements.

Problem always comes with a solution and opportunities for improvement hidden behind it; kaizen is the best tool which will identify the solutions and brings opportunities for improving the process. In a simple word, where there are no problems, there are no opportunities for improvement. A problem in the process always creates hurdles to the downstream people, to the next process or to the end customers. Kaizen concept will help in improving the process, setting the process and creating a new process.

Improvement can be process if there is an activity or a process. The starting point for any improvement is identifying the current state. There should be indicators for measuring the performance standards of employees, machineries, and processes. Kaizen strategy works with continual improvement process. For Kaizen, standards exist only to improve the existing standards for creating the better standards. Kaizen always work with constant upgrading and revision.

Kaizen covers the entire business processes, starting with monitoring the shop floor process and focuses on the improvements in the machinery and assets which reflects in the improvements in systems and procedures. It is necessary that top management properly understand the employees’ role in Kaizen and support each and every opportunity for improvement. Suggestion system is the best engine to drive kaizen in the organization. This system works with minor improvements in the work place and does not carry forward huge cost for implementing the same. It is the morale boosting tool for the organization for making employees to feel proud on his improvements. Morale is improved through Kaizen activities as every employee in the team will be involved to masters the art of solving immediate problems.

The starting point of the Kaizen is creating a positive attitude in employees for changing and improving the working process. The standard has to be revised whenever there is an implemented suggestion or a kaizen in the process. The team of employees who implemented the
improvement in their process will take his pride and follow the revised standards and avoid violation of the standards.

Kaizen always generates process-oriented thinking as processes have to be improved before getting the improved results. Kaizen is always people-oriented and will work with people's efforts. Hence,

**KI 1:** +  - *Kaizen has a positive effect on Inventory Management*

**KE 2:** +  - *Kaizen has a positive effect on Equipment Management*

**KEHS 3:** +  - *Kaizen has a positive effect on Environmental, Health and Safety Management*

**KP 4:** +  - *Kaizen has a positive effect on People Management*

*Figure – 4.3 Correlations between Kaizen and Common Maintenance Activities*
4.8.3 Visual Control System (VCS):

Visual control system is the tool of visual aid or device which promotes safer, efficient, and reduces wastes in the processes. "Status at a glance" is the key motto of visual management system. The purpose of visual control system is to identify normal vs. abnormal in the operating environment and the detection of abnormality will be easier.

The visual management can be in the form of a chart or a poster and also with colour coding like Red, Yellow and Green which will provide excellent visual signals; the color scheme concept is used in real time in our day to day activities.

Types of visuals boards

- Office board
- Plant board
- Value Stream board
- Team board
- Sign board

Office Boards

An office board is one of the visual boards used in a department like Purchasing, Engineering, Finance, HR and Administration. This board will measure the key performance of their departments against the set goals; hence the visual board is used in entire department to create an situation for employees to participate in improvements and other departments can understand the performance of the specific department and the focus on improvements and the need of other department support for getting the same benefits.
Plant Boards

A plant board is used in the manufacturing area which represents all the value streams within the entire plant. It helps in giving a glance of the processes where it stands on the important measures and the need of actions. The key purpose of the plant board is to serve as a real-time tool. The plant board shows the performance matrices against the set goal and the result and also identifies opportunities for improvement in the processes. It also helps in identifying the process owner of the respective process.

Value Stream Boards

Value stream board focuses on managing by product or customer instead of managing the departments. Managing through value stream has the following advantages:

- Covers entire picture
- Focuses on customer or product instead of departments
- Gives clear quality and cost responsibility of products
- Gives complete picture of customer requirements

Team Boards

A Team board is shows the daily update and tracks what is within a team’s control. A team is a small group of people performs similar job or as a functions. The responsibility of updating the team board is with the team leaders on daily basis and shows the matrices of Productivity, quality, On Time Delivery, attendance, Safety performance and so on.

Visual management tools are used to:

- Give a status at quick glance, and easy detection of abnormalities in operating conditions
• Gives visual aids to help employees complete tasks in time and identify improvements in more standardized approach

Sign Boards

Visual management system creates a standard work environment by providing instructions with Dos and Don’ts in the respective area with safety precautions and standard operating procedure of the specific task. The visual management can be extensively used in our day to day activities from home to the work area. As on today we live with the visual management system in our real time.

From traffic sign, to painted aisles for road crossing, to dial indicators on our vehicle, visual sign boards to show the directions with distance are the basic applications of visual management exist in our real time environment. The key purpose of the visuals is to use it creatively to reduce non value adding activities in our process. Some common visual management techniques include:

• Colour Coding
• Pictures/Graphics
• Kanban Cards
• Colour Lines
• Signage
• Labelling
• Control Boards
• Area Information Boards
• Gages, Dials, etc.
• Checklists

Visual management tools can be used as an error-proofing device or a measures and can be applied in vast areas as per the creativity of the employees. From home to the office and to the factory floor visual management can be used as a problem solving tool. Visual management system helps in identifying or generating improvements in the form of Kaizens. To have a clear understanding on application of visual management, look at the applications at airports,
highways, shopping malls, departmental stores, and libraries. Visual indications are the excellent visual management techniques. Hence,

**VI 5:** +  - Visual Control system has a positive effect on Inventory Management

**VE 6:** +  - Visual Control system has a positive effect on Equipment Management

**VEHS 7:** +  - Visual Control system has a positive effect on Environmental, Health and Safety Management

**VP 8:** +  - Visual Control system has a positive effect on People Management

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**Figure – 4.4 Correlations between Visual Control System and Common Maintenance Activities**
4.8.4 Total Productive Maintenance (TPM):

Total Productive Maintenance is considered as the medical science of the equipment. TPM is a proven and latest maintenance program for improving the life cycle of the equipment. TPM program is implemented to eliminate Breakdown, Accidents and Defects of the equipment. TPM program increase productivity by up keeping the equipment and equipment safety increasing employee morale and job satisfaction.

TPM is a powerful program for improving the equipment life cycle, to improve the product quality and to improve the overall equipment efficiency. Equipment abnormalities are identified “proactively” and the maintenance schedules can be planned before the failure or a breakdown. Maintenance technicians can be effectively utilized for the value addition activities and for improvement activities as the equipment reliability will be high and can predict abnormalities before failure.

TPM creates a cultural change in the organization and the operators will be given the ownership of the equipment which he operates and the maintenance team will assist them in special programs like training the operator in equipment, daily maintenance which need to be carried out by the operator and focuses on equipment reliability and life cycle management.

The main goal is TPM is to eliminate “ABCD” are

- Zero Accident
- Zero Breakdowns
- Minimal Cost
- Zero Defect
TPM program encourages all personnel to involve in continuous improvement activities and create an opportunity to align employees towards common set of values and behaviors on the shop floor.

TPM is a Top down approach with the common business agenda in-line with customer focus. The agenda is supported by a structured management process to improve equipment efficiency, Zero defects, improve on time delivery, reduced costs, and Zero incidents. TPM program is extensively used for cultural transformation of the organization.

TPM is a quality tool to deploy in a manufacturing organization of any size. TPM helps organization to systematically identify and reduce the hidden losses in the process by providing attention to detail in each and every process.

TPM is a Continuous Improvement process that focuses on maximization of equipment efficiency by creating relationship between people, processes and equipment. It has five principles:

- Increase the Overall Equipment Effectiveness (OEE) through focused improvement.
- Make front line Asset Care part of the job.
- Improve existing planned maintenance systems and the quality of maintenance.
- Increase hand/operational skills and team working and problem solving skills.
- Early Equipment Management: Involve operators and maintainers in the next generation of equipment design (TPM for Design).

TPM is directly applied to the shop floor for providing visibility on six major losses which improves the equipment performance. The key matrix for eliminating equipment losses is Overall Equipment Effectiveness (OEE).
The TPM process must be led by manufacturing and encourages production and maintenance departments to work in harmony as a team, with the goal of increasing equipment effectiveness and in turn the organization’s profitability. Hence,

**TE 9:** + - Total Productive Maintenance has a positive effect on Equipment Management

**TEHS 10:** + - Total Productive Maintenance has a positive effect on Environmental, Health and Safety Management

**TP 11:** + - Total Productive Maintenance has a positive effect on People Management

*Figure – 4.5 Correlations between Total Productive Maintenance and Common Maintenance Activities*
4.8.5 Waste Elimination:

Lean manufacturing is a systematic approach for identifying and reducing/eliminating waste in operations through continuous improvement for doing everything more efficiently, reducing the cost of operating the system and fulfilling the customers desire for maximum value at the lowest price.

Muda is one of the principles of Lean manufacturing which means Non value adding activities or Waste. Anything which does not add value to the process and customer is not willing to pay for Muda. Muda increases the costs of products and service without adding value to it. Taiichi Ohno classified Muda into seven types:

1. Defect/rework
2. Over production
3. Inventory/Work in progress (WIP)
4. Over processing
5. Unnecessary motion/movement
6. Excessive transportation of parts
7. Waiting for people/material

Defect/rework

Defect/rework are defined as the product non conformance.

Time spends on manufacturing a product and if the product failed to meet the standards then the additional time of spend on correcting the non conformity.

Over production

Manufacturing the products that are not required immediately is over production. Manufacturing extra units to the real quantity needed are waste. Time spend on manufacturing, machine time and operator time are wasteful.
**Unnecessary Inventory**

Unnecessary Inventory is referred as work in progress (WIP), it is an impact of overproduction and waiting.

**Over processing**

Over processing is over doing / processing in the process, product and design which customer not required and not specified in the requirement. As the activity is excess it is considered as a wasteful activity. Excess material finish which is not required and is not essential, or using extra components or parts that are not really needed or designing in futures where the customers don’t use and will not pay for are all wasteful.

**Unnecessary motion/movement**

There are lots of area where operators can perform non value adding activities in performing daily routines like moving around the process area to pick things up and put them down several times are all wasteful

**Excessive transportation of parts**

Excess WIP can cause excessive transportation of the products or parts where the excess parts needs to be stored away from the process area. The total distance travels of those materials to the process area are unnecessary. Transporting parts from storage area to the process area takes additional time and incurs extra cost. An operator is needed to move the parts to the process area that is taken away from the operator’s value-adding work and the overhead burden increases which will impact in increased lead time of the product.

**Waiting for people**

People waiting for the machine process to complete for loading the next part in the machine, operator waiting for another person to supply the parts they need and operator stops the process for the quality inspector to inspect the part and confirm the process leads to non value addition in operator efficiency due to unscheduled work, excess process time and extra costs.
Waste is any activity that consumes resources and will not deliver value to the customers. In other words, Waste is an activity where customer is not paying for. Everyone agrees that reducing / eliminating wastes in a workplace is a good practice, but gives lack of attention to reduce / eliminate waste with immediate attention. Lean principle emphasizes and gives awareness to the people to realize that waste in the process and the methodology of change things for the better to reduce the waste in the process. Waste reduction / elimination are lean processes. Hence,

**WI 12:** +  - *Waste Elimination has a positive effect on Inventory Management*

**WP 13:** +  - *Waste Elimination has a positive effect on People Management*

*Figure – 4.6 Correlations between Waste Elimination and Common Maintenance Activities*
4.8.6 Heijunka:

Heijunka is a Japanese term means work levelling or Work smoothing. Heijunka is a technique for reducing the Mura which is known as inconsistencies. Heijunka is essential tool for improving production efficiency in the Toyota Production System and Lean Manufacturing. The core idea in Heijunka is to produce goods what is needed now at a constant rate with constant and predictable rate.

When the demand is constant the production can be easily levelled, but when it comes to the real time the demand is set by the customers and there will be a huge fluctuation in demand. To have a balanced demand Lean principle mentions two approached: Demand levelling and production levelling through flexible manufacturing system.

The fluctuation in process increases non value added activities in the production line. The resources and other elements required for production should always build for peak production. This process incurs cost of flexibility.

If the process varies in withdrawal of parts with respect to timing and quality, the range of these fluctuations will increase as they move up the line towards the earlier processes. This is known as demand amplification.

To maintain the customer demand and the delivery, it is important to prevent fluctuation in the final manufacturing line to Zero. Manufacturing line balancing plays a vital role in preventing the line fluctuation and maintains flexibility in the process. One of the key factors which affect the manufacturing line balancing is changeover time. In the lean principle the changeover is improved with the tool Single Minute Exchange of Dies (SMED) and Quick Changeover (QCO) which also called one touch changeover (OTC).
Levelling by volume

If in a family of products that the manufacturer uses the same manufacturing process and the demand varies between 600 and 1200 units then it strengthens a good idea to produce order quantity. Toyota Production System (TPS) views that production systems varying from the required output experiences from Mura and Muri in capacity 'forced' in some periods. So TPS approaches to manufacture the average long-term demand and to carry a proportional inventory as per the demand variability, stability of the manufacturing process and the shipment frequency. So as for the case of manufacturing 600-1200 units, if the manufacturing process were 100% reliable and weekly shipments, then the manufacturing would be 800 with minimum standard inventory of 400 at the start of the week and 1200 during the point of shipment. The benefits of carrying the inventory are to smoothen the manufacturing throughout the manufacturing plant and that reduces the process inventories and simplifies the operations which intern reduces cost.

Leveling by product

The value streams manufacture product mix; hence organization develops a selection of production mix with its sequence. The economic order quantities (EOQ) take place subjected to product changeover and the respective inventories. Toyota Production System (TPS) approach focuses on product lead time reduction through changeover time reduction and changeover cost for reducing the significance of smaller production changeover time and cost. The product leveling with fluctuating demand can be simplified with the help of a visual scheduling management board which is termed as Heijunka box is regularly used for achieving the heijunka efficiencies. The other technique used for Production leveling is level production developed based on heijunka. Once product leveling is achieved then there is another leveling phase known as “Just in Sequence”. In this methodology the production leveling take place at the base level of product manufacturing. During 1980 Toyota achieved the maximum benefits in the vehicle manufacturing and inventory turns with the implementation of level production and lean manufacturing techniques.
If the process or the activity is not leveled proper it will lead to an activity backlog and create a demand which will lead to bottleneck in the process. Bottleneck process is the rate / capacity limiting factor in a production system. Hence,

**HI 14:** +  - *Heijunka has a positive effect on Inventory Management*

**HE 15:** +  - *Heijunka has a positive effect on Equipment Management*

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4.8.7 **Standardized Work:**

Standardized work is the well-organized method in Lean principle for producing the best in class quality product. Standardized work is essential to have in all repeated and critical processes. Standardized work helps in improving the product quality and in improving the Overall Equipment Efficiency (OEE). Standardized work helps in identifying the process abnormalities.

There is a difficulty in implementing the standardized work in handle in high-mix & low volume plants. The high mix & low-volume organizations are trying to implement work standards for all
the products and processes with similar methodology used in high mix & volume plants, developing and analyzing all the necessary documentation might lead to economic failure. Some options for choosing which processes require work standards in high-mix, low-volume plants are listed below

- Work standards can be developed for the top 20% of fast moving products for individual type or family of the products of the group
- Implement one work standard per product family
- General work standards for procedures is written with the inclusion of setups and changeovers, inspection standards, assembling methodology etc., The standards and the process efficiencies can be monitored with the usage of day-by-hour charts
- Work standards parts can be divided into elements from similar groups and can be combined together if found only few work steps are the same in the product family, and then define a standard time and method for each of the processes. The database can be developed to link each part number to its standardized work elements. Employees can access the required and necessary work standards for that process.

Another way is to develop work standards for the processes which have a concern or a problem or any needs are identified in the standard work. For an example, even if the activity starts without any work standards, when there was a quality issues because of improper work sequence, or forgotten work sequence, develop and post the work standard in the process areas. If the process done by two different operators or observed an inefficient process sequence, develop the work standard. Introduction of new process or a tool or an equipment will follow the steps of developing the work standards and train the employees on how to use the tool or an equipment or to work in the change process. Work standards will always require a format or a template to develop with documentation numbers.
Standardized work is an mistake-proofing work methodology; it brings out uniformity in the work process sequence even when different people work at different time. Hence,

\[ SP\ 16: + \quad -\ Standardized\ work\ has\ a\ positive\ effect\ on\ People\ Management \]

**COMMON PLANT MAINTENANCE ACTIVITIES**

*Figure – 4.8 Correlation between Standardized work and People Management*

4.8.8 **Material Control:**

Spare parts Management plays an important role in achieving the desired plant availability at an optimum cost. Presently, the industries are going for capital intensive, mass production oriented and sophisticated technology. The downtime for such plant and machinery is prohibitively expensive. It has been observed in many industries that the non-availability of spare parts, as and when required for repairs, contributes to as much as 50% of the total down time. Also, the cost of spare parts is more than 50% of the total maintenance cost in the industry. It is a paradox to note that the maintenance department is complaining of the non-availability of the spare parts to meet their requirement and finance department is facing the problem of increasing locked up capital in spare parts inventory. This amply signifies the vital importance of spare parts management in any organization.
The objective of spare parts management is to ensure the availability of spares for maintenance and repairs of the plant and machinery as and when required at an optimum cost. Also, the spares should be of right quality.

Every organization should proceed systematically and establish an effective spare parts management system. Codification helps the organization minimizing duplication of spare parts stocking thereby reducing inventory, aids the accounting process and facilitates the computerization of spare parts control systems. The inventory analyses carried out on the basis of different characteristics of the spare parts, such as annual consumption value, criticality, lead time, unit cost and the frequency of use, help the company in establishing suitable policies for selective control. This also helps in focusing our efforts on real problem areas.

A good inventory control system will help systemizing the ordering procedure and also achieving an optimum level of inventory. In addition, selectively efforts should be made to evolve optimum replacement policies for selected spare parts, for which cost of down time and cost of replacement are very high. So, we have to identify such spare parts and carry out the exercise for evolving optimum replacement policies.

For the successful spare parts management, it is essential to analyze the spare parts inventory based on various characteristics such as the frequency of issues, the annual consumption value, the criticality, the lead time and the unit price. This is essential as it would not be possible to exercise the same type of control for all items and it may not really be effective. Inventory analysis aids selection of policies for selective control. Hence,

*MI 17: + Material Control has a positive effect on Inventory Management*
**COMMON PLANT MAINTENANCE ACTIVITIES**

*Figure -4.9 Correlation between Material Control and Inventory Management*

**4.8.9 Value Stream Map (VSM):**

Value Stream Mapping has become accepted preliminary steps to make effective changes towards Lean Manufacturing. Value Stream Mapping helps to identify, demonstrate and decrease waste in the process. Waste being any activity that does not add value to the final product.

It is a graphical tool to pace the flow of material and information from beginning to end, addresses added-value and non added-value activities and streamlines the work processes by using Lean tools. The goal is to identify and decrease the wastes. A Future State Map about how the value should flow will be drawn afterwards. (12 Manage, 2008), (Lean Enterprise Institute, 2009)

Toyota designed VSM with the simple approach to characterize the way the organization works. VSM can be applied to the whole process of the organization throughout the organizational value stream. VSM create a unrestricted process flow eliminating the unnecessary stoppages and interruptions having minimum process losses and waste. VSM illustrates the entire
organizational process flow of the activities and helps to identify the opportunities for the improvements.

Value stream map is divided into two sections information flow and material flow. VSM helps to envisage the work station cycle times, inventory at work station also known as Work in Process (WIP), manpower and information flow across the supply chain. VSM allows the organization to ‘visualize’ the entire process in its current state and desired future state, which gives an indication and give a way to prioritize the improvement projects and close the bridge between the current state and the future state (Lean flow).

VSM is a mapping tool that maps not only material flows but also information flows that signal and control the material flows. This visual representation facilitates the process of lean implementation by identifying the value-adding steps in a value stream and eliminating the non-value-adding steps, or wastes (Muda). VSM focuses on lead time reduction, cycle time reduction, inventory reduction, etc. Hence,

\( VI\, 18: + \quad VSM\, \text{has a positive effect on Inventory Management} \)

**COMMON PLANT MAINTENANCE ACTIVITIES**

*Figure – 4.10 Correlation between VSM and Inventory Management*
4.8.10 **Jidoka:**

*Jidoka* is a Japanese term meaning "mistake-proofing" or "fail-safing". A Poka-Yoke is a methodology in a lean manufacturing process which helps the operator to avoid (yokeru) mistakes (Poka). The purpose of Poka - Yoke is to eliminate the defects arising in the product during manufacturing by corrective and preventing human errors in the processes. The concept was developed and adopted in Toyota Production System (TPS) by Shigeo Shingo. The original terminology described as baka-yoke means "fool proofing" or "idiot-proofing".

Jidoka will be helpful for the individual operator to encounter a problem at their work station. Operators are given responsibilities for correcting the problem in their work stations - if the problem cannot be solved by the operators, they are authorized to stop the line to eliminate the defective part in the line. The principle of Jidoka was first introduced by Sakichi Toyoda at the early 20th century when he invented a loom to stop when the loom when the thread broke.

Jidoka concept was introduced to "Built Quality into the process" or “Built Quality at Source”. The purpose is process inputs are controlled, and to bring ownership to the operators and authority to control the process to be within process control limits. Variations observed outside the process control limits which will be monitored through the devices integrated with the equipment are used to trigger and to stop the process. This contrasts approach is to control the process outputs through measurement, inspection and checking and then to respond for any non-conformance in the process. Most of the cases, Jidoka does not trigger a process 'stop'.

Poka Yoke or mistake proofing is a technique that is part of Jidoka as well as being a standalone tool in its own right. The idea of Poka Yoke is to design the process in such a way that it is impossible to process or create defective materials.

This methodology can be achieved by means of simple template of the component profile in the form of the fixtures which will only accept the right components, dowels pins will helps in showing if any holes missed in the component, simple sensors can be used to check the components present or properly placed in the line assembly.
Since equipment stops when a problem arises, a single operator can visually monitor and efficiently control many machines. As an important tool for this "visual control" or "problem visualization," Toyota plants use a problem display board system called "andon" that allows operators to identify problems in the production line with only a glance. Hence,

\[ JE\ 19: + \quad - \ Jidoka\ has\ a\ positive\ effect\ on\ Equipment\ Management \]

**COMMON PLANT MAINTENANCE ACTIVITIES**

*Figure – 4.11 Correlation between Jidoka and Equipment Management*
4.9 Correlation diagram of Lean Tools & Techniques with Common Plant Maintenance Activity:

The figure – 4.12 shows the correlation of the lean tools and techniques with common maintenance practices in-line with the study done in section 4.8.

Figure – 4.12 Correlation diagram of Lean Tools & Techniques with Common Plant Maintenance Activity
4.10 Lean Maintenance Model fit Analysis:

Primary data was collected through structured questionnaire and interview method from the Lean principle practicing organization. Secondary data was collected from Literature survey. Secondary data provides a better view for correlating the identified lean tools and techniques in the common maintenance practices which is also important in this study to validate the lean tools and techniques. The sample size is 17 Lean principle practicing organization.
4.10.1 Data Analysis and Interpretation:

The Weighted average methodology used for practicing lean tools and techniques in the Lean principle practicing organization as shown in table – 4.2.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Lean tools &amp; Techniques</th>
<th>Practicing</th>
<th>Not Practicing</th>
<th>Total</th>
<th>Score</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Material Control</td>
<td>15</td>
<td>2</td>
<td>17</td>
<td>0.88</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Value Stream Map</td>
<td>16</td>
<td>1</td>
<td>17</td>
<td>0.95</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Heijunka</td>
<td>17</td>
<td>0</td>
<td>17</td>
<td>1.0</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Kaizen</td>
<td>17</td>
<td>0</td>
<td>17</td>
<td>1.0</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Visual Control</td>
<td>15</td>
<td>2</td>
<td>17</td>
<td>0.88</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Waste Elimination</td>
<td>8</td>
<td>9</td>
<td>17</td>
<td>0.47</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Jidoka</td>
<td>14</td>
<td>3</td>
<td>17</td>
<td>0.82</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>TPM</td>
<td>15</td>
<td>2</td>
<td>17</td>
<td>0.88</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Standardized Work</td>
<td>16</td>
<td>1</td>
<td>17</td>
<td>0.95</td>
<td>2</td>
</tr>
</tbody>
</table>

Table – 4.2 Weighted Average table for lean tools and techniques

Inferences: The above Table – 4.2 shows the highest practicing lean tools and techniques in the Lean principle practicing organizations are Heijunka and Kaizen and least practicing lean tools and techniques in Lean principle practicing organization is Waste Elimination.
The identified lean tools and techniques from the Lean principle practicing organization was fitted in the Lean Maintenance model after the correlation check with the each lean tools and techniques in the common maintenance practices. The outcome of the lean tools and techniques are taken for the analysis to check the model fit from the lean principle practicing organization and the result are shown in table – 4.3

<table>
<thead>
<tr>
<th>S. No</th>
<th>Lean tools &amp; Techniques</th>
<th>N</th>
<th>Chi - Square</th>
<th>p - Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Material Control</td>
<td>17</td>
<td>9.94</td>
<td>0.002</td>
</tr>
<tr>
<td>2</td>
<td>Value Stream Map</td>
<td>17</td>
<td>13.23</td>
<td>0.000</td>
</tr>
<tr>
<td>3</td>
<td>Heijunka</td>
<td>17</td>
<td>17</td>
<td>0.000</td>
</tr>
<tr>
<td>4</td>
<td>Kaizen</td>
<td>17</td>
<td>17</td>
<td>0.000</td>
</tr>
<tr>
<td>5</td>
<td>Visual Control</td>
<td>17</td>
<td>9.94</td>
<td>0.002</td>
</tr>
<tr>
<td>6</td>
<td>Waste Elimination</td>
<td>17</td>
<td>0.588</td>
<td>0.808</td>
</tr>
<tr>
<td>7</td>
<td>Jidoka</td>
<td>17</td>
<td>7.11</td>
<td>0.008</td>
</tr>
<tr>
<td>8</td>
<td>TPM</td>
<td>17</td>
<td>9.94</td>
<td>0.002</td>
</tr>
<tr>
<td>9</td>
<td>Standardized Work</td>
<td>17</td>
<td>13.23</td>
<td>0.000</td>
</tr>
</tbody>
</table>

*Table – 4.3 Model fit analysis*
4.10.2 Findings:

It has been found from table – 3 Model fit analysis, the lean tools and techniques of Heijunka and Kaizen has the Chi-square value of 17 and the p-value of 0.000, Value stream map and Standardized work has the Chi-square value of 13.23 and the p-value of 0.000, Jidoka has the Chi-square value of 7.11 and the p-value of 0.008, Material control, Visual control system and TPM has the Chi-square value of 9.94 and the p-value of 0.002. So, the lean tools and techniques of Heijunka, Kaizen, Value stream map, Standardized work, Jidoka, Material control system, Visual control system and TPM which has the p-value of <0.005 fit in the Lean maintenance model. The Waste elimination has the Chi-square value of 0.588 and the p-value of 0.808, has the weakest practicing lean tools and techniques in the lean principle practicing organization. As the Waste elimination is part of the Value Stream Map and it is in practicing of the Lean principle practicing organization it will also considered in the Lean maintenance model as the core concept of Lean principle is Waste elimination.

The Chi-square values and the p-values of the lean tools and techniques with the common maintenance practice practices are shown in figure – 4.13
4.11 Lean Maintenance Model:

The above analysis gives the clear idea to frame a lean maintenance model with the lean tools and techniques in the common maintenance practices for improving the internal customer satisfaction.

In the common maintenance practices of Equipment Management the lean tools and techniques of Kaizen, Visual control system, TPM, Jidoka and Heijunka can be used for improving the needs of the customer like 100% equipment availability and for effective preventive maintenance.

Inventory Management can have the lean tools and techniques of Kaizen, Visual control system, Material control system, Jidoka, Heijunka and Waste elimination to focus and improve the
customer needs of 100% spares availability and for effective and efficient inventory management system.

The other common maintenance practice of Environmental, Health and Safety management covers the lean tools and techniques of Kaizen, Visual control system and TPM which will result in improving the needs of the customer like 100% safe working environment and creating a Zero harm work place.

People management can be covered with the lean tools and techniques of Kaizen, Visual control system, TPM, Waste elimination and Standardized work to fulfil the customer needs of 100% Total employee involvement in work place improvement and to develop multi skilling among the employees.

Accordance with the study and the analysis of the research, the Lean Maintenance model is developed as shown in figure – 4.14. The model is developed in-line with the Voice of the customer through the study and understood the internal customer needs. It covered the effective lean tools and techniques in the common maintenance practices which are adopted in the organizations. Hence, the Lean maintenance model will be useful for the maintenance professional to improve the effectiveness and efficiency of the plant maintenance management.
Figure – 4.14 Lean Maintenance Model with Lean Tools & Techniques for Improving Internal Customer Satisfaction