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CONCEPTUAL FRAMEWORK FOR IMPROVING BUSINESS PERFORMANCE WITH LEAN MANUFACTURING AND SUCCESSFUL HUMAN FACTORS INTERVENTIONS–A CASE STUDY

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Abstract: *Nowadays organizations compete between themselves in various categories such as faster delivery, price tags, state of art-technology and higher quality dimensions. A Conceptual framework with lean manufacturing and human factors interventions for improving business performance in terms of improved quality, reduced cost and faster delivery is presented and examples from literature are given to illustrate the desired situation in which ergonomics is considered as an integrated part of performance strategy . A case from an industry engaged in manufacturing shafts using lean manufacturing practices with successful ergonomic or human factors interventions is also investigated.*

Keywords: *Human Factors, quality, lean manufacturing, FMS, layout, worker*

1. INTRODUCTION

Global competition characterized by both a technology push and a market pull had forced the organizations to compete between themselves on various categories such as faster delivery, price tags, state of art-technology and higher quality dimensions. Various innovative techniques and management practices such as SCM, TPM, TQM, BPR, MRP, ERP,LM and JIT, etc., are becoming popular among the business houses to promote their products and processes (Carpinetti et al. 2003, Najmi 2005, Sharma et al.2006, Mishra and Sharma, 2011). In recent years, organizational performance measurement and metrics have gained a lot of attention from researchers and practitioners. The role of these measures and metrics in the success of an organization cannot be overstated because they affect all levels of management, as well as strategic, tactical and operational planning and control. Each business function i.e. forecasting, product design, operations planning, marketing management, financial management, logistics management or personnel management, have their own strategic goals and performance metrics. Managers and staff from these business functions often have different 'languages' of their daily business. Here, ergonomics must show that it can be possible to support the objectives of chosen strategies, tactics and performance indicators of the respective business functions and to contribute immensely in achieving company business strategies.

In the literature managers usually link ergonomics with occupational health and safety hazards and not with business performance. Managers generally do not link ergonomics with organizational effectiveness, but rather with health issues (Jenkins and Rickards, 2001) and related costs. Ergonomics is usually not a part of the primary business strategy. Managers are not to be responsible for that. According to Dul, 2005 ergonomists hardly ever write articles on ergonomics in business and management journals, limiting the possibilities to expand the management community's perception of the possible tangible and intangible paybacks available by means of successful ergonomics interventions. According to the International Ergonomics Association (IEA): *''Ergonomics (or human factors) is concerned with the understanding of interactions among humans and other elements of a system,. In order to optimize human well-being and overall system performance.'' (IEA Council, 2000).* The definition implies that ergonomics has both a social goal (well-being) and an economic goal (system performance); that ergonomics considers both physical and psychological human aspects; and that ergonomics is looking for solutions in both technical and organizational domains. System performance aspects could include manufacturing lead time, production flexibility, quality levels, desired output at right time and right quantity, and operating cost among others. In the literature over the last two decades lean manufacturing and related tools cum techniques have become popularized among business houses, resulting in remarkable improvements in all spheres of business. Particularly managers have attempted to enhance company productivity and eliminate wastes through adoption of lean manufacturing practices such as Tom, Kaizen, Kanban and JIT. The objective of this study is to establish a research paradigm whereby lean manufacturing and ergonomics can be integrated to achieve business outcomes. This paradigm is aimed at providing a framework for proximate application of the results in industry.

2. LEAN MANUFACTURING

Many manufacturing firms, envious of Toyota's quality, productivity, and profit margin have attempted to implement the Toyota Production System TPS, also called *"lean manufacturing"* on their shop floors with varying levels of achievements. *Lean* starts from the refusal to accept *waste*. Credited to Taiichi Ohno, Toyota's chief of production, the lean system was developed through the 1950's and 1960's to provide the best quality, lowest cost, and shortest lead time through the elimination of waste. The Japanese term for what American companies usually categorize as waste is *muda* and was defined by Fujio Cho of Toyota as *"Anything other than the minimum amount of equipment, space and worker's time, which are absolutely essential to add value to the product."*. The presence of these types of waste in a system has a negative impact on lead-time, cost, and quality. The waste of unnecessary motion is particularly related to ergonomics. Excess motion consists of bending, twisting, lifting, reaching and walking. These often become health and safety issues and should be dealt with as soon as they are recognized. Different categories of waste are distinguished, such as (i) overproduction (ii) excess motion (iii) processing, (iv) transportation/material movement (v) correction, rework (> 100% quality) , (vi) waste of waiting, and (vii) inventory waste as shown in Table 1. A comprehensive framework of principles, methods and tools has been developed to fight waste, as evident from literature studies i.e. Hines and Rich (1997), Shah and Ward (2003) and Womack and Jones (2003), Melton, (2005) Abdulmalek and Rajgopal, (2007). Table 2 presents Key Lean manufacturing elements.

Table 1: Types of wastes

WASTES	Overproduction	Produce *only* the amount of goods necessary –not faster, sooner, or more.
	Motion	Simplify standardized work sequence to eliminate unnecessary movements.
	Processing	Provide *only* the required amount of processing and effort for each operation.
	Transportation/ Material Movement	Minimize the distance between processes, and avoid temporary material locations.
	Correction	Perform each operation without error. Build quality into every process
	Waiting	Assure machine availability. Perform preventative maintenance. Use man/machine to ensure optimization of operator's time
	Inventory	Provide material when needed by the customer and only in the quantity required.

Table 2: Key Lean manufacturing elements

Lean Production or Toyota Production System (TPS)

- The basis of TPS is the absolute elimination of waste. The basic idea in TPS is to produce the kind of units needed, at the time needed and in the quantities needed so that unnecessary intermediate and finished product inventories can be eliminated.

- Lean production uses half of the human effort in the factory, half of the manufacturing space, half of the investment in tools, half of the engineering hours to develop a new product in half the time. It requires keeping half of the needed inventory, results in many fewer defects, and produces a greater and ever growing variety of products.
- Lean production is most frequently associated with elimination of waste commonly held by firms as excess inventory or excess capacity (machine and human capacity) to improve the effects of variability in supply, processing time, or demand.
- Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability.
- TPS includes standardization of work, uninterrupted work flows, direct links between suppliers and customers, and continuous improvement based on the scientific method .Lean production is an integrated system that accomplishes production of goods/services with minimal buffering costs (Womack et al., 1990, Hopp and Spearman, 2004, Shah and ward, 2007).

Just in time (JIT)

- A name for the Toyotistic way of supply management, demanding strict time discipline of deliveries.
- Just in time production system as ‘‘only the necessary products, at the necessary time, in the necessary quantity’ .
- JIT philosophy is associated with three constructs: total quality, people involvement, and JIT manufacturing techniques
- Programs associated with JIT include ‘‘elimination of waste, and full utilization of people, equipment, materials, and parts’’
- JIT is a comprehensive approach to continuous manufacturing improvement based on the notion of eliminating all waste in the manufacturing process
- JIT is composed of three overall components, namely, flow, quality and employee’s involvement.
- JIT is based on the notion of eliminating waste through simplification of manufacturing processes such as elimination of excess inventories and overly large sizes, which cause unnecessarily long customer cycle times (Hall, 1987, Davy et al., 1992, Flynn et al., 1995, McLachlin, 1997,Sakakibara et al., 1993).

Total Quality Management (TQM)

- TQM is an approach to improving the quality of goods and services through continuous improvement of all processes, customer driven quality, production without defects, focus on improvement of processes rather than criticism of people and data driven decision making .
- TQM is an integrated management philosophy and set of practices that emphasizes continuous improvement, meeting customer requirements, reducing rework, long range thinking, increased employee involvement and teamwork, process redesign, competitive benchmarking, team-based problem solving, constant measurement of results, and closer relationships with suppliers.
- TQM is a philosophy or an approach to management that can be characterized by its principles, practices and techniques. Its three principles are customer focus, continuous improvement, and teamwork.
- Common guiding TQM precepts can be conceptually distinguished into three clusters (a) focusing on customer satisfaction (b) stressing continuous improvement, and (c) treating the organization as a total system (Ross, 1993, Dean and Bowen, 1994; Sitkin et al., 1994,Flynn et al., 1994)

Kanban System

- Kanban system, production smoothing and setup time reduction are critical components of any JIT system
- Ohno (1988) devised kanban as a means to pull material from an upstream station and manage product flow.
- The manufacturing components are connected to final assembly with Kanban links which withdraw material from the subassembly and component supplier’s cells as needed by final assembly and give production orders to all the suppliers automatically. This rule governs the maximum inventory in any link.
- The inventory is held in links (between the cells) in the system and controlled by the

internal customers (the users of the inventory) using the Kanban system of production control. The inventory in the links is standardized, controlled, and minimized by the internal customers.

- Control the where, when, and how much material. The design of the manufacturing system defines flow and the kanban operate within the structure. This is integrated production control or kanban.
- Kanban is a visual control system that is only good for lean production with its linked cells and its namesakes; it is not good for the job shop. (Monden, 1981, Ohno 1988, Black 1991, JT Black 2007).

Housekeeping or 5S Principles

It is an indispensable ingredient of good arrangement. Through good housekeeping employees acquire and practice self-discipline. The 5S activities include:

- *SERI:* Proper arrangement Sort out unnecessary items from the workplace. For instance unused machinery, tools, defective products etc should be removed.
- *SEITON:* Orderliness or Straighten i.e. set in order the remaining items. Every tool bin pallet should have a place. So that its location can be easily identified.
- *SEISO*: Clean or scrub up everything that remains. Clean and paint to provide a pleasing appearance
- *SEIKETSU:* Personal cleanliness. Keep workplace clean from dirt, dust and oil to provide pleasant work environment
- *SHITSUKE*: Discipline means following work instructions, safety precautions, getting better discipline and work culture.

Kaizen

- Kaizen means continuous improvement. It comes from Japanese words "kai" meaning school and "Zen" meaning wisdom. According to Imai (1991), an important follower of Kaizen; Kaizen means "Continuous gradual and orderly improvement".Kaizen's philosophy is based on seven key concepts as presented here under.

Concept i	*Continuous Improvement Cycle*	(P-D-C-A). Plan- Do- Check- Act.
Concept ii	*Customer*	Customer or end user is important .Ask him what he can do to improve product or services?
Concept iii	*Quality is first*	Focus on progress in quality improves both cost and delivery, while focus on cost causes both deterioration in quality and delivery.
Concept iv	*Market in Vs Product out Approach*	Instead of pushing products into the market and hope that customers will buy them, ask potential customers what they need/want and develop products that meet their needs and wishes.
Concept v	*Upstream management*	If the problem can be found in the design or pilot test and is rectified, the less time and money is wasted.
Concept vi	*Voice by data*	The quality tools such as histograms, Pareto diagrams ,control charts and run charts will provide realistic background for collecting the data thus analyzing the problems with facts
Concept vii	*Variability control and prevention*	Ask 'Why?' five times to get to the real cause of a problem and to avoid just treating the effect of the problem.

3. ERGONOMICS OR HUMAN FACTORS PRINCIPLES

Because people are one of a manufacturing organization's most valuable non-depreciable resources, manufacturing system designers must develop a safe and healthy work environment. Concepts from the field of industrial engineering have had considerable influence within the field of ergonomics, particularly with regard to working smarter, not harder, elimination of waste, and maintaining a systems view, including the economic impacts. According to the US Occupational Safety and Health Administration (OSHA), "*work-related musculoskeletal disorders (WMSDs) are presently the leading cause of* *injuries, lost workdays and worker compensation costs"* (Steve L. Hunter, 2002).The definition of ergonomics (or human factors engineering or human-centered design) simply refers to designing for human use. Over the years, the objectives of the ergonomics field has grown to encompass the design of work systems (including equipment, materials, tools, interfaces, environment, etc.) within human capabilities so as to improve productivity and reduce injuries and fatigue. Ergonomics principles and guidelines are useful in prevention of operator fatigue and stress leading to potential work-related musculoskeletal and neurovascular disorders (musculoskeletal disorders, or MSDs). Some of the key ergonomics principles for sound workplace design include (Konz, S & Johnson 2004, Helander, M., 2006):

i. *Workstations - Providing adjustable workstations and a variety of tool sizes. Many types of assisting devices can be utilized to adhere to ergonomics principles, including carts, lift devices, adjustable worker elevation platforms, tool balancers, manipulators, vacuum assist devices, workstation cranes, conveyors, stackers, container tilters, and pallet invertors and rotators, and vibration dampening devices.*
ii. *Postures- Avoiding prolonged, static postures and promote use of neutral joint postures*
iii. *Anthropometric Principles- Locating work, parts, tools, and controls at optimal anthropometric locations*
iv. *Adjustable facilities - When appropriate, providing adjustable seating, arm rests, back rests, and footrests.*
v. *Utilizing feet and legs, in addition to hands and arms and gravity and conserve momentum in body motions.*
vi. *Strategic location- Providing strategic location or platforms for lifting, lowering, and releasing loads*
vii. *Accommodating for a broad variety of workers with respect to size, strength, and cognitive abilities*.

4. LITERATURE STUDIES

Table 3 presents summary of examples from literature to illustrate the desired situation in which ergonomics or human factors engineering is considered as an integrated part of performance strategy fewer than three headings i.e. in automobile sector, electronics and office work systems.

Table 3: Summary of Literature studies

Automobile industry		
Authors	**Scope of study**	**Outcomes**
Bao, S.,et al 1996	Ergonomic effects of a management-based rationalization in assembly work	Improved working conditions in assembly work
Bullinger, H et al 1997.	Ergonomics in assembly planning.	Improved postures and reduced strain
Sugimoto et al.(1998)	Assessment model to match workstation design to worker strain capacity	Reduced physical strain and MSDs
Jimmerson, D.G., 1998	Ergonomics analysis software in vehicle manufacturing/assembly	Flow simulation and video ananlysis of postures
Miles, and Swift, K., 1998	Design for manufacture and assembly	Improved quality and reduced MSD incidence
Siffer, L., Jimmerson, G., 2000	Ergonomic guidelines for electrical connectors for vehicle component assembly.	production quality improved
Fredriksson, K etal 2001	Studied the impact on MSDs of changing physical and psychosocial work environment conditions	Several workstation improvements and better team spirit
Lin, L et al 2001	Effect of Ergonomics and quality in paced assembly lines	Reduced costs and productivity increase
Moreau, M., 2003	Developed a Corporate ergonomics programme	Training and workstation design

Munck-Ulfsf.alt et al.2003	Studied ergonomics process involving increased ergonomics reactive and proactive measures.	Training of personnel on various ergonomic issues
Sengupta & Jacobs, 2004	A comparison study of assembly cells and assembly line for a variety of operating environments.	Team culture and job enrichment and reduced MSDs, accidents and compensations
Kazmierczak, K.,et al (2004).	Car disassembly and ergonomics in Sweden	Improved quality of work life and productivity
Sundin, A., etal 2004	A different perspective in participatory ergonomics in product development	Better work organisation and improved assembly work in the automotive industry
Johnsson, D.J. 2005	Converting assembly lines to assembly cells at Sheet Metal Products	Improved work design and waste reduction
Kazmierczak K, et al 2007	Presented a novel approach to integrating production engineering and ergonomics.	Mimimized Muda –waste and improved productivity with stress on human factors in development of disassembly systems
S.Z.Dawal , etal 2009	Effect of job organization on job satisfaction among shop floor employees in automotive industries in Malaysia	Improved productivity job satisfaction and quality of work life
Battini, Det al 2011	Developed a methodological framework to improve productivity and ergonomics in assembly system design	Ergonomic design of assembly station results in improved quality , reduced fatigue, MSD in workers
	Electronics Industry	
Authors	**Scope of study**	**Outcomes**
McKenzie et al., 1985	Implemented a program for control of repetitive trauma disorders associated with hand tool operations in telecommunications manufacturing facility.	A positive effect on MSD was obtained by a change of tools, and training in ergonomics of engineers and supervisors
Chatterjee 1992	Summaraised Workplace upper limb disorders: a prospective study with ergonomic intervention.	Improved tools and work- Reduced MSD incidence stations through training
Aaras,1994	Studied changes of workstation design in electronics assembly	Reduced MSD incidence and work related stresses
Helander, M.G., Burri, G.J., 1995	Studied Cost-effectiveness of ergonomics and quality improvements in electronics mfg	Improved quality with ergonomic development programmes
Herring and Wick (1998)	Reducing the probability of ergonomics related injuries in manufacturing.	Reduced worker compensations and improved quality of work life
Neumann etal 2002	A case study evaluating the ergonomic and productivity impacts of partial automation strategies in the electronics industry.	Reduced MSD and improved quality, reduced defects and better employee morale
Yeow, P.H.P., Sen, R.N., 2003	Quality, productivity, occupational health and safety and cost effectiveness of ergonomics improvements in the test workstations of an electronic factory.	Remarkable improvements in quality, productivity, occupational health and safety
Sen, and Yeow, 2003	Analyzed ergonomic redesign of electronic motherboard.	Improved quality
Helander, M., 2006	A Guide to Human Factors and Ergonomics	Ergonomic procedures for work station design
Saw Bin Wong and Stanley Richardson,2010	Assessment of working conditions in two different semiconductor manufacturing lines	Effective ergonomics intervention resulted in improvement in throughput, quality rate and lead time

Office or Work place Design		
Authors	**Scope of study**	**Outcomes**
Punnett, L., and Bergqvist, U., 1997	Visual display unit work and upper extremity musculoskeletal disorders—a review of epidemiological findings	Improved work postures and movements
Albin, T et al 1997	Studied office-ergonomics	Reduced movements and material handling
Aaras et al.(1998)	Analyzed musculoskeletal, visual and psychosocial stress in VDU operators before and after multidisciplinary ergonomic interventions.	Improved lighting, furniture and Reduced visual discomfort
Aaras (1999)	co-operation in ergonomics	Participation and team work
Landsbergis, et al 1999	The impact of lean production and related new systems of work organization on worker health.	Reduced waste and Improved Health and morale
Robertson, et al 2000	Office ergonomic interventions: strategies and practices	Improved working conditions, reduced fatigue
Karsh, et al 2001	Performed critical analysis of the peer-reviewed literature on the efficacy of workplace ergonomic interventions	Reduced musculoskeletal disorders
Anderson-C et al 2002	Studied workplace transformation and employee well-being	Employee participation and improved work culture
Gavin, J.H., Mason, R.O., 2004	The virtuous organization: the value of happiness in the workplace.	Improved quality and reduced MSDs
Den Hartog, D.N., Verburg, R.M., 2004	Studied High performance work systems, organizational culture and firm effectiveness	Firm effectiveness and better organizational culture
Silverstein, B., Clark, R., 2004	Studied various ergonomic interventions to reduce work related musculoskeletal disorders.	Improved Office Culture and reduction in absentees
Angelis, J., 2004.	The effects of just-in-time/lean production practices on worker job stress.	Improved work perceptions ,work rotation ,enrichment and improved productivity
Sepa la¨, P., Klemola, S., 2004	Studied how do employees perceive their organization and job when companies adopt principles of lean production	Better quality , enhanced productivity by reduction in manufacturing lead time and following JIT principles
Fabrizio TA and Tapping D.2006	5S for the Office: Organizing the Workplace to Eliminate Waste,	Better workplace management, reduced movements and elimination of wastes
Conti, R.,etal 2006	The effects of lean production on worker job stress	Improved lighting, furniture and Reduced visual discomfort
Ceylan, C et al 2008	Can the office environment stimulate a manager's Creativity	Management commitment for ergonomic programmes
Seim, R.; Broberg, O. 2010	Explained Participatory workspace design: A new approach for ergonomists?	Improved postures and reduced fatigue disorders

5. FRAMEWORK FOR LEAN MANUFACTURING WITH HUMAN FACTORS ENGINEERING INTERVENTIONS

Figure 1 presents a framework to illustrate how lean manufacturing practices integrated with ergonomic interventions.

Can help in achieving business excellence in terms of cost effectiveness, faster delivery and quality improvement.

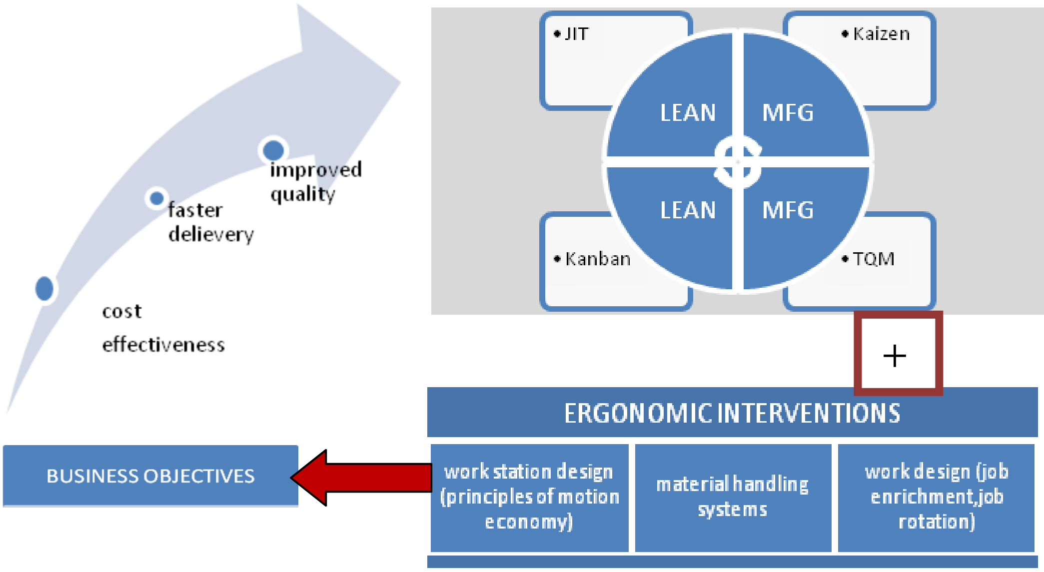

Figure1: Conceptual Framework for Lean Manufacturing with Ergonomic interventions

6. CASE STUDY

The framework has been applied in a company engaged in manufacturing shafts for automobiles. The manufacturing facility is designed to make shafts and In-line layout (Figure 2) which is used for processing work at different stages. The work is classified under six major processes i.e. grinding, verifying dimensions, drilling and tapping, assembly and alignment and finally washing of components in tank before shipment. According to the management reports, company was experiencing more number of rejections and rework. Both qualitative and quantitative data were collected through general survey and by subjective assessment through interviews with managers, shift engineers, production supervisors, and operators. Direct observations through field measurements, video recordings were also made and historical data with regard to manufacturing lead time, costs and processes, work instructions, operations planning and layout, etc is collected. The different types of wastes were identified such as excess motions, wastes incurred during transportation/material movement and rework because of reduced quality. Ergonomic interventions (EIs) were implemented by the means of real life experiments, one at a time, to envisage each cause and effect relationship at workstation-1 and workstation-2. Figure 3 provides the operation time curves for each process before and after implementation of the proposed framework in the cell. Thus, it is concluded that an ergonomically-designed manufacturing process with lean philosophy is less error-prone to accidents, workplace hazards, and human discomfort and more productive with respect to time cost and investments.

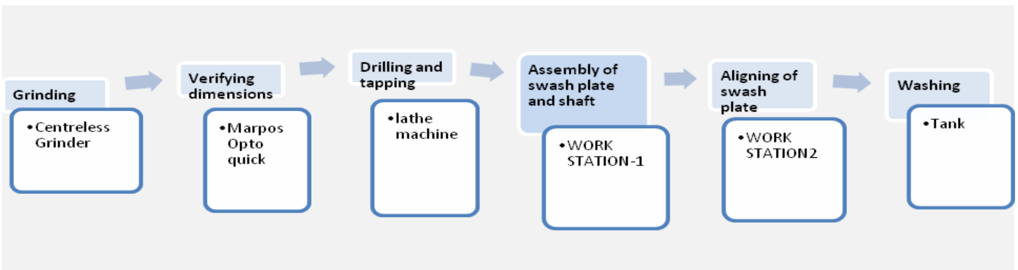

Figure 2: Line layout of investigated Process

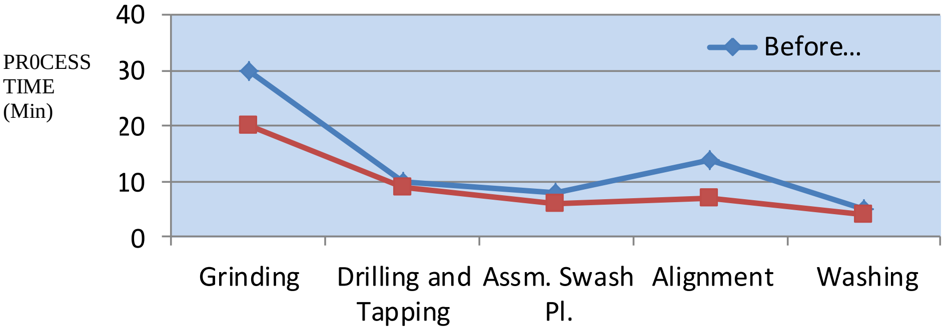

Figure 3: Time curves before and after implementation of framework

7. CONCLUSIONS

Following conclusions are drawn from the study

1. As evident from examples in literature that increasing research efforts in the field of ergonomics have yielded a considerable body of knowledge concerning the design of tools and workstations, as well as organizational design to prevent worker discomfort, illness and absenteeism, and also to improve productivity and product quality.
2. Integrating ergonomics into the process of production system requires management commitment and financial support.
3. A key issue when implementing an ergonomics programmed in an enterprise is the training of the staff and participative approach at all levels whether it is strategic, tactic or operational. For example, in the Volvo Car Corporation the ergonomics programme received tailored training programmes at all levels from top management to shop floor staff. The experience of Volvo's senior ergonomist illustrates this challenge in words as ''*The ergonomics work is not a separate entity, but is based on the corporate strategy. It was much easier to get the management and other employees to understand, realize, accept and become involved in ergonomics work when they saw the link with the strategy.*'' (Munck-Ulfsfa et al., 2003).
4. Quality has deep rooted links to workplace ergonomics and is a function of technological and human factors, and is greatly influenced by "ergonomics" in its broadest sense (Drury (2000). It is concluded that poor working conditions are related to quality deficiencies and vice versa. Errors in the process can result in product unreliability, poor productivity or even injury to the workforce or product user.
5. Product design and Optimal design of workstations results in reduction in work-related musculoskeletal and neurovascular disorders. The design of hand-held tools has lately improved considerably in terms of ergonomics. Is addressed in many company programmes for ergonomics. In particular, the opportunities for job variation, rotation and enlargement are of great importance for the prevention of MSD.
6. As evident from the case in section 6 that in order to remove *Muda* i.e. waste from the system, improvement processes should focus on simplification, combination, and elimination. Simplifying work includes creating standard work so that everyone knows, and does, the same work the same way every time. Additionally, using workplace organization disciplines such as 5S, and techniques such as job enrichment, job rotation, color coding, can simplify a process as well as remove waste and minimize safety hazards. However, the utility of ergonomics research is not limited to predicting and eliminating work place injuries. Good ergonomic design can also be used to enhance productivity.

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