A case study on implementing lean ergonomic manufacturing systems (LEMS) in an automobile industry

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Abstract:

Lean manufacturing is a business strategy developed in Japan. In the present scenario, the global market is developing new techniques for getting more and more production rate with a good quality under low cost. In this context, human factors have to be given importance to their working conditions. This study demonstrates the impact of lean manufacturing system principles on the improvement of organizational performance and the ergonomic conditions of the employees. Here, the author wants to bring an idea about the human well beings, within the continuous improvement process of the industry. The aim of ergonomics is to adapt the new techniques to their work in efficient and safe ways in order to optimize the well being and increasing the production rate. By conducting survey on various disciplines and showed how the production rate and human well being is affected.

Keywords: lean manufacturing systems, ergonomics, ergonomic risk factors, LEMS, organizational performance.

1. Introduction

A widely used tool some time since the 1940 season in order to get a (Lean Production) for a production system Lean Manufacturing is a model that serves to facilitate competitiveness in several segments, aiming to eliminate waste (not Value Added) and also in improving working conditions. For the auto companies when the application of Lean Manufacturing is to be improving production processes from the supplier of raw materials and consumption to its final production of their products. Enabling with some tools to help in this application to a set of activities encompassed with better resources and lower costs.

The Lean Manufacturing opens up a range to insert other tools that aid, such as: (Kaizen, 5 Senses, Poka-Yoke, Takt-Time, Balancing stations or workstations, supply flow of parts and products, Flow Mapping Val ue, Safety, Ergonomics, etc.). In the application of Lean Manufacturing should be made a direct correlation between vision of working conditions with a support tool mentioned the (Ergonomics). Each continuous improvement held in any work environment, this correlation can be carried out in order to adapt the improvements to the executor of activities[17]. The common 8 wastes of lean manufacturing are shown in below fig 1.

Fig.1 Common wastes of lean manufacturing

The main goal of ergonomics is to develop and apply the man adaptation techniques to their work and efficient and safe ways in order to optimize the well-being and thus increasing productivity. The concept of ergonomics applies to the quality of adaptation of a machine to its operator, providing an effective handling and avoiding an effort worker extreme in implementing the work. The repetitive stress injuries (RSI) are the most common physical problems that can cause limitations or inability to work. Using ergonomic solutions in the workplace is an initiative that can significantly increase the levels of satisfaction, efficiency and worker efficiency.

Reviews of numerous researches of ergonomics are using a variety of definitions to describe the concept. Below are the definitions of ergonomics stated by previous authors [11].

Authors	**Definition of ergonomics**
Te-Hsin & Kleiner [14]	Ergonomics is a combination of the words ergo, a Greek word meaning "work" and nomics, meaning "study" - the study of work An applied science that co-ordinates the design of devices, systems and physical working conditions with the capacities and requirements of the workers
Tayyari & Smith [15]	A branch of science that is concerned with the achievement of optimal relationships between workers and their work environment
Lee [10]	Promoting compatibility between humans and systems
Fernandez [4]	The design of the workplace, equipment, machine, tool, product, environment and system, taking into consideration the human's physical, physiological, biomechanical and psychological capabilities and optimizing the effectiveness and productivity of work systems while assuring the safety, health and wellbeing of the workers. In general, the aim in ergonomics is to fit the task to the individual, not the individual to the task.
Brooks [3]	A system of interacting components which includes the worker, the work environment both physical and organizational, the task and the workspace

The commonly highlighted view of the definition of ergonomics as stated above is mainly about the relationship between humans, machine systems, job design and the work environment. Below fig 2, shows the injury type claim counts in an industry, where the ergonomic conditions are not given importance. This is why the author tries to improve and

implement the human well being conditions in an industry to decrease the injuries, accidents to the employees [13].

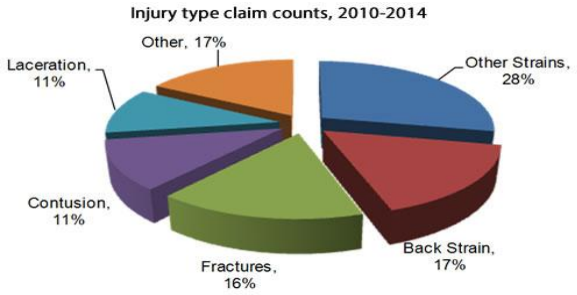


Fig 2. Injury type claim counts

According to Yelin et al.[16], 90% of disabled older workers had musculosketal disorders (MSDs). The treatment of the MSDs problems will cost tens of billions of dollars as stated by Praemer et al. [12].These statements shows that studies on ergonomics is really important to develop the best prevention method of the MSDs which can benefits the employer and also their workers.

The primary ERF are repetition, force, awkward posture, vibration, contact stress, static loading and extreme temperature. Risk factor exposure is an early warning of progressively more serious problems - physical signs and symptoms that can lead to serious injury. Long-term exposure to risk factors will reduce the quality of life. Every job carries risk. The key issue is relative risk.

Organizations and individuals can become better informed to reduce MSD injury risk by being aware of risk factors, becoming skilled in recognizing and categorizing these factors, and examining options to reduce the frequency or duration of exposure to the risk factors. Reducing exposure to risk factors should make the task smoother and more predictable in its outcome. Reducing risk factor exposure should make task performance less variable.

Ergonomics Risk Factors (ERF)

Workplaces traditionally have been designed to move products or support machines efficiently. Since people have always seemed so adaptable, how they fit into the workplace has received less attention. The increasing number of injuries caused by repetitive motion, excessive force and awkward postures, ergonomics has become a critical factor in workplace safety. According to Hagberg et al. [6], ergonomics and human factors are often used interchangeably in workplaces. Both describe the interaction between the worker and the job demands. The difference between them is ergonomics focuses on how work affects workers, and human factors emphasize designs that reduce the potential for human error. While Bongers et al [2] stress that by addressing traditional and environmental risk factors, it can keep workers injury free.

The Ergonomics Risk Factors (ERF) that are discussed in this study are listed below:

Repetition

Repetition rate is defined as the average number of movements or exertions performed by a joint or a body link within a unit of time or performing similar motions with the same body part with little rest or recovery. Repetition could also be defined as performing the same motion or group of motions excessively. This applies to both large muscles and small muscles. Repetition put workers at a higher risk of injury when other risk factors are also present (such as an awkward posture or heavy force). Repeated identical or similar motions performed over a period of time could cause over-extension and overuse of certain muscle groups, which could lead to muscular fatigue. Sometimes, by varying tasks, muscle groups have periods of activity alternated with periods of rest, which may be beneficial in reducing the possibility of injury.

Repetition also is the time quantification of a similar exertion performed during a task. A warehouse worker may lift and place on the floor three boxes per minute; an assembly worker may produce 20 units per hour. Repetitive motion has been associated with injury [15] and worker discomfort. The greater the number of repetitions, the greater the degree of risk. However, the relationship between repetition and degree of injury risk is modified by other risk factors such as force, posture, duration, and recovery time.

Force

. Force can be defined as the amount of physical effort required to perform a task (such as lifting) or to maintain control of equipment or tools. The force that a worker exerts on an object is a primary risk factor. There are three types of activity that require force such as force involved in lifting, lowering, or carrying, force involved in pushing or pulling and grip force. A pinch grip produces 3-5 times more force on the tendons in the wrist than a grip with the whole hand.Using hands instead of a clamp to hold an object while performing a task shows that force occurs..

Generally, the greater the force causes the greater the degree of risk. High force has been associated with risk of injury at the shoulder, neck low back, forearm, wrist and hand. It is important to note that the relationship between force and degree of injury risk is modified by other work risk factors such as posture, acceleration/velocity, repetition, and duration.

Vibration

Vibration may be defined simply as any movement which a body makes about a fixed point. This movement can be regular, like the motion of a weight on the end of a spring, or it can be random. Vibration has been found to be an etiological factor in work environments utilizing tools vibrating in the frequency band of 20 to 80 Hz. For example, use of a chain saw or powered wood working tools for extended periods of time.

Vibration gives effects such as damage caused to body organs as a result of their being buffeted by high vibration levels at relatively low frequencies and breakdown of body tissues due either to continued resonance or to their absorption of high energy vibration. Vibration applied to the hand can cause a vascular insufficiency of the hands/fingers (Raynaud's disease or vibration white finger). Further, a strong association has been reported between carpal tunnel syndrome and segmental vibration. Hand-arm vibration (HAV) is typically associated with

operating power tools. Exposure of the whole body to vibration (usually through the feet/buttocks when riding in a vehicle) has some support as a risk for injury.

Awkward Posture

Awkward posture occurs when any joint of your body bends or twists excessively, outside a comfortable range of motion

Various work activities can result in awkward postures:

i) Leaning sideways, such as when reaching into a low drawer to one side (awkward back posture)

ii) Bending down to work at a low level (awkward back posture)

iii) Reaching overhead (awkward shoulder posture)

iv) Flaring" the elbows out to the side (awkward shoulder posture)

v) Bending the wrist when moving objects or keyboarding (awkward wrist posture)

vi)Bending the neck down, such as looking at small components in poor lighting conditions (awkward neck posture)

vii)Twisting part of the body, such as twisting the neck to view documents while keyboarding for a longtime(awkwardneckposture)

If the position is held long enough for you to feel aches and pains, then your muscles have been held in one position for too long. A posture held for a long time is called a static posture.

Posture is the position of a part of the body relative to an adjacent part as measured by the angle of the joint connecting them. Postural stress is assuming an extreme posture at or near the normal range of motion. For each joint the range of motion is defined by movements that do not require high muscular force or cause undue discomfort. Some postures are shown below fig 3.

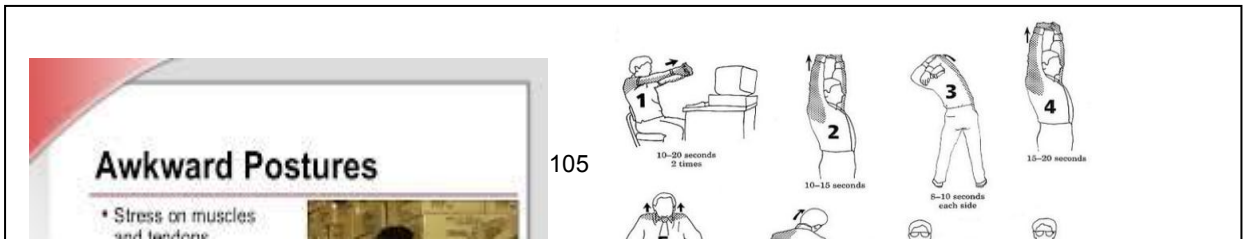


Fig3. Awkward postures

Injury risks increase whenever work requires a person to perform tasks with body segments outside their neutral range in a deviated posture. Awkward posture include repeated or prolonged reaching, twisting, bending, kneeling, squatting, working overhead with your hands or arms, or holding fixed positions.

Working with the arms abducted away from the body, overextended and shoulders hunched places these joints at the end of their normal range of motion, requires higher muscular force and greatly increases the risk for injury. Strained sitting positions, such as tilting sideways, twisting the vertebral column, bending forward or slumping begin in response to compensation for specific work relationships but can become habit over time.

Contact Stress

Contact stresses are defined as impingement or injury by hard, sharp objects, equipment or instruments when grasping, balancing or manipulating. Contact stresses are encountered when working with forearms or wrists against the edge of a desk or work counter. The muscles and tendons are impinged when pressed into the sharp edge. The nerves and the tissues beneath the skin can be injured by the pressure. Here are some examples of activities that can result in local contact stress:

i) Ridges and hard edges on tool handles digging into the hand
ii) Edges of work surfaces digging into the forearm or wrist
iii) Striking objects sharply with the hand, foot, or knee (such as striking the carpet stretcher with the area above the knee when laying carpet)

Extreme Temperature

Extreme temperature can be classified into two that are extremely cold and extremely hot. Cold temperature can be define as a low temperature reduces manual dexterity and accentuate the symptoms of nerve-end impairment. Systemic symptoms that a worker can present when exposed to cold include shivering, clouded consciousness, extremity pain, dilated pupils, and ventricular fibrillation.

Heat stress is the total load the body must accommodate. It is generated externally from environment temperature and internally from human metabolism. Excessive heat can cause heat stroke, a condition that can be life threatening or result in irreversible damage. Less serious conditions associated with excessive heat include heat exhaustion, heat cramps, and heat-related disorders (e.g., dehydration, electrolyte imbalance, loss of physical/mental work capacity).

Static Loading

Our body is built to move about, not to remain still. It is uncomfortable and tiresome having to maintain anybody position without change over extended periods. We experience this discomfort while driving a motor vehicle where the location of the trunk on the seat, of the head in order to see, and of the hands and feet on controls constrains us to a nearly immobile posture. The condition is a combination of force, posture, and duration. The degree of risk is in proportion to the combination of the magnitude of the external resistance, awkwardness of the posture, and duration

2. Lean ergonomic manufacturing systems (LEMS)

This study presented was applied in a factory with production of automotive vehicles installed in the state of Jharkhand, India. And with approximately about 1700 direct employees and three production shifts. The kind acts with the lean production system based on the Toyota Production System. The application of Lean Manufacturing is part of the lean process that organization to eliminate waste and reduce production costs and Ergonomics it is part of the concept of tools that same production system in order to provide good working conditions for employees and consequently the welfare of the same. However, when there is a realization of applicability of tool concepts to seek improvements and cost savings for this Organization, the rule has to be followed according to the methodologies and also following your current Production System. In the application of Lean Manufacturing, the correlation was performed with the tools that help this Production System and were also applied some tools with techniques for achieving results [7].

These are the basic elements of the current Production System: 5'S => The application of the 5 Senses of Japanese origin (Seiri, Seiton, Seiso, Seiketsu and Shitsuke) apply the 5 Senses to reduce waste, and organized work will also reduce the displacements, improving safety, improve team motivation with a pleasant working environment.

Dexterity => You learns the operation of the workplace through training. The Dexterity field allows the repeatability of gestures, which reduces the dispersion of implementation and the risks of non-quality, skill helps streamline operations, improve the fluidity of movement. The relationship with the ergonomics of dexterity is teaching correct posture through training applied to employees.

Standardization => Standardization is the default operation being the best production method at the time, but there is no reason why there is no pattern of change.

Ergonomics => The Production System, Ergonomics is the basis, along with standardization, Dexterity and 5 Senses. They are all interconnected to have a good working condition to the developer, optimize the movements, gestures and movements on one hand, and

to prevent damage, including postures and efforts. Implement effective versatility, according to the principles set out in the dossier of the department record and organize the work of rotation within the posts or stations, taking into account constraints and capacity of operators.

Kaizen => is a method of continuous improvement, particularly suitable to improve the productivity of a workstation, in order to ergonomics thereof. The implementation indirectly helps to promote the flow and the quality of production and standardization, can be effectively applied only, if the area in question has already been normalized.

Just in Time => improvement of a position within a Kaizen site takes into account the flow of components and parts to be assembled and the supply and disposal of the post or centre.

MPM => Media Performance Management, usually in automated lines, leads to reduction causes of malfunctioning. It has a positive impact on the operating income line.

MDT => is a set of methodologies that allows to build and measure the performance of the stations or direct labour workstations, these methods allow the determination of the time required and sufficient for manual operation. It is connected with the standardization of the post or workstation. It allows you to associate the time of Operation Standard, in Factor of Safety analysis and engagement.

QC => Quality and controls to ensure the quality, capacity building and training compliance with the standard, are necessary conditions for improving quality.

PDCA => is an interactive method of four-step management, used for the control and continuous improvement of processes and products. It is also known as the circle / cycle / Deming wheel, Shewhart cycle, circle / cycle control. The Plan is to establish the objectives and processes necessary to deliver results in accordance with the projected (objectives or goals). The Run is to implement the plan, run the process, enables you to develop a plan. The Check is to study the measured and collected a result; compare it against the results look for deviations mainly in the application. The Fix is to take corrective actions on significant differences between actual and planned results. When a pass through these four steps need not result in any improvement, to which the method is applied PDCA can be refined.

VSM => The meaning is the Value Stream Mapping. It is a technique used in lean manufacturing to identify logistics flows (material and information) needed to produce and deliver a product / service. Identification uninterrupted flow value; A value stream is all action (adding value or not); Set product families based on the customer's perspective; Identify demand, in stock and frequency; Identify the main sources or root causes of waste and surpluses, to build the ideal situation; Producing the rate and in accordance with the following process need (takt time) and check the state of continuous flow or pull production system.

After the advent of the production system called "Toyota Production System", began a new way of thinking, with a lean process and without waste and, consequently, reducing costs, without forgetting the worker welfare, improving conditions of their work environment. Through many studies and the emergence of ergonomics after World War II, entrepreneurs and society observed that the condition of well-being in the workplace is directly proportional to productivity and employee effectiveness in carrying out its tasks [9]. Many companies looking to adopt Lean principles, in many different industry

segments, such as aerospace, automotive, consumer products, industrial products and metallurgy, construction, administration [8].

Similarly ergonomics also deals with the human well beings in the working environment of the industry. Similar like the lean manufacturing process, ergonomics also have the various implementation phases in order to be implemented in a right direction. The different phases of the ergonomics are shown in the below fig4.

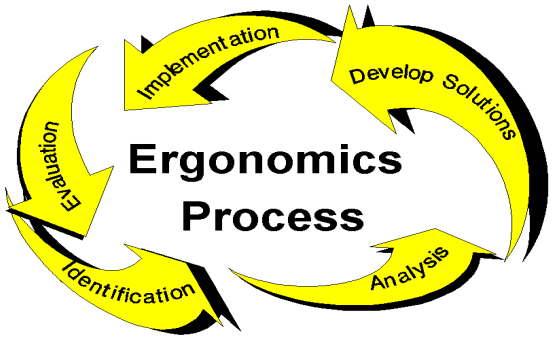


Fig 4. Ergonomic Process

The challenge of the future activity is to provide the space of possible forms to evaluate to what extent the design choices allow the implementation modes operative compatible with the chosen criteria, in terms of health, productive efficiency, personal development, and also about the collective work [4].

A decision support system (DSS) model is defined to help in decision making process in the integration of ergonomics and the lean manufacturing continuous improvement process. This is useful for both the expertises and the upper level managers in the continuous improvement process which is shown in fig 5.

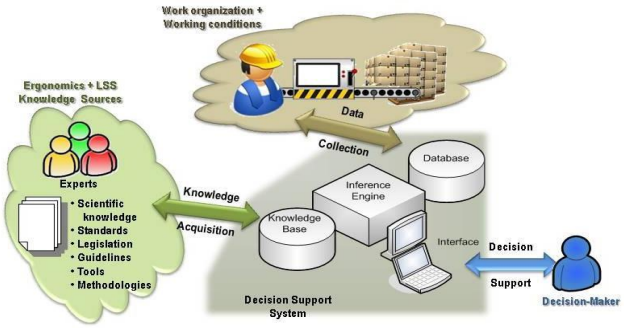


Fig 5. Decision support system

3. Results

So far, the author dealt with the lean manufacturing techniques and employee risk factors in the previous sections and he adopted these techniques in this factory. For this, he created a questionnaire which consists of about 20 issues regarding various departments with the qualitative and quantitative responses to identify the view of employees in relation to the post, workstation, ergonomic factors and organization of these production methods and techniques.

These forms consist of 20 questions with answers which are explained to each worker by rigorous training method for filling it. These forms were given at random about 50 employees in

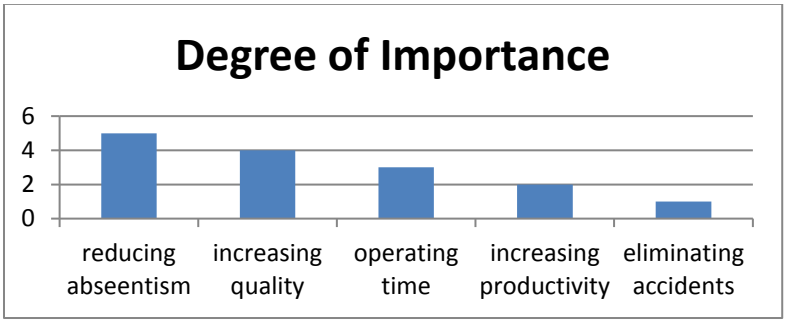
various expertises. Most of the forms given to manufacturing side as the most of the work relays on lean manufacturing, working conditions and ergonomics human factors only. The distribution was 20 Manufacturing, 5 engineering, 5 Maintenance, 5 Quality, 4 Logistics, 2 RH, 2 Suppliers, 5 Ergonomics, 1 Occupational Safety, 1 Communication. After collecting the data, it is observed that 36 samples nearly 72% have given a positive response towards the adoption of lean manufacturing techniques with continuous improvement process for the progress of ergonomic conditions of the employees and organization performance.

The survey made for this study is a tool concept, which had given a good response for cost reduction and good working conditions of employees within the lean production system. The methodologies adopted and experienced on daily basis has modified the organization and made to run in an improving direction. Adoption of lean manufacturing principles made ergonomic condition factors to the best of the employees. Some of the employees review:

1. I think, when a company gives value to the employees, it will definitely run in an improving direction.
2. I am unfortunate to express my views as i didn't expect this type of drastic change results a very good overall improvement in my company.
3. I attended to several modifications aimed for improving ergonomic human factors and the expertises came to me for my ideas regarding my department as i did the maximum operations in the department.
4. I felt very happy that the expertises changed the working environment with new principles and also the attitude of the employees in a positive way.

In this context, the author suggests to conduct this type of surveys for the better development of the industry and also to know the present status of the industry. Everyone must know about the preventive targets of their work in order to avoid accidents.

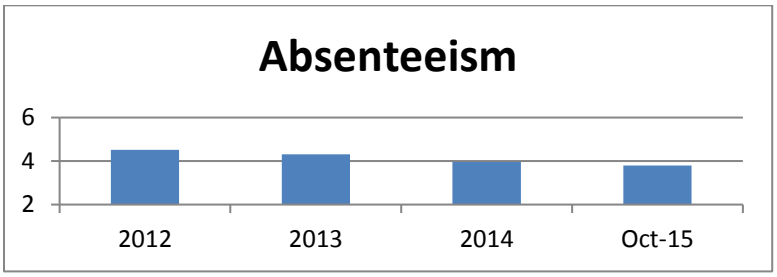
This study draws an attention that the continuous improvement given to the lean manufacturing principles gives the positive improvements in the production rate relating to the better working conditions of their employees. while implementing the continuous improvement process the degree of importance to various fields is given below shown in graph 1. However the management, employees has known that the ergonomics has correlation with the production rate. Better ergonomic conditions will sustain the productivity.



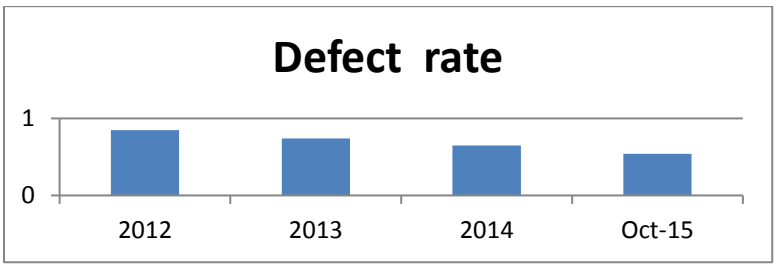
Graph 1. Indexing the degree of importance

The results had showed the reduction in absenteeism of the employees, as they are interested to work in the better working conditions and to increase their income. Often they are putting their full effort to get the desired output with the best quality and quantity. Now, let us see the impact of these improvements on the product quality.

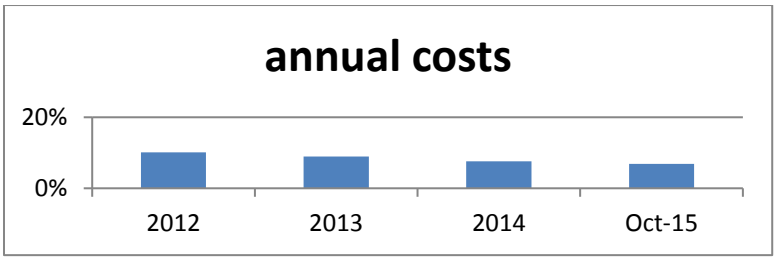
For getting a product with good quality, there is a need of consideration of the manufacturing process from the starting of the process of the production lines. From the survey, it is observed that the improvements made for the well tool applied with the improvements set gets a good working condition and has a positive and well-significant result for both employees who can perform operations and make quality, and for the organization that relies on the quality of its production carried out by its employees. This shows the improvement in the quality of the products. In the same way, considering the average defects before and after implementation of these techniques gives the positive improvement in product defects and other fields as shown in below graph 2,3,4.



Graph2. Indexing absenteeism of employees

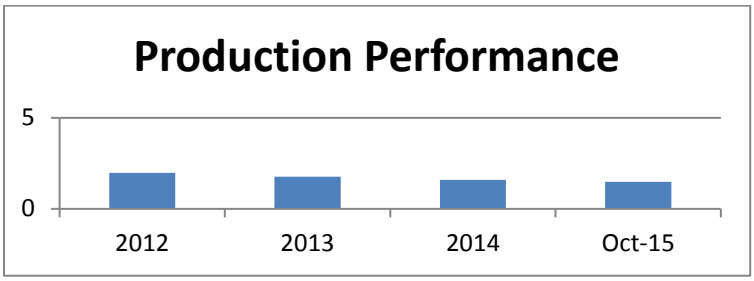


Grapf 3. Indexing product defects per unit



Graph4. Indexing annual cost loss

Considering the effective production performance of the company is also important by eliminating the waste to reduce the cost. This means producing more with less. In this study there is a reduction of 27% of waste compared to the years from 2012 to Oct 2015, which means a progress for the organization. In relation to improve the ergonomic conditions of the employees gives the improvement in the performance of the industry and the production performance is shown in graph 5.



Graph 5. Indexing the production performance

Ergonomics implemented in the workstations brings better results in the various fields of the industry. On implementation of these principles there is an improvement in the organizational performance also. In the present scenario, it is very important to apply these ergonomics methods to all industries and in all fields of applications like marketing, shopping, constructions etc., in order to be competitive to the global market. These ergonomics training supports the employees in new gestures of postures for the working environment to get a good quality product operated at the first time by eliminating waste.

In the current market scenario the new performance evaluation models are required to, check and report the position on the market and motivate progress and the commitment of employees to the changes or improvement projects that are deployed; and to assist in decision making about the process of implementation and management of the improvements and changes within the organization.

Conclusion:

Continuous improvement process is getting adopted by the various companies, due the increase in the competitiveness in the global marketing. Lean manufacturing is an very powerful tool for the improvements in the industry. The integration of Ergonomics during the lean manufacturing implementation has the potential to obtain substantial gains in productivity and to simultaneously improve the working conditions. The model of a framework regarding the integration of Ergonomics and lean manufacturing systems based on the various tools was presented. The proposed framework associates to the lean manufacturing system procedures used in each phase of the ergonomic tools and methodologies introducing an additional ergonomic perspective.

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