

# How to Make Maintenance Processes More Efficient Using Lean Tools?

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**Abstract.** This paper discusses the combined issues of lean thinking and maintenance in particular performance indicators to identify the impact of lean thinking within maintenance. Specific attention focuses on the contribution of lean thinking within an organization, the need for maintenance to align itself with the business objectives of the organization, and the need for performance measures to inform of improvement within the organization, and maintenance in particular, through lean tools and activities.

**Keywords:** Human factors · Human-systems integration · Systems engineering

## 1 Introduction

Today, the organizations must be flexible in their operations, capable of producing quality products and delivering the products to the customers with competitive price [1–6]. These demands emphasize the need for high levels of overall system reliability that include the reliability of human resources, machines, equipment, material handling systems, other value adding processes, and management functions throughout the manufacturing system [7–10]. Low productivity, downtime, and poor machine performance is often linked to inadequate plant maintenance, which in turn can lead to reduced production levels, increasing costs, lost market opportunities, and lower profits. These losses have given firms worldwide the motivation to explore and embrace proactive maintenance strategies over the traditional reactive firefighting methods [11–14]. One approach to improve the performance of maintenance processes is to implement lean tools.

The objective of this papers is to identify the different types of maintenance waste evident in the companies and to see how the identified maintenance wastes are reduced or eliminated by the lean tools. The structure of this paper is organized into five sections. The next section is literature on lean thinking review. The third section is literature on maintenance strategies and activities, and lean thinking within the maintenance process, review. The fourth section discusses the maintenance process from lean perspectives. The last section contains a conclusion of the paper and proposals for future research.

## 2 Lean Issues

The philosophy of Lean and its practices have emerged as one of the most successful and widely used systems in today's world. Many researchers have recommended Lean as a very effective system for making an organization better and more capable. Lean can be considered from both a philosophical perspective, related to guiding principles or overarching goals, and from a practical perspective, as a set of management practices, tools, or techniques that can be observed directly [15]. In the book [16] the authors argue that a lean way of thinking allows companies to "specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively". Shah and Ward [17] define lean production as "an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability".

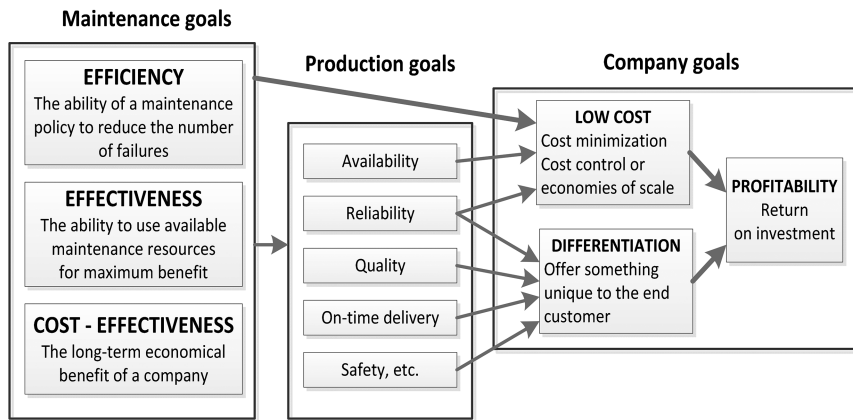
The focus of Lean is about waste elimination. Waste in Lean, is defined as anything that does not add value to the product or service from a customer's perspective [18]. Since waste elimination is one of the Lean objectives, it is crucial for companies to identify wastes relevant to: defects, waiting time, overproduction, transportation, inventory, unused creativity and over processing. To identify the waste and take actions striving for eliminating or limiting them, operational perspective needs to be applied. Lean from an operational perspective involves implementing a set of shop floor tools and techniques aimed at reducing waste within the plant. Such tools and techniques include, for example, setup time reduction, work standardization, kaizen, visual displays (e.g. 5S), Kanban and preventative maintenance.

Although lean manufacturing has its origins in the automobile manufacturing sector, other industries have adopted the practices to improve their own operations [19–23]. Analysis of literature and observation of businesses operations, led to formulation of the following thesis "transition towards a Lean production system requires fundamental changes in the maintenance operations". Lean does not work without highly reliable and predictable machines and processes. A failure in equipment or facilities not only results in loss of productivity, but also in a loss of timely services to customers, and may even lead to safety and environmental problems which destroy the company image. Lean Manufacturing requires equipment to be available on demand. The requirement leads to the revision of the traditional maintenance process in companies.

## 3 Lean Thinking and Maintenance

Companies are seeking to gain competitive advantage with respect to cost, quality, service and on time deliveries. The effect of maintenance on these variables has prompted increased attention to the maintenance areas as an integral part of productivity improvement [24]. The term "maintenance" is defined in standard EN 13306 as the "Combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function (function or a combination of functions of an item which are considered necessary to provide a given service)." By Khairy [25] the key objective of

maintenance is “total asset life cycle optimization” and this objective must be attained in a cost - effective way and in accordance with environmental and safety regulation. Hence, that maintenance management must align with business activities at strategic, tactical, and operational levels [26]. Kans [27] has described maintenance management as activities in order to reach the goals of efficiency, effectiveness and cost-effectiveness in the maintenance area and where the overall goal is to contribute to company’s profitability and competitiveness (Fig. 1).



**Fig. 1.** Connection between maintenance and profitability [27]

Many maintenance strategies have been developed in the last decades and applied to a large array of industries. The interesting classification of maintenance policies is found in [28]. The author describes, from his point of view, the traditional division of maintenance policies into 3 categories: technology oriented (Reliability Centred Maintenance - RCM), human factors oriented (Total Productive Maintenance - TPM) and monitoring and inspection oriented (Condition-Based Maintenance - CBM). The strategies listed above are widely discussed in the literature. However, in the enterprises many “individualized maintenance strategies” refer to “knowledge-based enterprise”. The main objective of such methods is to use the immaterial resources of each organization in order to increase the economic benefit resulting from the construction of a maintenance strategy adapted to the requirements and resources of each organization [29].

Looking at maintenance as a profit center rather than a cost center is fundamental to Lean and promotes the idea of investing in maintenance to achieve a future return in production efficiency. However, most companies are solely focusing on manufacturing efficiency by Lean production tools, but a prerequisite for the success of a Lean manufacturer is the concurrent adoption of Lean maintenance [23].

The concept of lean maintenance, which originated in the manufacturing industry, is known as a systematic approach to identify, analyze and eliminate waste through proper management and continuous improvement. Levitt [30] defined lean maintenance as delivery of maintenance services to customers with as little waste as possible. This promotes achievement of a desirable maintenance outcome with fewest inputs possible.

Inputs include labor, spare parts, tools, energy, capital, and management effort. The gains are improved plant reliability (availability) and improved repeatability of process (less variation). Broader definition was formulated by Ricky Smith [31], he defined Lean Maintenance as a “proactive maintenance operation employing planned and scheduled maintenance activities through total productive maintenance (TPM) practices, using maintenance strategies developed through application of reliability centered maintenance (RCM) decision logic and practiced by empowered (self-directed) action teams using the 5S process, weekly Kaizen improvement events, and autonomous maintenance together with multi-skilled, maintenance technician-performed maintenance through the committed use of their work order system and their computer managed maintenance system (CMMS) or enterprise asset management (EAM) system”.

The fundamental concept of Lean maintenance is to reduce all resource needs (inputs) to the lowest possible level consistent with achieving the desired level of equipment reliability (output). To achieve this goal requires removing waste from all processes and activities. Waste is defined as any resource or activity related to the process that is not contributing value to the end “product”, in this case defined as equipment availability. The biggest losses in maintenance, and thus the biggest improvement opportunities include:

- Manufacturing Reliability (loss in quality, stop times, loss in speed);
- Partnership between Operations – Maintenance – Engineering (reliability and maintenance related design, operator based maintenance);
- Elimination of root cause of the problem (choose problem to eliminate; eliminate problems, educate and teach);
- Storage (reduce the store value at the same time as you preserve service level to maintenance);
- Integration and application of increased knowledge and skills (education and training of crafts people to enable multi craft or multi skills);
- Over maintenance (perform too much and wrong preventive maintenance, perform preventive maintenance before it is needed, do corrective maintenance with higher priority than needed);
- Use of new technology (less need for maintenance, better maintainability, smart tools and methods).

Lean Manufacturing can never achieve the best possible attributes of “Lean” without a Lean Maintenance operation. By definition, Lean means quality and value at the least possible cost. Without maximum equipment reliability - a product of optimized Lean maintenance practices - maximum product quality can never be attained. A manufacturing plant with intentions of implementing Lean Manufacturing should begin with a few essential preparations. One of the most important preparations is the configuration of the maintenance organization to facilitate, first - Lean Maintenance, and next - Lean Manufacturing. The Maintenance function needs to implement plans to integrate and evolve its methods to meet the new demands placed on it by Lean Manufacturing. Lean Thinking can help the Maintenance department to deliver improved departmental performance, lasting change and raise the profile of Maintenance as a value adding function rather than a cost. The efforts of Lean will improve the maintenance “product” quality by lowering measurable process outputs (amount of rework, number of

maintenance-induced failures, and so on). Identifying the customer and focusing on improving quality and lowering cost of the product are common elements to both maintenance and manufacturing.

## **4 Lean Maintenance Tools and Its Effectiveness**

The Maintenance function needs to implement plans to integrate and evolve its methods to meet the new demands placed on it by Lean Manufacturing. A comprehensive lean tools developed for maintenance activities within an organization include VSM, 5S, overall equipment effectiveness (OEE), Kaizen, work standardization TPM, SMED, computer maintenance managed system (CMMS) [32]. The above-mentioned lean maintenance tools are used in enterprises representing different industries, results of tier implementation are evaluated with metrics and indicators of financial and non-financial character. The examples of the implementation of lean tools into maintenance in three different companies representing food industry are presented below. According to numerous studies, the food industry is, together with the automotive industry the sector in which maintenance process is under particular supervision. It is consequence of the fact that the maintenance of machinery and equipment has a direct impact on the health safety of products.

### **4.1 Value Stream Mapping - VSM**

Value stream mapping has supporting methods that are often used in Lean environments to analyze and design flows at the system level (across multiple processes) [33]. Value stream mapping analyzes both material and information flow. By drawing the VSM, the practitioners were able to: visualize and clearly see the entire flow, identify the waste in the value stream, establish the linkage between the information flow and the material flow and understand how the organization will be in the future, if all the improvement activities are implemented properly and if the identified wastes were eliminated or removed. Although value stream mapping is often associated with manufacturing, it is also used in maintenance. Implementation of the tool to maintenance was introduced, among others, in [34]. The example in the Fig. 2 presents breakdown procedure.

Evaluation of the result of the project was presented by non-financial measures (reduction of time), but in operating conditions of the company that measure has a significant impact on the number of goods produced, and therefore money.

### **4.2 5S Practices**

5S practices are a component of lean maintenance which creates room for standardized environment for work, with a focus on waste elimination and involves five steps. Successful application of 5S may provide the following advantages in maintenance: workplaces more efficient, organized, clean, productive and safe; improvement of

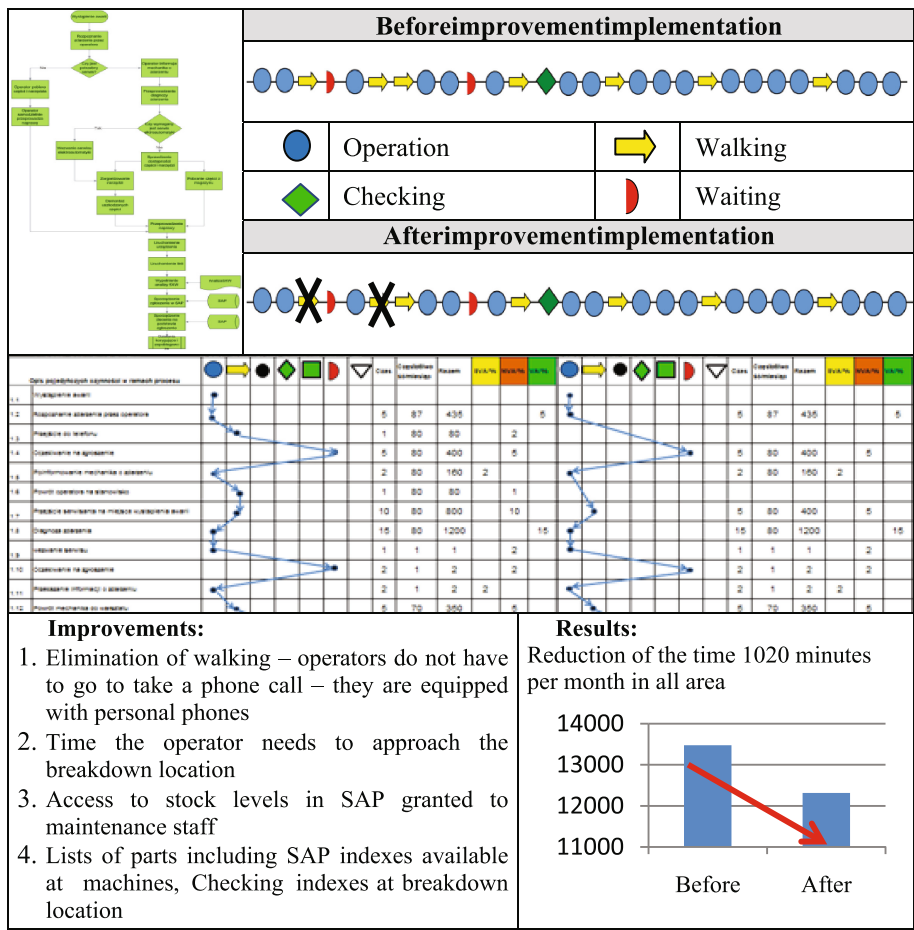
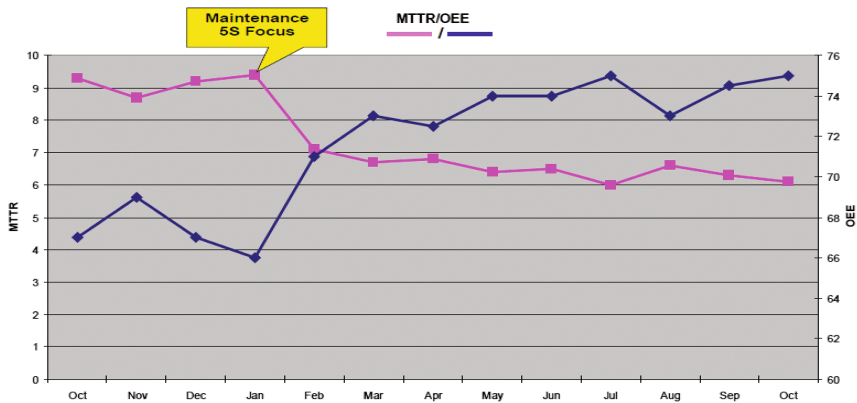


Fig. 2. Value stream mapping - breakdown procedure

working conditions; better view of the problems; reduction of costs, unproductive time, space and movements; and reduction of losses related with failures and breaks.

Introduction of 5S practices into maintenance processes shortens the time of repair (one of the indicators most commonly used to assess the effectiveness of the work of maintenance is MTTR - Mean Time To Repair), which affects the efficiency of production equipment, increasing OEE (Fig. 3).

In the 5S process a key role play visual controls by providing an effective tool to remove clutter and organize the workplace. Visual controls present to the manufacturing operator/maintainer: What the user needs to know; When the user needs to know it; Where the user needs to see it; in a format that is clearly understood by the user. Visual controls are varied and may be specific to a particular production environment. Some examples of visual controls include: graphic visual controls, audio visual controls and automated visual controls.



**Fig. 3.** Relation between MTTR and OEE - example

According to Gupta and Jain [35], 5S is the basic starting tool used to make companies neat and standardized.

### 4.3 Standardization

For many Lean projects, the key to sustainability is standardization of work technique. The standardized work process is designed for the purpose of providing the technician with the current best method to safely and efficiently perform his or her work, at a target quality level set by the organization. In the food industry standardization of activities carried out by operators (e.g. washing a machine) and maintenance staff (repairs, adjustments, etc.) is of particular importance. Identifying places of accumulation of dirt, eliminating places hard to reach from the perspective of maintaining cleanliness and the process itself are actions that reduce the possibility of contamination of the product in its manufacturing process. In companies that benefit from TPM practices within Autonomous Maintenance pillar teams of operators and maintenance staff identify possible places of accumulation of dirt, places difficult to reach and develop standards for cleaning and washing. These standards are the most commonly known under the name One Point Lesson - OPL. Sample procedure shown in Fig. 4.

Lean maintenance activities are only as effective as their sustainability. This implies the need to establish goals, analyze trends and take actions adequate to the situation. Identifying the need to develop OPL is one thing, another, no less important is the content of OPL - how to perform the work contained in the document. A commonly used tool is the PDCA cycle (Deming cycle), which not only systematizes actions of teams working on the reduction of losses and the definition of standards, but also draws attention to the fact that the standard to be effective must lead to repeatable results, regardless of which of employees will use it. Hence the need for trend analysis and the definition of the moment in which sustainability has been reached. An example of an analysis of the effectiveness of measures taken by the AM team towards definition of the standards of cleaning machines in one of the food industry representatives is shown in Fig. 5.

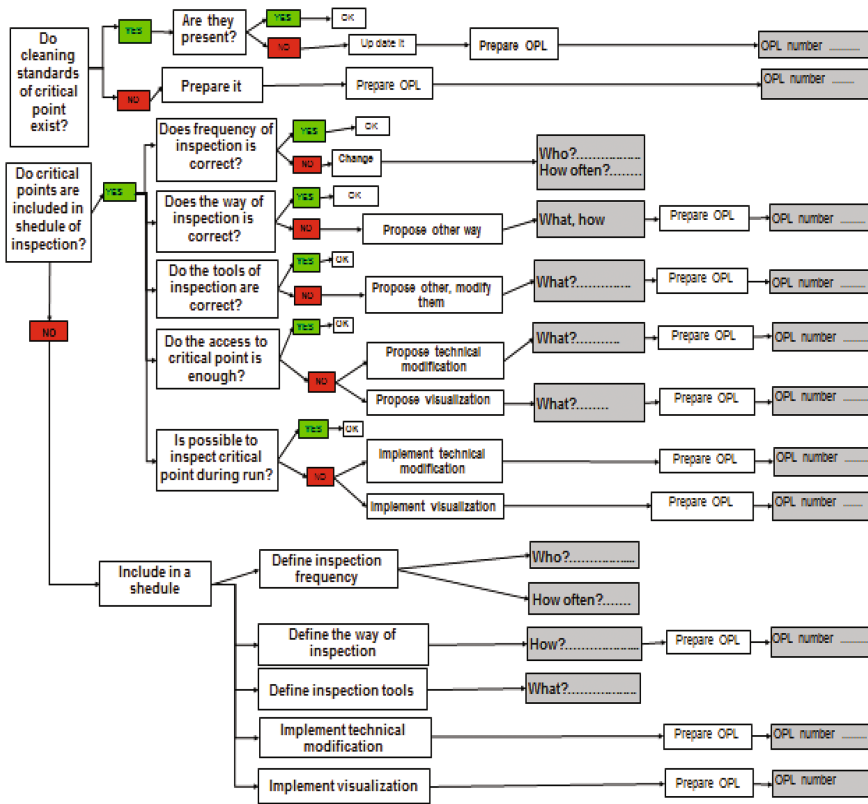


Fig. 4. Critical point analysis sheet - example

Analysis of the trend enables assessment of not only the effectiveness of the actions taken (the goal was to reduce the cleaning time for the machine) but sustainability of results in the longer term. If the effect is maintained over a longer period of time (this time is determined by the team at the planning stage) then the method of implementation can be documented in the form of OPL.

#### 4.4 Total Productive Maintenance

A very foundation of Lean Maintenance is Total Productive Maintenance (TPM). TPM is an initiative for optimizing the reliability and effectiveness of manufacturing equipment. TPM is team-based, proactive maintenance and involves every level and function in the organization, from top executives to the shop floor [5]. TPM addresses the entire production system life cycle and builds a solid, shop-floor-based system to prevent all losses. TPM objectives include the elimination of all accidents, defects and breakdowns. One of the most important pillar of TPM concept is “Autonomous maintenance”. This pillar includes the following issues: team work (operator, mechanic



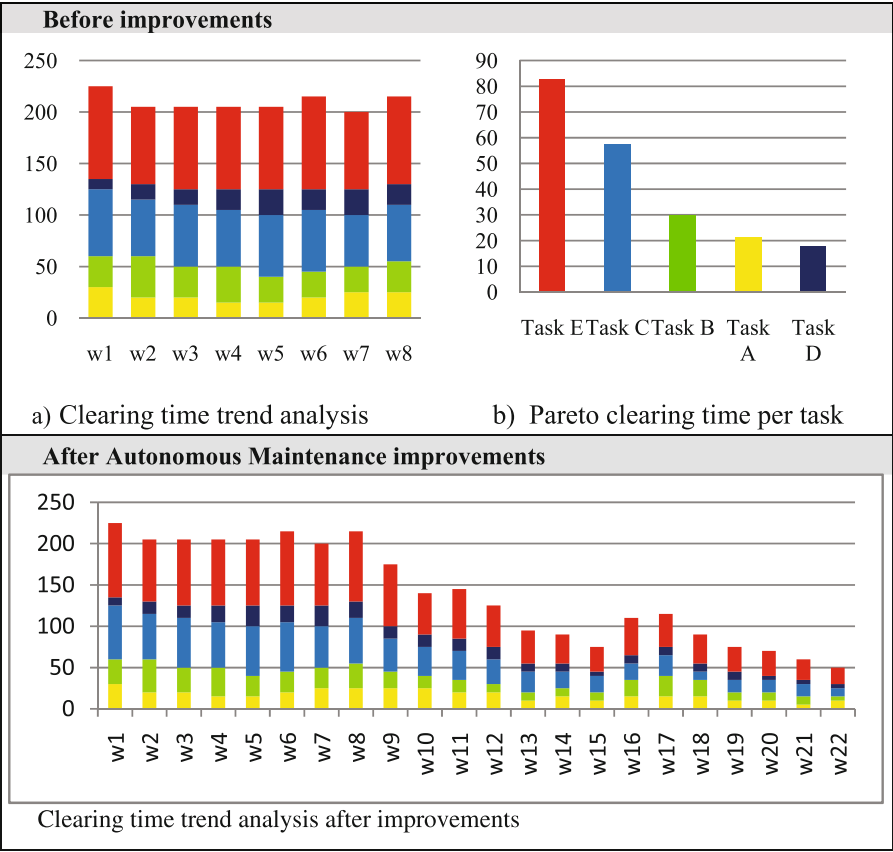


Fig. 5. Clearing time trend analysis before and after improvements

and electrician together take care for machines and other devices to produce high quality products at reasonable costs), bringing optimal work conditions back (installations without defects, easily conservable, clean, operating according to technological and quality specifications), maintain optimal work conditions (systematic inspections, cleaning, planned lubrications). As a result of involving employees in improvement action, a system of initiatives development “Kaizen” is developed. To be successful “Kaizen” requires good leadership, careful planning and good performance measurement system. The measurement of performance is important for both teams of employees who design and implement improvement actions and for managers. The effectiveness of work of teams can be assessed using both measures of financial and non-financial character. An example of such evaluation is shown in the Fig. 6.

The form described above enables the assessment of effectiveness of individual teams involved in activities to improve the maintenance processes. Any action taken by a team is associated with resources and can be treated as a form of investment. Thus, the assessment of these activities from the perspective of ROI is justified.

Potential benefit	Theoretic Performance	Before team	After team	Change	PLN / year	Financial Factor	
	A - Stock value (euro)					Carrying cost %	....
	B - Stock Turnover						
	C - Material Expenses (euro/year)					direct impact	....
	D - Service expenses (euro/year)					direct impact	....
	E - Total task time (man-hours / year)					hour rate maintenance	....
	F - Planned downtime (Hour/year)					planned down cost	....
	G - Breakdown time (Hour/year)					unplanned down cost	....
	Cost: Man-hours used in team					hour rate team members	....
<b>Return On Investment</b> = .....							

Fig. 6. The effectiveness of work of teams evaluation - example

## 5 Conclusion

Nowadays every company aims to increase, or at least sustain, their profitability by controlling and reducing production costs. The Maintenance department and maintenance service it provides don't exist in isolation to the rest of the business – it is part of a system. Maintenance activity is a fundamental pillar sustaining product high standards and plant availability. Without this viewpoint, the maintenance results remain restricted to the performance of each action, losing the overall perspective.

Maintenance influences and is influenced by Lean Manufacturing. The impact of Maintenance on Lean Manufacturing is its ability to improve the value adding capability by delivering: (1) stabilized performance to reduce unplanned events and waste and (2) optimized performance to reduce quality defects, cost and delivery lead times. The Impact of Lean Thinking on Maintenance is its tools to guide the reduction of waste and non-value added maintenance activities i.e. stabilize and extend component life by controlling contamination and minimizing human error; analyze and remove unnecessary maintenance procedures; developing standard countermeasures to common problems; reduce time to repair; engage operators in asset care and improve ease of inspection and early problem detection.

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