Lean maintenance
(case study: Teen Dairy Industry Co.)

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ABSTRACT: The paper is aimed to briefly investigate lean maintenance. We have collected necessary data through local survey. Then, validity of the questionnaire was reviewed and approved by industry and academia experts; its reliability was also confirmed by Cronbach's alpha. Later, data was analyzed by SPSS software package. Additionally, the research hypotheses have been examined by using t-test in the case study on Teen Dairy Industry Co. (aka Damdaran Co.). Finally, the results indicate that the selected measures were approved.

Keywords: Maintenance; Lean Production; Lean Maintenance

INTRODUCTION

With the fast growing industries and intense competition in recent decades, the organizations are in seek to apply the methods and techniques which lead to increase in production, quality improvement, and above all customer satisfaction among the other things.

However, many factors could contribute greatly to the success or failure of organizations, such as availability of sufficient capital, high quality raw materials, reducing the maximum defects and faults, and so on; in general, maintenance issue is the most important and main factor of success for manufacturing and production organizations.

Note that what makes net system necessary in a plant along with above mentioned is a role which plays in determining the amount of production and decreasing costs, - i.e. lost profits due to failure of devices and machinery in the production process.

The necessary role of a comprehensive net system will be highlighted in plants where have continuous and integrated production system, because failure of one or more devices and machinery could lead them to hinder in the production process of one or more parts resulting in delay and deviation from the intended production plan.

Since 2010s, most of production organizations have adopted lean production strategies to enhance their global competitiveness. Further, most of them have used significant measures and factors to progress in the implementation of lean production. However, some of them also have been successful in planning the measures of lean production in various aspects of their business activities such as supply chain, net, and so on. Their efforts also led to the creation of lean thinking and lean organization in all activities of the organization (Bruun, Mefford, 2004). This system is aimed to minimize losses while maximizing resource efficiency.

Overview on philosophical basics

Maintenance

Normal everyday activities such as cleaning, inspection, lubrication and adjustment are those mostly performed for the maintenance of the equipments and their routine conditions. In fact, it is during such those tasks when the possible or existing defects and faults might be detected and eliminated. In general, those tasks involve regular and expected maintenance and repair. This practice is very similar to human life as we know that the disease could be prevented with complying health care instructions (Charlot, 2007). Maintenance systems affect directly budget and the profitability of the organization; hence, lack of proper maintenance planning in the organization might lead to reduction of equipment useful life (Xiaoning, 2010). A maintenance plan is based on new concepts for the maintenance of equipment and machinery. The main objective of the maintenance plan involves the obvious increase in productivity along with job satisfaction and human issues, as

1 Aka Damdaran co.
productive maintenance plan focuses on various important and critical aspects of the organization; that is while such importance component might has its own process integrated into a organization or a plant; further it could also be intended to minimize the emergency and unexpected repairs (Mun, Park, HoPark, 2010).

The main underlying philosophy of such maintenance is that as long as an equipment is functioning well, it wouldn't need to perform any repair on it. All maintenance and repairs activities such as, inspection, lubrication, cleaning machinery to prevent failures through periodic inspections are known as PM. Monitoring system works through using the new sciences such as audition, oil, vibration tests and analyses among the others (Enaghani, 2009).

**Maintenance types**


**Lean production**

In 1997, the first article has been published on the Toyota Production System. There are issues such as the use of computing system to organize reasonably the production process and also imposing unnecessary costs. Further, it focuses on kanban\(^1\) as being a simple and capable (Reizebos et al., 2009). In 2010s, many organizations have utilized lean production strategies to enhance their global competitiveness all around the world. However, some of them have been successful in planning and implementation of lean production, while it has also been expanded to the many business activities such as supply chain through such those efforts; it is also worth noting that it has led to establishing lean thinking in all aspects of the organization (Bruuna, Mefford, 2004). Notice that this novel attitude in production systems is well-known as "Lean Production" (aka "Lean Manufacturing" or "Lean Enterprise").

It has been firstly proposed in Japan as it makes organizations capable of producing more quickly better quality, inexpensive products than the competitors in the market, meanwhile contributing to the innovation and enhancing the diversity of products. Through lean production systems, multi-skilled workers, multitasking groups, unified communications and fully automatic machines with high flexibility have been utilized to product various products. The study mainly emphasized on efficient use of resources, reducing waste and continuous improvement, thereby reducing the costs and possible defects and faults. Such a system integrates the superior characteristics of a mass production system and an older industrial system into one to produce and deliver a wide range of various products in as shortest time as possible (Charlot, Kennes, and Nadeau, 2007). In general, lean production has several different aspects, including: Just-In-Time (JIT) production, team work, cell production, and so on in a an integrated system which could lead to synergy in the work, and finally producing products required by customers in a as shortest loss of time as possible (Ward, 2003).

Lean production is one of the novel inventions, which has been used to enhance competitive advantage by major American organizations in the global markets as it focuses on the reducing costs by removing non-value-added activities (Rajgopal, and Abdulmalek, 2007). Lean thinking is based mainly on the implementation of lean production basics to reduce losses and thereby costs; it should be also noted that implementation of lean production isn't all we need to achieve the desired result (Browning, and Heath, 2009).

In summary, lean production primarily focuses on reducing costs through eliminating losses and intensity of stored material and goods in the store (Browning, and Ralph D. Heath, 2009).

In a continuous production in seek of reducing needed resources such as direct and indirect staffs, equipments, facilities, space and so on, lean production causes fully perceivable and deep rooted change in the structure and physical factors\(^1\) of future production mode in relation to the traditional, mass production, as well as establishing an integrated production process intended to utilize the maximum capacity and reduce system reliable reserve (Treville, and Antonakis, 2006). Japanese production emphasizes mainly on reducing waste through lean production (Browning, and Heath, 2009). Global production has faced with the need of respondersing the increasing demand on the basis of

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\(^{1}\) Japanese manufacturing system in which the supply of components is regulated by way of an instruction card sent along the production line

\(^{1}\) Physical factors: capacity reduction, supply reliability, variation reduction and changing system
worldwide order (Houshmand, and Jamshidnezhad, 2006). (In general, lean production means working with minimums as its concepts function well when demand is on a constant and predictable basis where there is a trivial separation (Pool Wijngaard, 2001). Lean is a combination of capability of human resources and organizational methods and techniques to achieve highest output with the lowest resources (Abdulmalek, and Rajgopal, 2007). Today, lean production systems have a high competitive market, implied that it responses to needs as quick as possible. Later, we discuss the capacity of lean production to accommodate with demand, culture, region and technology. So people, technology, organizational structure and their interactions should be analyzed deeply. To do so, we need a system approach to cover comprehensively all system parameters (Houshmand, and Jamshidnezhad, 2006). However, many challenges have emerged to in international competition over the past two decades in relation to many manufacturing organization along with adapting to the new approach of production (Shah, and Ward, 2003). Toyota production system has exploited the tools and techniques of lean production for a variety of uses such as Just-In-Time production, productive maintenance, and so on (Abdulmalek and Rajgopal, 2007). In summary, production systems are combined systems involving the interactions among and across various sections and segments of the system.

Consequently, we need a practical approach to present complex issues and problems occurred in the production system. It is worth noting that lean production has been originated when mass production has grown and led to emerging and expanding a novel innovation in the Toyota production system, Japan. Specially, Just-In-Time (JIT) production means distributing material among the production stations with an emphasis on the minimizing the work flow to achieve continuous improvement; as continuous improvement is itself based on two principles, standard work and JIT production (Browning, and Heath, 2009). Moreover, the principle of lean production seeks to improve following matters simultaneously; productivity, quality, and servicing.

However, the distinction between compressive and tensile systems could here explain the material control system. One of the prevalence reasons for tensile system is in which most of production planning is implemented based on the group production, cell production, and team work. Tensile system tries to reduce time efficiency on the plant level, while declining the mean time efficiency to its minimum (Riezebos et al., 2009). In recent years, there is seen as indications of paying more attention to the concept of lean production and in more general sense, lean enterprise. Lean approach particularly focuses on reducing waste or material – consumed (Kathleen, and Roger, 1999). Although in traditional mass production, focus is on enabling based on the higher production capacity at every stage, but there is trend specifically to make inventories useful and eliminate possible or existing problems and ineffective issues in the lean production.

Since lean production emphasizes on production-on-demand, it lowers the consumption volume without any wastes; because problems related to inventories or intermediate products along with other production issues just when there are high material and product inventories might be faced and need to be eliminated. In the traditional mass production, the precautionary reserve creates a balance between the speed and the level at different production processes, while, in lean production, there are controlled processes and no need to precautionary reserve (Marlow, 2003). Being lean is a path to achieve a standardized product based on costs and prices. Consequently, it could contribute to organizations in the competition on the lower prices (Charlot, 2007).

**Lean maintenance**

Lean maintenance is mainly the application of lean principles in the maintenance and repair field. The lean success is in finding efficient ways to eliminate hidden losses which is followed by applying those principles in the net activities, reducing costs, higher quality, and finally, productivity and higher profit.

So, ant fault and defect in the equipment should be examined and analyzed as it could lead to find underlying key causes to prevent future possible similar faults or defects. The planner is responsible to ensure keeping appropriate record of observed faults and defects by assigning codes to them. These codes provide the analytical tools required to solve problems related to the equipments. After eliminating the problem, the planner and net engineer must adjust and modify work procedure, the number of their repetitions, and parts specifications on the basis of obtained results (Enaghanli, 2009). Since failure in equipment and machinery results in loss of the capacity of systems which couldn't be easily compensated, there is felt the need of long-term management commitment and net course of actions for eliminating possible losses along with achieving the necessary lean goals. Indeed, any production system must be towards customer satisfaction (Salleh, 2011).

For competing in the today global economy and enhancing profits, many plants and organizations are moving forward to the lean production, the next step after JIT, strengthening maintenance division, and training among the other things. This method has been evolved since 1977 to reduce set-up time and rework, as well as increasing reliability and performance, and finally improve profitability.

Lean maintenance causes generally reduction in net overload and as a result:
50% reduction in mechanical failure
80% reduction in hydraulic failure of the system
92% reduction in electronic system failure (Cooper, 2007).

Lean net has been started with evaluating and assessing the weaknesses and strengths of maintenance plans. Lean net is dedicated to reducing non-valuable factors as reducing costs by about 30%; additionally, it reduces work hours in net section of the plant by 22% internally. In fact, lean net seeks to remove any losses existing in the net such as inventories, stock parts, rework and so on. Lean net is the lost ring in many plants and organizations which has originated from the basics of lean production concept of Toyota production system. However, lean net means a continuous improvement as a continuing process resulting in more efficiency and reduction of non-concurrence costs (Clark, 2010).

**Research Questions**

3.1. Lean approach reduces losses and rework of maintenance systems in the field of net.
3.2. Lean approach establishes more discipline and order in production environment in analogy with other systems such as TPM.
3.3. Net – related costs (Corrective maintenance) in lean net is lower in analogy with governing on net (net fixed and variable intervals).

**Research scope**

The statistical population consists of 110 managers and experts (industry and university) of Damdaran Co. at the time of study (2011-2012).

**RESEARCH METHOD**

The research method used in this research is descriptive and survey on the basis of experts point of views as we collected information to examine and describe the conditions of net section.

**Data collection**

<table>
<thead>
<tr>
<th>Table 1. data collection</th>
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<tbody>
<tr>
<td>Data and data collection methods</td>
</tr>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
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</table>

**Sample Population**

In various texts, there are generally two major research methods to estimate the sample size:

- Personal estimation
- Calculation estimation

**Personal estimation**

The researcher personally estimates the sample size or determinates it as the percent of the population. Smaller the population, the percents are higher.

<table>
<thead>
<tr>
<th>Table 2. Sample size</th>
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<tbody>
<tr>
<td>Correlation</td>
</tr>
<tr>
<td>experimental</td>
</tr>
<tr>
<td>Descriptive and survey</td>
</tr>
<tr>
<td>Classified population</td>
</tr>
</tbody>
</table>

Sometimes, there is provided bound on sample size which should be considered in the estimation of it to reach non lower sample size.
Validation of questionnaire (validity of measurement)

Validity determines how much the tools measure well the specified concept. In the other words, validity tells us whether the true concept (or specified one) is measured; reliability determines if the test repeated, it will provide the results identical to the past ones. Reliability of the mentioned questionnaire was tested by calculating Chronbach's alpha with SPSS software package equal to 0.783, indicated that it is good.  

Statistics and tables

Table 3 illustrated the frequency and frequency percent of respondents’ education. Since the highest frequency was related to B.S. class (63% of respondents), and lowest one was diploma class (below 5% of respondents).

<table>
<thead>
<tr>
<th>Education</th>
<th>No</th>
<th>Percent</th>
<th>Fc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diplom</td>
<td>6</td>
<td>0.052</td>
<td>0.052</td>
</tr>
<tr>
<td>know-how</td>
<td>14</td>
<td>0.122</td>
<td>0.174</td>
</tr>
<tr>
<td>Bachelor</td>
<td>73</td>
<td>0.635</td>
<td>.809</td>
</tr>
<tr>
<td>Masters and Above</td>
<td>22</td>
<td>0.191</td>
<td>1000</td>
</tr>
</tbody>
</table>

Respondents inferential statistics

Hypothesis 1

H0. Lean approach in the net field won't reduce the amount of losses and rework of maintenance systems.

H1. Lean approach in the net field will reduce the amount of losses and rework of maintenance systems.

<table>
<thead>
<tr>
<th>N</th>
<th>Mean</th>
<th>Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>105</td>
<td>3.29</td>
<td>0.71</td>
</tr>
</tbody>
</table>

As shown in the table 4, H0 is rejected and, as a result, H1 is accepted since calculated t value doesn't fall in related the upper 2.98 at confidence level of 95%.

Investigating 105 questionnaires indicated that the hypothesis that lean approach won't reduce rework is rejected; so it has an effect on reduction of rework.

4 Cronbach's Alpha of more than 0.60 as sufficient to signify the validity of the variables used in the questionnaires.
Hypothesis 2
H0. Lean approach in analogy with other systems such as TRM won't create higher discipline and order in the production environment.
H1. Lean approach in analogy with other systems such as TRM will create higher discipline and order in the production environment.

Table 5. Hypothesis 2

<table>
<thead>
<tr>
<th>N</th>
<th>Mean</th>
<th>Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>5S</td>
<td>.105</td>
<td>2.48</td>
</tr>
<tr>
<td>Lower</td>
<td>Upper</td>
<td></td>
</tr>
<tr>
<td>.98</td>
<td>3.14</td>
<td></td>
</tr>
</tbody>
</table>

As shown in the table 5, H0 is rejected and, as a result, H1 is accepted since calculated t value doesn't fall in related the upper and lower limits (.98-3.14) at confidence level of 95%.

Investigating 105 questionnaires indicated that the hypothesis that lean approach won't create higher discipline and order is rejected; so it has an effect on increasing discipline and order.

Hypothesis 3
H0. Net-related costs (corrective maintenance) of lean net in analogy with other methods governing on net (net fixed and variable intervals) won't be lower.
H1. Net-related costs (corrective maintenance) of lean net in analogy with other methods governing on net (net fixed and variable intervals) will be lower.

Table 6. Hypothesis 3

<table>
<thead>
<tr>
<th>N</th>
<th>Mean</th>
<th>Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>financial</td>
<td>105</td>
<td>4.67</td>
</tr>
</tbody>
</table>

As shown in the table 6 and mentioned in the chapter 1, H0 is rejected and, as a result, H1 is accepted since calculated t value is 13.7 doesn't fall at confidence level of 95%.

Investigating 105 questionnaires indicated that the hypothesis that lean approach won't lower costs on the lean net is rejected; so it has an effect on lowering costs in lean net.

FINDINGS

Calculated test statics (at error level of 5%) indicated that calculated t statics of 9.3 (p = 0.000) fall in the acceptance region of H1. As a result, with the confidence level of 95%, it could be said that observations aren't enough to accept H0, so H1 is approved. Consequently, it is found that calculated p-value is less than 0.05, so H0 is rejects.

In general, applying lean net in the specified organization has an effect on the reduction of rework.

Calculated test statics (at error level of 5%) indicated that calculated t statics of 5.75 (p = 0.000) fall in the acceptance region of H1. As a result, with the confidence level of 95%, it could be said that observations aren't enough to accept H0, so H1 is approved. Consequently, it is found that calculated p-value is less than 0.05, so H0 is rejects.

In general, applying lean net in the specified organization has an effect on increasing discipline and order.

Calculated test statics (at error level of 5%) indicated that calculated t statics of 8.94 (p = 0.000) fall in the acceptance region of H1. As a result, with the confidence level of 95%, it could be said that observations aren't enough to accept H0, so H1 is approved. Consequently, it is found that calculated p-value is less than 0.05, so H0 is rejects.

In general, applying lean net in the specified organization has an effect on the reduction of net-related costs.
RESULTS AND DISCUSSIONS

The main objective of JIT production system could involve a series of well-known principles required for operational success in the organizations which have numerous competitors – in their markets. Those principles are originated from Japan, and then expanded to US for managing inventories. Later, they have also extended to various management aspects such as production and quality managements. As the success of JIT system depends on internal organizational factors, it is also dependent on contribution of external factors such as suppliers and providers of material (Gunasekaran, 2001).

The concepts of continuous improvement or kaizen\(^5\) are at the heart of continuous lean production theory (Qumer, 2008).

If an organization wishes to actually move towards a lean enterprise, it needs to establish strong relations with its counterparts in the supply chain on a continuous infrastructure basis, such as delivery on-demand in a correct amount and at a right time and location. For JIT delivery by suppliers and providers, they should produce in parallel with the need of customers (Amasak, 2007).

Successes in the implementing TPM and lean are critically dependent on training. Trial and error, and problem solving are two abilities which should be considered in the training programs of lean and TPM (Enaghani, 2009).

No organization will move forward to the lean until fully recognizing the need for continuous improvement as the product of enough knowledge; since there must be done the necessary groundwork and the organization is committed to increasing scientific knowledge of its employees.

Remaining in competitive world needs high quality products to have remarkable presence at the domestic and foreign competitive markets.

In summary, lean production is among ideas considered for improving production and reducing wastes. Hypotheses test indicated that all proposed hypotheses in the research were approved in complete compliance with data obtained and analyzed from questionnaires; means that financial, environmental and discipline issues and being lean have positive and significant effects in the implementation and executive lean net.

Generally, results demonstrated that effective implementation and executing the concepts of lean successfully in the net section entail clear understanding and specified definition for the concepts, design and formulating key measures and field coordination as the net unit engages in those concepts and supports them. It is aimed to create actual order in the net unit to achieve more sustainable competitive advantage in the organization by a more effective planning and more value added for the customers.

With calculated t-value of 7.9 and standard error of 2.9 in the 5S hypothesis calculation, it is found that those factors have effects on the workplace environment.

Any task has a permission to spend in PM; that is why it is important to minimize the amount of work and related costs to meet expectations reliably. As it is believed that 1$ of 3$ spent on PM is loss. Therefore, by identifying and eliminating losses, we could release significant cost and time as the main objective of lean net.

Recommendations

For establishing a lean philosophy in the various sections except for production, we try to gradually begin to look forward to implement it for creating significant cultural changes in the organization.

Rigorous and continuous training necessary with commitment to establish fundamental lean measures in the organization at all levels of management and employees. The data analysis indicated that the most important factor in the net section is the lack of training for human resources about new and novel production matters; hence, it is suggested that at first training is provided for employees at various level with the contribution of university professors and industry experts to implement appropriately the mentioned measures.

Future research

It is suggested that smaller variables influencing on the lean net would be selected, and factored to determine which one is superior and has higher influence.

It is proposed to extend the research subject to the producers of other segments for achieving better measures for all organizations.

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\(^5\) Japanese business philosophy stating the necessity for successive and incremental improvement in the personal and professional life of a person.
With a brief study of successful organization in the specified industry, more practical and precise lean concepts and key measures would be achieved for various organizations to be used by managers in implementing and executing lean net.

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