Enhancing Productivity of Mixed-Model Assembly Line in Tikur Abbay Shoe S.Co

By

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ABSTRACT

Tikur Abbay shoe S. Co is one of leather industry in Ethiopia, which produces a variety of shoe model for local and export markets. The research is mainly focus on the export product, men shoe (HARBER) model, production condition has different problem not good working environment and less production efficiency this means the company not satisfies internal and external customer interest such as quality, delivery time and work environment problem.

Footwear assembly tasks are very repetitive and provide the operators with little opportunity for rest. Many operators perform only one operation with no job rotation. The repetitive nature of the job caused work overload and that was made worse by other workers delivering unfinished shoes to the operators.

The general objective to enhance productivity and increase competitiveness of company by export product to meet international quality and workplace ergonomically comfortable, improve work environment and safety requirement.

The methodologies for the study follows are discussion with target group, direct observation, face-to-face interview and distribute questioner to collect ergonomic problem fact and observe production section to record working environment problem this all use to collect the research useful data. Data analysis is interpreted through a descriptive method by using MS–Excel 2016 software, were used to present data in pie chart, Minitab 16.2.4 software were used to prioritized shoes model and MS-Visio were used to draw root causes analysis of work load and to illustrate the processes layout.

The finding of the study shows that about 33.6 % of defected product is caused by operators due to work overload in the production stations and due to existing layout problem 28 m distance which is unnecessary movement and ergonomic problems.

Therefore, improving human ergonomics problem is used to reduce work overload and worker health problem, improve work condition and improve chair and table design. If proposed layout of production area implemented and ergonomics problem is solved the output of company increased by 38 pieces of shoe per day and 33.6 % of defected products are solved and the production efficiency is increased by 28.19 % which is 88.95%.

Key words: *Assembly line, Mixed Model, Work overload, Working Environment, Ergonomics*

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LIST OF ABBREVIATIONS

TASSCo – Tikur Abbay Shoe Share Company

SMAL- Single Model Assembly Line

MMAL- Mixed Model Assembly line

IEA-International Ergonomics Agency

ANSI- American National Standard Institute

BSI- British Standard Institution

ECRS- Eliminate, Combine, Rearrange and Simplify

HSE- Health and Safety Executive

OSHA- Occupational Safety and Health Administration

WRMDs - Work-Related Musculoskeletal Disorders

M-Meters

Sec-Second

CHAPTER ONE: INTRODUCTION

The Industrial Strategic Development Plan of Ethiopia gives great emphasis to improve export-led products, such as livestock and livestock products, textiles, garments, floriculture, and others to join the international market in a large scale. In Ethiopia, the lather industry is one of pioneer development sector because Ethiopia possesses the largest populations of livestock in the world (CSA, 2010).

The leading Leather Industries in Ethiopia were start production in 1928 G.C. Even though these leather industries establishments were earlier their contribution to the countries' economy is minimal. Since their production methods are traditional they can't be globally competitive, the main problems of the companies are poor working condition, high operating cost and work overload on employee that refers to uncompleted operations for operators within their working station. By these features the performance of company is insufficient (Manavizadeh, 2011).

Today, traditional production methods in footwear industries are replaced with mixed assembly line method because of demand for greater product variability and shorter life cycles (Salin, 2012).

As research indicates, the most industry uses different assembly line method to produce the products. Those are single model assembly line (SMAL); and mixed model assembly line (MMAL). Before the 1970s, assembly lines are mainly the SMAL type, whereas since the 1980s manufacturers have adopted the MMAL style. In mixed model assembly line, a variety of product models are processed on the same assembly line. Mixed-model assembly is the ability to assemble a family of products that share similar processes, similar work content and similar materials; on the same production line, this refers that footwear industry followed with Mixed-Model Assembly Line. From those footwear industries who's followed mixed model assembly line Tikur Abbay Shoes Company is the one, to meet diversified demand of consumer without holding large number of inventories. In order to increase productivity of company and performance of employees, to minimize work in process inventories' and to keep the promises of customer the mixed model assembly line by minimizing work overload.

Bringing in mind the main purpose of this study would be enhancing productivity of mixed model assembly line and identifying major causes of work overload on employees for a single product model.

1.1 Problem Statement

Ethiopia gives great emphasis to improve export-led products. Among the known exporters, lather and leather products industries, particularly those produce shoe products are one of the sectors, which generate sufficient foreign currency (CSA, 2010). However, Export performance of the lather unsatisfactory, not competitive in the global market due to high cycle time, work in process inventory, less production line efficiency, poor quality of product, work overload due to poor work place organize that are results less production capacity (IPD, 2013).

Tikur Abbay shoe S.CO is one of leather industry in Ethiopia, which produces shoe for local and export markets. The company has mainly five sections in which progressive routes are followed in order to produce the final product. These are technical design and styling, cutting, closing (stitching), lasting and packing department. According to this the main, longest and value adding operation done in the stitching process the second one is lasting process is the final process to convert the sewing lather part into different shoe models. This study were focused on the stitching and lasting assembly line, which are the major work overload problems occurring at this station. The planned production capacity of Tikur Abbay shoe S.CO in its two-production section within three conveyors is about 600 pairs of shoes per day respectively and the actual production is about 398 pairs of shoes per day (Report, 2008).

From this report, it has clearly shown that Tikur Abay shoe S.CO is performing under its planned production capacity, currently the production efficiency is 0.6. Other major cause that minimizes the efficiency of company is defect rate of products, 33.6 % of defect caused by operators, and 18.4 % of defect caused by machine, 25.5% of defect caused by material and 22.5 % of defect caused by method. And also the company does not meet customer delivery time because of different problems in production line work environment is not attractive and not comfortable situation for employee's and unorganized flow of processes. Due to this problem, workers leave their work station with uncompleted operation to take the raw materials/ inputs they require for their effort. These is also one major cause for work overload on employees that result low throughput, high work in process inventories, high waiting time between the workstation, high defect rate of product, low productivity, dissatisfaction, sickness and turnover of employees.

Therefore, the motivation of this paper is enhancing productivity of mixed-model assembly lines through minimizing work overload and identifying the major problem that caused work overload on employees.

Therefore, this research were answered the following questions,

- What are the major problems that caused work overload on employees?
- What are the impacts of work overload on employees, mixed model assembly line productivity?

1.2 Research Objectives

1.2.1 General Objective

The general objective of the study is to enhancing productivity of Mixed Model Assembly Line through minimizing work overload in Tikur Abbay Shoe S.co.

1.2.2 Specific Objectives

- To identify the major problems that caused Work overload
- To assess the impact of work overload on employees productivity
- To propose the probable solution that minimize the work overload
- To enhance the productivity of Mixed Model Assembly Line

1.3 Significance of the Study

Work overload improvement is the key for any industry, to handle the internal customer, to minimize defect of product, to compete and to be productive in today's competitive market. Therefore, any manufacturing company especially shoe factories can be benefited from this study by customizing the core concepts, and it also help as for further research on the same topics.

1.4 Scope of the Study

The scope of this study is focused on identify major cause and assessing impacts of work overload in Tikur Abay shoe Share Company for export product. These export products are manufactured in large quantity with different shoe models, the study focus on Stitching and Lasting assembly line, because the major work overload occurred at this station.

1.5 Organization of the Study

The study is organized in **five** chapters.

The **first chapter** deals about introductory of the research. This contains background of the study, problem statement, general and specific objectives, significance and scope of the study.

The **second chapter** is discussed on related literature reviews on concept and definition of mixed model assembly line, work environment, work overload, performance and productivity.

The **third chapter** deals with methodologies, data analysis and interpretation of the data to make soft the entire raw data showing. This chapter elaborates the background of the study area, which discusses select specific research area and more clarify the research methodology.

The **fourth chapter** deals about data analysis and result of the study. Using observation to identify the work environment problem and work overload causes, measure the impacts of work overload on employees and productivity, and improve the problem area to minimize the work overload.

The **fifth chapter** presents conclusions that drawn from data analysis and result, work environment analysis, assessing ergonomics problem for seating and standing work, measurement of work overload and improves the production area and lastly recommendations are made.

CHAPTER TWO: LITERATURES REVIEWS

This chapter review in details literatures available in the area of mixed model assembly line, quality and productivity, impact of ergonomics on work place, factor affecting productivity, work environment, work overload and productivity issues related to the area of this study and history of lather industry in Ethiopia.

2.1. Concepts of Quality and Productivity

2.1.1 Concepts of Quality

Quality is perceived differently by different people. However, everyone understands what is meant by "quality." In a manufactured product, the customer as a user recognizes the quality of fit, finish, appearance, function, and performance. Different quality Guru's define the term as; conformance to requirements, fitness for use, the degree to which performance meets expectations, the degree they conform to requirements and satisfy customers. Quality can be measured by meeting main specification set by customer and quality standard agency for various grade of products; like thickness, size, softness and color. It is similar in shoes factories as well (Bekele, 2013).

2.1.2 Concepts of Productivity

According to (Kumar, 2009; Krugman, 1994; Syverson, 2011) Productivity is defined as the ratio of the output to the input of a production system. The output of the production system is the products or services delivered while the input consists of various resources like the labor, materials, tools, plant and equipment, and others, used for producing the products or services. Khokhar et al. (2014) described productivity as the combination of effectiveness and efficiency. Tangen (2002) stated the concept of productivity beyond the output input ratio as it is the efficient use of the resource that needs to be considered and Productivity was also described as the value created to the product being produced. Productivity represents the relationship between inputs and outputs in production process. According to MD Abdual (2017) productivity can be calculated as follows:

$$\textbf{Productivity} = \frac{\textbf{Output}}{\textbf{Input}} \text{..... (1) Or}$$

$$\textbf{Productivity} = \frac{\textbf{Total number of Output}}{\textbf{Total labor hours spent for production (Input)}} \text{..... (2)}$$

Even though, Productivity will not only be measured by the number of output the equipment produces per day or per month, instead the proper use of input (raw material, man-hour and other resources) makes the company produces expected amount. Thus, productivity incorporates the effective and efficient use of resources throughout the production.

Different authors illustrated the merits of being productive based on their perceptions. Chandra et al. (2015) mentioned that improving productivity will increase the performance of companies by various types of resources. Kumar et al. (2012) interpreted productivity as an essential substance for the company's competitiveness and partial productivity can affect the overall productivity. One of the inputs, material productivity has its contribution to overall productivity. Raw material is an input which can be transformed into a product (output). By the formula of Productivity, high quality of input (use small amount, less defect or reject) may lead to have high Output and result on high productivity.

2.1.3 The Quality of Footwear Products

The quality of the footwear products is defined as its degree of fitness to meet the needs and desires of the customer. The quality of products can be measured in terms of various requirements; after the product has been delivered to the customer. The most common quality definitions in manufacturing include: Conformance, Performance, Reliability, Features, Durability and Serviceability. The relative importance of these definitions is based on the preferences of each individual customer. It is easy to see how different customers can have different definitions in mind when they speak of high product quality (Mengstu Ashebre, 2013).

2.2 History of Lather Industry in Ethiopia

In Ethiopia, the leather soaking and tanning industry emerged with the establishment of the ASCO tannery (nowadays Addis Ababa tannery) in 1918 and Darmar/Awash (nowadays, ELICO) tannery by Armenian traders in 1927. The modern leather processing industry also dates back to the 1930s, a period associated with the establishment of shoe factories Tikur Abbay and Anbessa, by Armenian merchants. In the 1990s, the privatization policy adopted implied that all state-owned tanneries where auctioned off, in 2008 there 21 tanneries in Ethiopia with combined tanning capacity 4,000pieces of hides and 30,000pices of skins per day. There are now 26 tanneries and more than 15 large export-oriented footwear producer and innumerable number of micro and small shoemaker in Ethiopia (Florian, 2013).

2.3 Overview of Tikur Abbay Shoe S.co (TASSCO)

Tikur Abbay Shoe Share Company has been established and registered in accordance with the commercial laws of the Federal Democratic Republic of Ethiopia in 1948 at Asseco, Addis Ababa with initial capital of 200,000 Birr. At this moment the company has 679 permanent employees. Tikur Abay shoe S. Co currently is engaged in the production of various types of men's and ladies shoes. Total production capacity is 3350 pairs of shoes per day at two factories for local and export market, Percentage of export is 15.3%. To meet the demand it has made great expansion and investment. Now, it has two separate factories which are called casual and military and working shoes making Factory. The main product models which are produced in the company are T model, Ashewagrf, Harber and H model.

2.4 Mixed Model Assembly line (MMAL)

Different classification of assembly line is presented in literatures of assembly line. Assembly lines can be classified into two different types: single model assembly line (SMAL) and mixed model assembly line (MMAL).

In a mixed model assembly line, different models which are slightly different from each other but have the same parent product are assembled. Different models can have different process constraint each defining its model task durations and precedence relations. In mixed model production line, different products are produced in the same production line according to production schedule and order quantity (Zemczak, 2014). Mixed-model assembly lines are widely used in many manufacturing industries to meet the diversified demands of customers without holding large product inventories (Ayanezhad etal, 2010; Zhao, 2007).

The need to production a wide variety of products has led to many changes in the requirements of production systems. In the single model assembly lines, manufacturing companies have efficiently produced large quantities of the same product. But the diversification of customer demand necessitated the invention of more modern manufacturing methods. Mixed Model Assembly line (MMAL) is a production line where different variants of common products (called models) are intermixed to be assembled on the same line. According to Pravin Y. Tambe, the stability of work station is particularly important from the company's point of view, Stability allows the sufficient time for the workers so that they do not have to rush to complete the allocated task, this indirectly aid in quality improvement.

According to Kumar and Nagaraj (2014), “line system can produce the production sequentially by mixing more than one product on the same line. Product ranges produces on the same line are quiet similar to the main product.”

Most of leather industry followed mixed model assembly line they produced different model of shoes, that share similar processes, similar work content and similar materials; on the same production line.

2.5 Assembly Line Optimization - ALO

Assembly Line Optimization is the powerful tool for optimizing assembly lines designed for customized or multi-variant products.

Different characteristics of the product within the assembly line cause a continuously changing workload at the interlinked work stations. An assembly line of this type is efficient only if the engineering team balanced the assembly line properly and the assembly team is able to continuously balance the upcoming variations of workload. The ALO-System supports the optimization of such an assembly line during the processes of engineering, production control and product assembly.

2.5.1 Optimization of Engineering

The ALO-System undertakes all order data of the customer and production components and allows a simulation-assisted analysis of suitable line balancing and line efficiency. There are three analysis levels: first level is Analysis of the average workload per work station, Second level is Analysis of workload variance i.e. frequency of extreme workloads and third level is also Analysis of line efficiency under certain conditions and optimization strategies. Then the engineering team is able to check the allocation of work packages in the ALO-System as long as the line balancing gets solid and efficient.

2.5.2 Production Control Optimization

If the ALO-system is linked to the customer's IT-based production control system, the ALO-system regularly adopts the required order data for the assembly lines. Based on this data the ALO-System simulates the estimated efficiency and output of the assembly lines. Therewith the team of production control is able to identify early unbalanced workload caused by new products or changed order mix. As a result, necessary actions can be initiated in time.

2.5.3 Assembly Line Optimization

Today, customers usually use additional workers, work stations designed for exotic scope of work and group-related salary systems for promoting different workloads in the assembly line. The ALO-System is able to check the efficiency of these customized solutions. Additionally, the ALO-System offers an optimized working system based on clear rules for an alternating support in case of overload at the work station. These rules make the workers co-operate and concurrently avoid redundant waiting periods. As a result, the assembly line efficiency can be considerably increased.

2.6 Production Efficiency

Efficiency is an important measure of a company's performance. Unlike productivity, which a company achieves by maximizing the number of units produced in a given time frame, efficiency requires the maximization of costs and the minimization profits for a given level of output. Efficiency, therefore, enable a business to make the best possible use of the company's resource. For example, an efficient company will produce a greater number of quality products, with less waste, using less energy and other resources during a given period than an inefficient company.

Efficiency is measured by dividing a worker's actual output rate by the standard output rate and multiplying the outcome by 100 percent. The standard output rate is a worker's normal rate of performance or the volume of worker a trained employee can produce per unit of time using a prescribed method and with the usual effort and skill. As production efficiency increase, production costs go down. The operations strategy, technology, job design and process influence the rate of output as does worker's skill and effort (Bruce B., 1992).

2.7 Factors Influencing Productivity

Identifying productivity factors are the main element for productivity improvement. Productivity factors can either boost or hinder productivity improvement. Gruenberg classifies the factors influencing the performance of operation into four. These are process, control, product and resources. Process factors are lead times, bottlenecks, material flow, volumes, losses layout, cycle times transport etc. while factors related to control are purchasing, overproduction, total quality, location, etc. Factors related to product are design of assembly, product variants, standardization and modularization. The factors related to resources are organization, efficiency, measurement, work methods, capacity, communication, motivation, satisfaction etc. (Gruenberg,

2007). Yamfwa also shows productivity can be influenced in both internal and external factors. The internal conditions include condition of production process, labor, management firm level investment, organizational structure; marketing etc. the external influencer's performance includes national infrastructure, trade policies, good governance, political stability, demand inflation, national systems of governance (Bailey D., 1995)

2.8 Working Environment

The definition of working environment is "the physical geographical location as well as the surroundings of the workplace, such as a factory site or manufacturing area". It has proven that when employee feels comfortable with their working environment, they will perform more effectively and enjoy the working process better than those who are feel uncomfortable. Therefore, it is necessary for company to consider their employees' workplace factor carefully. Organization understand that their employees spend almost day at work, that is the reason why companies need to actions to make sure working environment is conducive for employees to be productive, satisfied and engaged in the workplace. If any company have Good Work environment it increased production and efficiency of the operation, and decreased injury rates for the operator. The Work environment design included different ideas,

1. Ideal work conditions this must improve the safety record, Reduce absenteeism and tardiness of employees, and employee's turnover, Raise employee morale, and Improve public relations.
2. Lighting this includes Visibility (clarity with which the human sees something), Glare means the excessive brightness in the field of vision, Color, Both color and texture, Use of color may improve the environmental conditions of the workers by providing more visual comfort.
3. Noise - is any unwanted sound, Temperature, Ventilation and Vibration Radiation

According to Jain (2014) the productivity of employees is determined by an immoderate level, on the environment in which they work. Work environment includes all the aspects which act and react on the body and mind of an employee.

Under organizational psychology, the physical, mental and social environment where employees are working together and there work to be analyzed for better effectiveness and increase productivity. The major purpose is to generate an environment which ensures the ultimate ease of effort and eliminates all the causes of frustration, anxiety and worry. If the environment is congenial, fatigue, monotony and boredom are minimized and work performance can be

maximized. Work has an economic aspect as well as mechanical aspect and it has also psychological aspect. Effective work environment encourage the happier employee with their job that ultimately influence the growth of an organization as well as growth of an economic. The concept of work environment is an actual comprehensive one including the physical, psychological and social aspects that mark up the working condition. Work environment performs to have both positive and negative effects on the psychological and welfare of employees. The work environment can be described as the environment in which people are working. Such as, it is very wide category that incorporates the physical scenery (e.g. noise, equipment, heat), fundamentals of the job itself (e.g. workload, task, complexity) extensive business features (e.g. culture, history) and even extra business background (e.g. industry setting, workers relation). However all the aspects of work environment are correspondingly significant or indeed appropriate when considered job satisfaction and also affects the welfare of employees.

Elements of work environment: Work environment may be divided into three broad components

1. Physical Environment: Ventilation & Temperature, Noise, Infrastructure & Interior and Amenities.
2. Mental Environment includes Fatigue, Boredom, Monotony and Attitude & Behavior of Supervisor & colleagues.
3. Social Environment: denotes to the cluster to which an employee's to be appropriate within an enormous ceremonial work group employees form casual cluster in their personal. Employees develop an intellect of belonging to their cluster. The standards and privileged of the cluster impact significantly the attitude and behavior of individual employees.

The main aim of this study is to identify the impact of work environment on job satisfaction. However the physical work environment creates the physical condition that can affect the health of employees. Yet, the way in which the mental environment creates venomous condition (e.g. fatigue boredom, attitude and behavior of supervisor and colleagues) for employees and social environment can affect the confidence level or performance of employees. So, ultimately the work environment can influence the satisfaction level of employees or else these factors can consequence the performance of overall.

2.8.1 Characteristics of Work Environment

1. Apparent and Open Communication: - In essence, it addresses the employees feel that they are appropriate in the organization. However it is necessary for staff to deliberate the organization's philosophy, mission and values.

2. Stability of Work-Life: - There has to some sort of balance between work and personal life. In general having the sense of balance will improve job satisfaction among employees.

3. Impartiality: - Employees need to identify that they are being impartially rewarded established on their performance. Impartiality means that the consequences of performance are resolute by the quantity and quality of the performance.

4. Consistency: - Consistency means predictability. Subordinates want to know how their supervisor will react in a given situation. According to management studies consistency is a single most effective standard to establish with your own leadership.

According to Chandrasekhar (2011) many managers and supervisors labor under the mistaken impression that the level of employee performance on the job is proportional to the size of the employee's pay packet. Although this may be true in a minority of cases, numerous employee surveys have shown by and large this to be untrue. In fact, salary increases and bonuses for performance, in many instances, have a very limited short-term effect. The extra money soon comes to be regarded not as an incentive but as an "entitlement". It is the quality of the employee's workplace environment that most impacts on their level of motivation and subsequent performance. How well they engage with the organization, especially with their immediate environment, influences to a great extent their error rate, level of innovation and collaboration with other employees, absenteeism and ultimately, how long they stay in the job. Many studies have revealed that most employees leave their organization because of the relationship with their immediate supervisor or manager.

There are also other factors that may impact on performance like environmental factors and physical factors. A close consideration of each of these factors is also very useful in ensuring that employees apply the skills they learn during training programs once they return to their workplace.

A positive work environment is not only important for the physical, mental and emotional health, but is also important for the product or service. The better a person feel at work, the more likely a person will take pride in her/his work functions and be loyal toward the place of employment. We have all worked at places where we were less than excited to get up and go to work in the

morning. This can be an awful feeling. It is much more pleasant, and less stressful to work in an environment that is positive and enjoyable (Queensland, 1997).

2.9 Impact of Ergonomics on workplace

Ergonomics is used to design an environment (layout, work methods, equipment, noise, etc.) which is compatible with each individual's physical and behavioral characteristics. Ergonomics looks at the behavior of the person performing the job. Good ergonomic design makes the most efficient use of worker capabilities while ensuring that job demands to not exceed those capabilities.

According to International Ergonomics Association (IEA), (2012) Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. A publication by the Health and Safety Executive (HSE), UK in 2003: "Understanding Ergonomics at Work" also defines Ergonomics as the scientific study of human work. It considers the physical and mental capabilities and limits of the worker as he or she interacts with tools, equipment, work methods, tasks and the working environment.

The publication further postulates that the application of Ergonomics to workplace improves health and safety by: reducing the potential for accidents, reducing the potential for injury and ill health and improves performance and productivity. Ergonomics permeates every aspect of human endeavor. As a result, various branches or concepts of Ergonomics have evolved and developed over the years. A well designed workstation is important for preventing diseases related to poor working conditions, as well as for ensuring that work is productive. Every workstation should be designed with both the worker and the task in mind so that work can be performed comfortably, smoothly and efficiently.

If the workstation is properly designed, the worker should be able to maintain a correct and comfortable body posture. This is important because an uncomfortable work posture can cause a variety of problems, such as: back injury, development or aggravation of RSIs and Circulatory problems in the legs.

The main causes of these problems are: poorly designed seating, standing for long periods, reaching too far and inadequate lighting forcing the worker to get too close to the work.

2.10 Work overload

Yunus (2015) points out six sources which may cause occupational stress, i.e. work overload; work insufficiency; work ambiguity; work boundary; work responsibility; and physical environment. Work overload happens when an individual experience the lacking of resources, including time and energy, needed to meet the demands of all roles. Ahmady et al. (2007) defines work overload as having too much to do and too many responsibilities to do everything well.

Different Authors explained work overload in different ways and in methods; some of them are included in this literature. According to Yano and Rachamadugu (1991), Kim and Choi (2015), Aroui, Alpan and Frein (2014), when products with rich content are introduced sussecively into a stations or assembly line, work overload can occur and work on products can be left unfinished due to the limited spare-time window for worker. And correspondingly, when it is not possible to complete the entire task/ work required, it is said that an overload is generated.

To minimizing the total overload generated or maximize the total work completed in all stations different models are developed. Work overload define as utility workers or not completed work in any station by the employee's, who either are dispatched to assist the regular workers during peak load situations, or are stationed at various points along the assembly line to complete the unfinished operations.

According to Aroui, Alpan and Frein (2014), when work overload is occurred the employees has to rush to finish his/her task on time, the risk of quality product or defects, accidents due to fatigue or health problems due to bad postures, etc. increased. The use of strengthening operators to handle the work overloads is expensive.

According to Ashfaq, Mahmood and Ahmad (688-695, 2013), Work overload affects the employees' performance and the associates of the work overload also affect the outcomes of the employees. It is case when peoples feels pressures on themselves or when the demands of a situation are largest than they can handle work. According to Khuong and Yen (April 2016) work overload was significant effect on job stress and job stress has an impacts on job performance of employees and Warokka and Febrilia (2015), job performance also defined as the level of productivity of an individual employee.

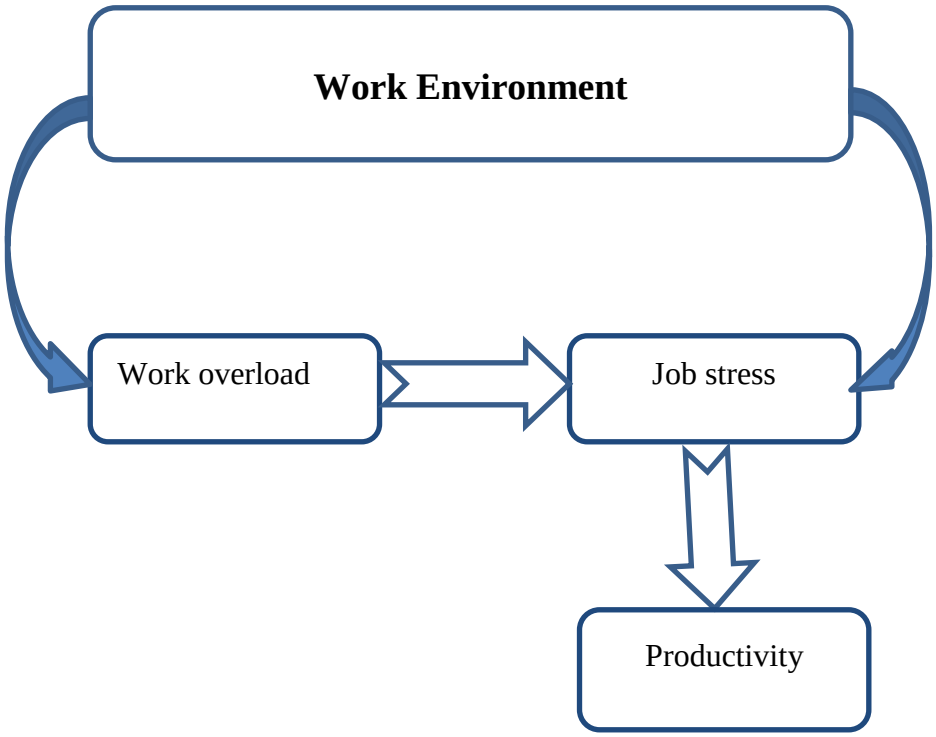

Figure 2.1:- Relationship of Work Environment, work Overload and productivity

(Source: (Sobia Ali, 2004))

The above figure shows as the work environment is direct relationship with work overload and job stress, this means the cause of work overload and job stress on employees is poor work environment. In other way work overload and job stress has impacts on employee's performance, the quality of products and productivity of employee's is decreased.

2.11 Findings of work overload in mixed model assembly line

The table below shows different findings of work overload in mixed model assembly line by using different methodology and finally the gap of the articles, journals is indicated.

Table 2.1:- Different findings of Work Overload in Mixed Model Assembly Line

No.	Author/s, year	Research objective	Methodology	Finding
1.	Zhao et al, (April 2007)	To analyze expected overload times for Mixed Model Assembly Lines	Nonhomogeneous Markov Processes with continuous state spaces.	The length of subintervals is taken to be 0.001 m; the accuracy of obtained result is high enough.
2.	Zhao et al, (2003)	To minimization of "total overload time" in mixed Model Assembly balancing	Identify major difference Identify between the research and other related MMAL balancing works. -Justify the minimization of "total overload time" as an appropriate objective in MMAL-balancing. Develop a Heuristic Balancing Procedure.	The output is Heuristic procedure for balancing a mixed model assembly line Heuristic solutions from its optimum are no more than 0.93%, 2.57%, and 5.82%, respectively.
3.	G. Heike et al, (2000),	Developing models to evaluate and understand different alternatives for mixed model assembly case of aerospace industry.	The concept of using processing rates as decision variables are applied to the labor-intensive process of assembling aircraft body structures.	Linear and nonlinear programs (Models I-III) is developed in order to evaluate variable cycle and random cycle, Model IV used to evaluate the prospect of allocating workers to different stations.
4.	Asst. Prof. Dr. Al-Zubaidy et al, (2016)	To minimize the overall make-span of multiple mixed-model assembly lines by finding the best job sequence and allocation.	Goal chasing 1 method and Heuristic balancing method	The models mix of the case has been sequenced using (Goal Chasing 1) method are generated that are scheduled for delivering the customer with production every 80.54 min (actual time) instead 92 min (the expected time).

2.12 Literature Gap

To conduct this study different literatures and study were reviewed. Different authors focus on how to minimize the work overload in a mixed model assembly line by conducting different methodology. But before going to minimizing the work overload in mixed model assembly, the researcher must have to point out two things such as identifying the factors that caused work overload and analyzing the impact of work overload on employees and on productivity is prior work. This helps to eliminate the problems that caused work load on employees in other way it increases the performance of employees and productivity. Therefore to fulfill this gap, this study is focused on enhancing the productivity of mixed model assembly line through minimization of work overload, identifying major causes of work overload, impacts assessment of work overload on employees and productivity.

CHAPTER THREE: METHODOLOGY

Detailed explanations of the procedures to be followed by the researcher have been discussed in below. This section mainly covers the approach used by the researcher to answer the research question and explain the reason why the approach was selected. The main steps of the research are the overall assessment of the company, method of data collection, data collection instrument and method of data processing and analysis.

3.1Method of Data Collection

The products of the company are military shoe, safety shoe and civilian shoe. The civilian shoes are highly demandable product by exported market and the company produce civilian shoes fully export, and it increase profitability of the company and the country. This civilian shoe has different types of shoe based on customer requirement, such as Gents, Ladies and children shoe. Based on the data gathered Gents shoe has high customer demand and it has four T model, Ashewagrf, Harber and H model.

Data collection method is the fundamental activity that enables the study to be fruitful. To accomplish this study different data collection technique were used i.e. Primary and secondary data. The detailing is presented as follows:

3.1.1 Primary data collection method: can be gathered by using several approaches in order to collect reliable and valid information; the researcher is contacted with employees of the production department of the company. The method used in collecting the primary data is discussion with target group, direct observation and face-to-face interview.

Face to face interviews is conducted in order to assess the current working condition of station and factors related to work overload and low productivity.

Semi structured questioner is used to gate relevant information and data regarding to Ergonomics problem and to identify main factors that caused work overload. These surveys also used understand the impacts of workload on their performance and productivity.

3.1.2 Secondary Data : the sources of the secondary data includes annual and monthly reports of the company, Ergonomics books, different website, past thesis, articles and journals related to the study. This help to identify how others authors defined and measured key concepts, the data sources that of others used and this helps to discover how this research is relate to other studies.

3.2 Product Selection Methodology for Local and Export

It is important to identify one or more products among the most important ones. The study conducted by selecting a single product of the company since it is difficult to address all the product types due to time constraint. In order to identify the critical product, all the shoe models are evaluated according to the market share, customer demand, number of components and number of processes. The data which is important for product selection phase is gathered from the production, design and marketing department, by an interview to the supervisors and also observing the company archive. The detail analysis is presented in chapter four (Data analysis and Result).

Table 3.1: Market Share of Major Product

No.	Major product	Market share		Planned production capacity	Actual production
		Local	Export		
1	Military	95%	5%	2300 pair/day	1762 pair/day
2	Safety	40%	60%	450 pair/day	240 pair/day
3*	Civilian shoe	0%	100%	600 pair/day	398 pair/day

The above table show civilian shoes are prioritized/ selected, because this product has gain foreign exchange from the exported market. The civilian shoes are highly demandable product by exported market and the company produce civilian shoes fully export, and it increase profitability of the company and the country. Since our country gives great emphasis to improve export-led products this study also focused on exported product which is civilian shoe. This civilian shoe has different types of shoe based on customer requirement, such as Gents, Ladies and children shoe. Based on the data gathered Gents shoe has high customer demand and it has four models which is T model, Ashewagrf, Harber and H model. Table below shows sales amount of each shoe models and number of parts and process.

Table 3.2: Sales amount, Number of Process and Parts of Gent Shoes Model

No.	Gents Product models	**Sales Amount (pairs of shoe)**			**Number of Part**	**Number of Process**
		2008 EC.	**2009 EC.**	**Total sale**		
1	Harber	11,883	37,575	49,458	13	79
2	Ashewagrf	11,377	27,939	39,316	9	68
3	H model	11,601	28,663	40,264	6	58
4	T model	11385	25,823	37,208	5	56

3.3 Data Analysis Instruments

To achieve the objective of this study, the data is collected using the above means of instruments; face to face interview, target group discussion, direct observation and secondary data were analyzed. This data is interpreted through a descriptive method of data analysis by using MS–Excel 2016 software, were used to present data in pie chart and Minitab 16.2.4 properties software is statistical analysis software used to prioritized shoes model, it answer the reason why that shoe model is selected.

Microsoft office Visio 2007 were used draw root causes analysis of work load and to illustrate and Edraw Max 8.4 the current processes layout and future processes layout which is usable to minimize the work overload through eliminating unnecessary movement and fatigue of employees.

3.4 Data Validity and Reliability

In order to construct validity in this paper the data were collected from different sources of evidence. The evidences include the direct company archive, an interview and observation at the actual workplace (Gemba). In the case of an interview, to get reliable information the objective of the study is clearly clarified for the respondents. This is important to minimize the risk of biased answers due to misunderstanding. In order to understand the existing layout system of company, actual working situation, flow of processes some pictures taken without consciousness of the employees is also done to find out the actual unbiased information.

Furthermore for the analysis of the data internal validity is built, In order to do so different tools and techniques such as cause analysis by fish bone diagram are used to give a proper explanation of the problem.

CHAPTER FOUR: - DATA ANALYSIS AND RESULT

The data gathered is going to be analyzed in this chapter furthermore the results and the discussion of the study will be presented. It contains aspects such as design complexity of products, selection criteria of shoes model, prioritized shoe model, defect rate of products, root causes analysis for the work overload, existing/old process layout and proposed layout of company, proposed countermeasure for observed problems.

4.1 Product Selection

In advance to choosing the specific product, the overall product types on which the company is currently producing are identified. The severely product type is selected among them according to a specified criteria. The selection criteria are number of process/ design complexity, number of parts, customer order and cost of products, these selection criteria are prioritized by focused group discussion. The members of focused group are production planning, production supervisors, marketing and finance departments each have represented by two persons.

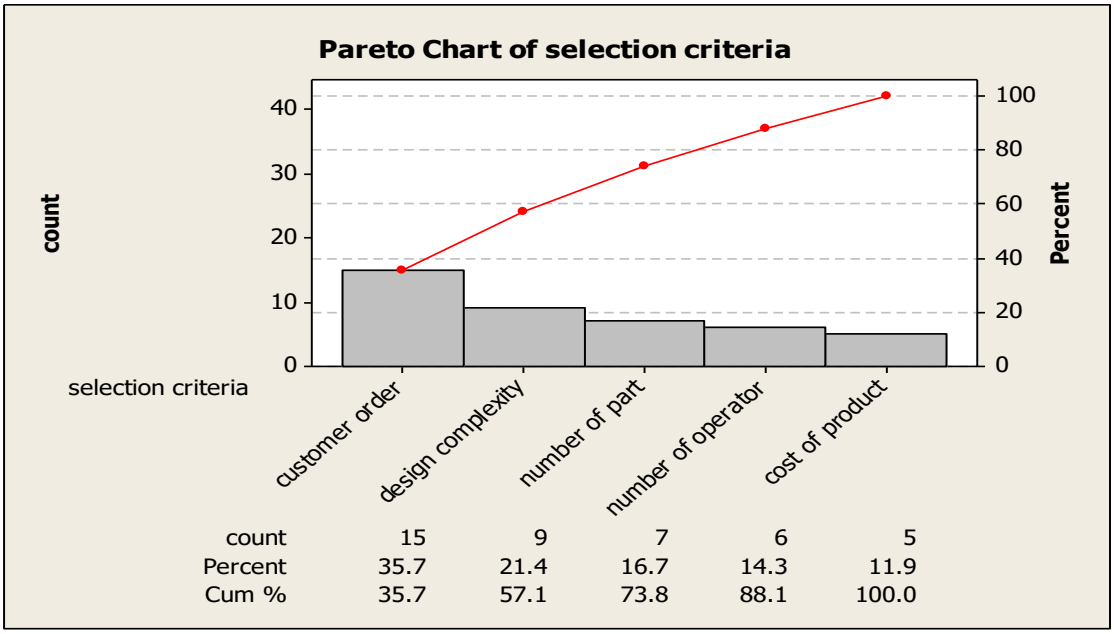

Figure 4.1:- Pareto Chart of Selection Criteria

The above figure shows, prioritized selection criteria those are design complexity, number of parts and operators, customer order and cost of products. These selection criteria are list out by focused group through discussion, based on the discussion all members' prioritized customer order. If the other selection criteria was solved or simplified it increases the productivity of

company however if there is no enough customer order it's pointless to prioritize others. Therefore, it's important to prioritize the customer order selection criteria. The next activity were prioritized single shoes model based on prioritized criteria, figure below shows prioritized shoes model

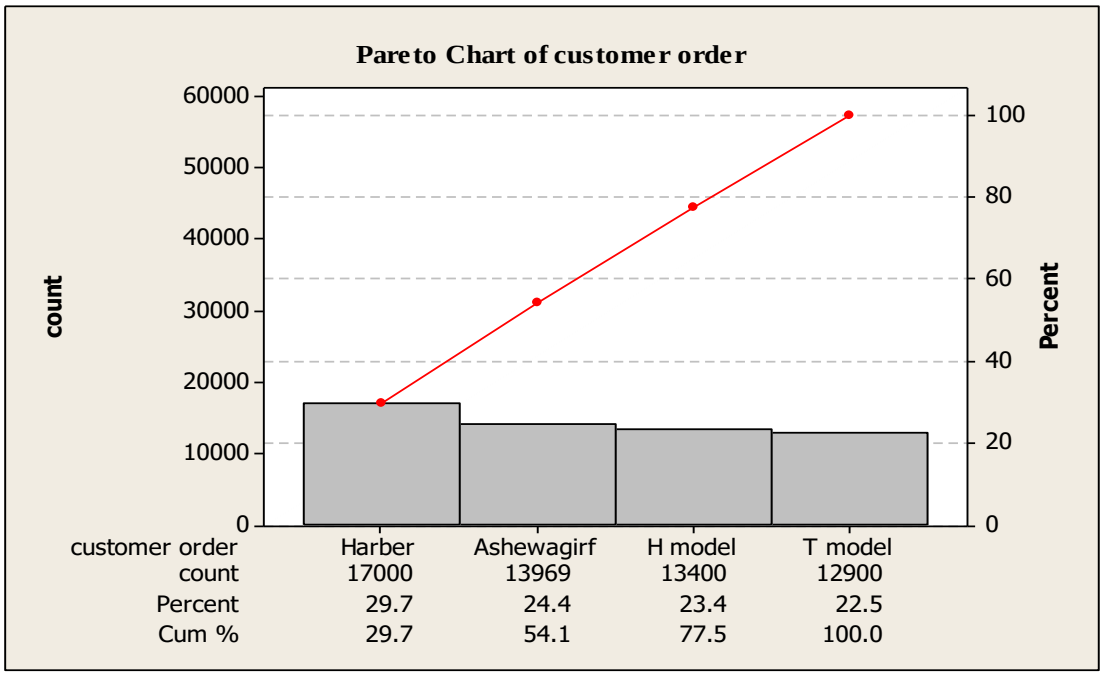

Figure 4.2:- Prioritize Shoes Model

The above figure shows prioritized shoes model of Genet Product, six months customer order data were used to prioritize single shoes model. Based on the data gathered Harber shoes model have highest count than other shoes model such as Ashewagirf, H model and T model. Finally, for further analysis Harber shoe model were selected.

4.2 Analysis of product quality

Company use daily report format for product that has been produced in each stations. The quality report checklist formats are including cutting, stitching and lasting processes. Form this report six (6) months data are analyzed to gate the current defect rate information. This product defect has occurred due to employee's stress, poor inspection within a process because of these reason different kinds of quality problems are occurred in stitching and lasting process. The problems are high rework, customer compliant and defected product can be produced.

Table 4.1: Monthly Defect rate of Products

Stations	Amount of defect per month						Total
	month 1	month 2	month 3	month 4	month 5	month 6	
Cutting	55	23	61	28	40	43	250
Stitching	141	123	157	105	74	87	687
Last and finishing	243	296	204	229	125	159	1,256

After gathering the defected product identification and categorization of defect type is the next activities. This defected product is produced by different causes and the categorization is also based on the causes such as man, material, machine and method. The below shows the categories of defected product,

Table 4.2: Categories of Defected product

Stations	Categories of defected product			
	Man %	Machine %	Method %	Material %
Cutting station	33.7	16.2	39.1	11.3
Stitching station	37.2	15.9	17.9	29
Lasting station	30	23.2	19.4	27.3
Total	**33.6**	**18.4**	**25.5**	**22.5**

The above table shows the highest quality problem or defected product caused through man it covers 33.6 % it's caused by different challenges. Therefore to reduce the defect rate and increase the production efficiency identify major challenges for operators/works is main activities, method of doing the operation and working environment must need improvements. The main cause for operators to produce defected product is work overload during this they become stressed this affected the productivity. The figure 4.3 shows that causes and effect diagram for work overload of operators,

4.3 Existing Productivity of the line

As explained in equation 1, productivity is the relationship between the output of an enterprise and its required inputs. The existing line productivity is below the benchmarked target.

$$productivity = \frac{out\ put}{Input}$$

So, existing labor productivity is

$$productivity = \frac{398\ pair\ of\ shoe}{48\ workers * 7\ hr} = 1.18\ pairs\ of\ shoe\ per\ workers\ per\ day$$

Labor productivity within existing working condition and inputs current productivity of operators 1.18 pairs of shoes per worker per day, which means they finished single piece of shoe and starts second shoe but cannot be finalized within existing period of time.

Production efficiency = actual output / planed production = 398/600= 0.66

According to international labor association the standard labor productivity of the shoe is six pairs per hour. However, the labor productivity is less than the benchmarked. Therefore, the identified major problems and causes that minimized the productivity of operators are discussed in figure 4.3.

4.4 Identifying the general factors for work overload

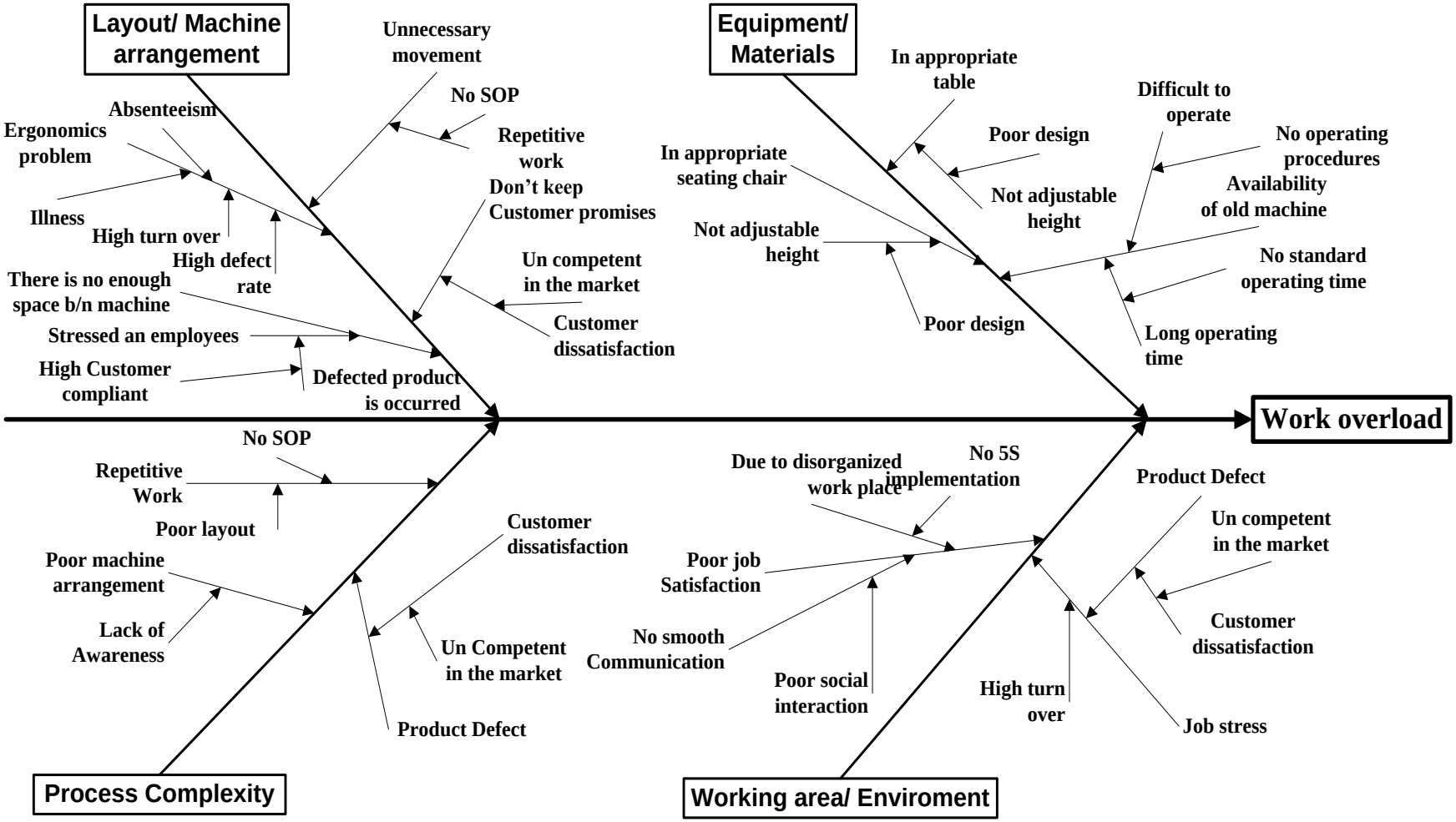

Figure 4.3: Root Cause Analysis of Work Overload

4.5 Prioritized Root Causes of Work Overload

The root causes of work overload are identified, this shown in figure 4.3. The above root causes are prioritized through interview, discussion with focus group members and selecting repetitive causes. The selected causes are discussed:

4.5.1 Layout/ machine arrangement

The current company production line layout is very compacted together or there is no enough space between each machine especially in the stitching line. In this section there are different kinds of stitching machines for example Flatbed two needles, Flatbed one needle, Post bed one needle and Post bed two needles. Company use similar layout for different design of products by this reason many kinds of waste occurred in the production line. Mostly in the production section transportation waste and unnecessary movement or motion waste are occurred. This layout problem has an impact on employee's productivity, because they become stresses during this not concentrated on their tasks so they make defected product and increase production takt time.

Figure 4.4:- Not enough space between stitching machines (Source: Field visit)

According ANSI the distance between stitching machines is must be 60cm because the worker move and work freely. As illustrate in the figure 4.4 which is stitching production section the machines are very close to each other the distance between them is 47cm it's less than the standard. This affects workers performances because of operators are not comfortable within existing working environment they cannot move and work freely.

In existing process layout of company hasn't machinery waiting area and finished product stored in every production area these also affects the movement of employees and the job was transfer from one operator to another operator manually. In existing layout there is machine and

different table which are not necessary in current production system. Due to this, workers leave their workstation and go far to take inputs they require for their work. The floor space was taken up by redundant stock, raw materials and unnecessary machines. Some of these goods have been sitting there for years, getting dusty and dirty. In this company the layout is not given an attention and the workers accept as it is correct. In process analysis table 5.5 and table 5.6 the existing layout transportation distance 28m and the time takes for transportation is 40 min these also affect employee's performance and productivity of company. Due to this layout problem delay time between processes is 17.54 minutes these also affects delivery time of products and process time.

Table 4.3: Distance and time taken by existing layout

layout	Constraints		
	Distance	**Time**	
		Transportation /Movement	**Delay**
Existing layout	28m	40 min	17.54 min

As table 4.3, due to existing layout problem operator's moves 28 m which is unnecessary movement it takes 40 min and delay time between processes 17.5 min because of constraint the company lost 57.5 minutes per day.

Existing lay out of lasting and stitching production section is draw by using flow diagram, the existing layout for military and working shoe is presented in figure below.

Representations: the shapes shown in figure below represents the following terms


Operators


Movement of material


Machines

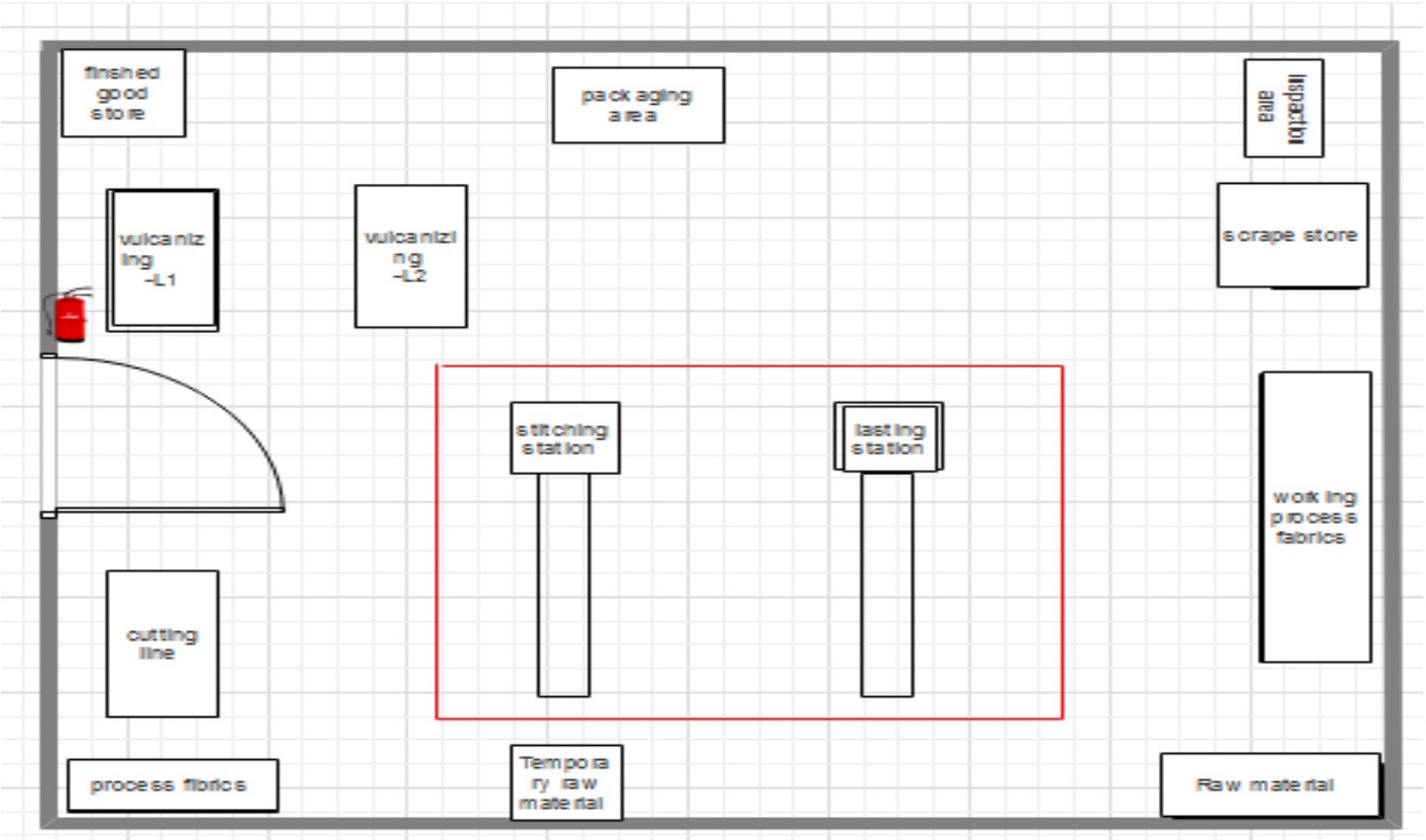

Figure 4.5:- The overall production layout (Source: Filed visit)

The above figure 4.5 shows the overall layout of production section but the analysis focused on selected area which is stitching and lasting station. The detail layout station is shown in figure 4.6.

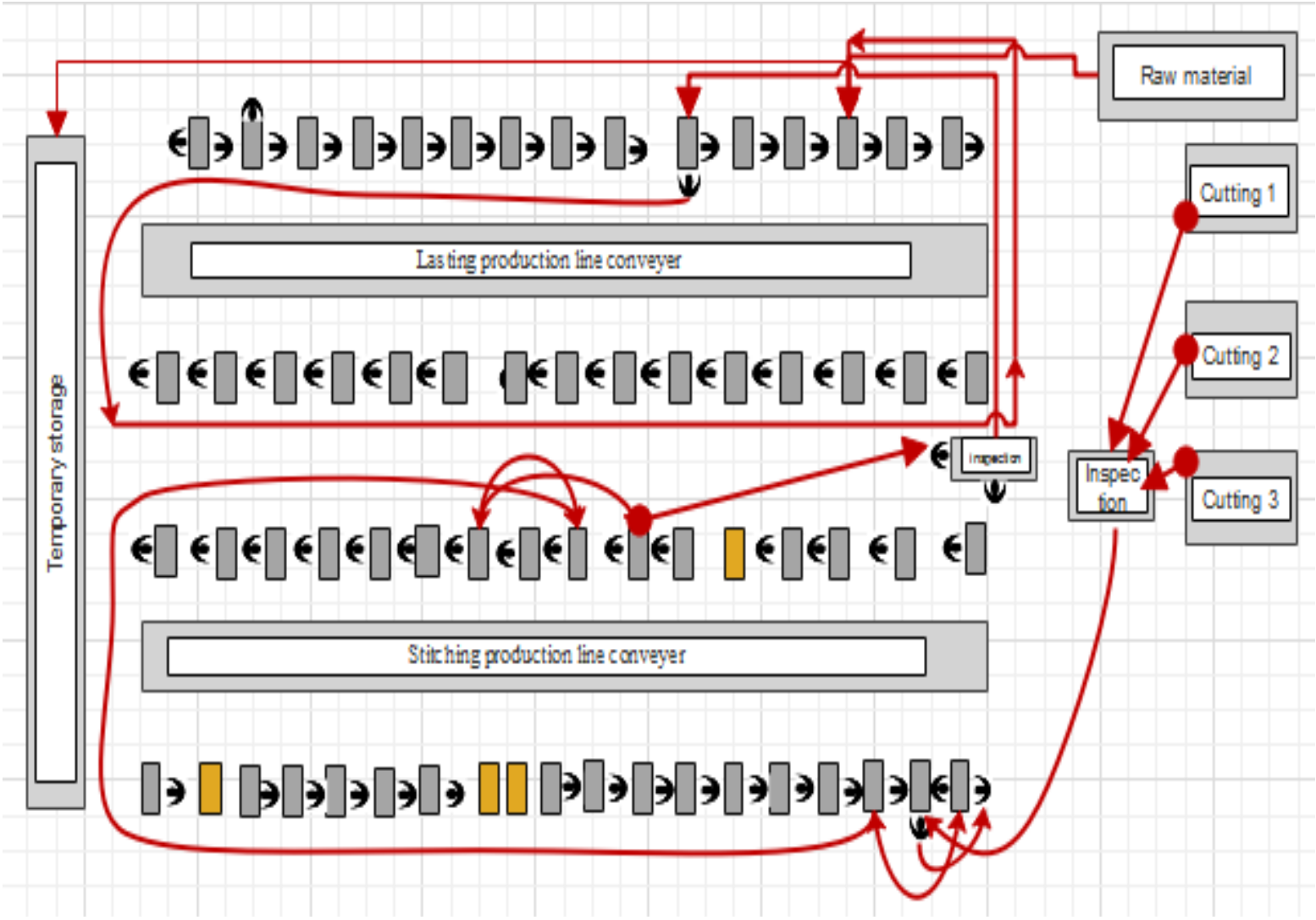

Figure 4.6:- Existing layout of Stitching and Lasting station

4.5.2 Equipment's/ Materials

Poor design of equipment/ materials are caused ergonomic hazards on operators. Ergonomic hazards causing work-related musculoskeletal disorders (WRMDs) are major problems in the shoe manufacturing industry. These hazards are due to the specialized equipment used and hands-on work requiring repetitive movements, forceful exertions and awkward body postures. BSI data show men's footwear to be one of the "industries with the highest rates of nonfatal illness disorders associated with repeated trauma" (BSI 1995). The incidence rate for the total footwear industry for illnesses and injuries combined was found to be 11.9 per 100 workers, with 8.6 being the incidence rate for injuries alone. These rates are slightly less than the incidence rates for all manufacturing (Parter, 2011). Shoe manufacturing (Cutting, Sewing/Assembly and Finishing) Ergonomics, the term "Manufacturing Ergonomics" refers to the application of ergonomic principles in a manufacturing environment. In a typical footwear factory, cutting area activities may involve loading product material on to spreading machines, cutting through multiple layers of material, numbering individual product parts, and manual lifting.

In the assembly area/sewing, workers are often required to perform repetitive tasks while in a seated position. During various manufacturing operations, the worker might apply static force to match work parts while sewing, twisting and bending to bring parts to a machine, bending wrists in non-neutral positions to maintain part alignment, and engaging in other poor work postures.

In the finishing area, workers typically stand to perform pressing operations, folding and pinning activities, and bagging/boxing of finished products. Ergonomic stressors include standing for long periods in fixed locations, heat exposure from pressing equipment, working in a bent position, and working above shoulder height. Mostly in the lasting process different operation is not comfortable to done the activity in terms of human activity (motion).

The main selection criteria for lasting and stitching operations are difficulty and unconformable work because long time standing work and seating work by this the long working time without sufficient rest and changing different task this operation had effect operator health condition. The worker/operators spent long time to perform their activity this means all working hour and every working day. Generally the company working day five and half (5and1/2) and the working hour per day 7hr. this detail description one worker on the sewing operation and ironing operation spent 39hr/per week so it's difficult.

Commonly in the footwear industry seating and standing works are done continuously and repetitively. From those processes stitching and Adhesive process are categorized under seated work, whereas Cutting, Lasting and finishing are performed by standing position.

1. The existing seating position in stitching table and chair

From equipment's/ materials effects seating chair and table is prioritized through questioner, include all seat work involve in the production section operators. The number of total workers in seating work is 56 workers, 48 Women and 8 Men. From those target works/operators 92.86% is not comfortable with in existing seating chair and table. Currently, company is not use appropriate equipment such as seating chair and table.

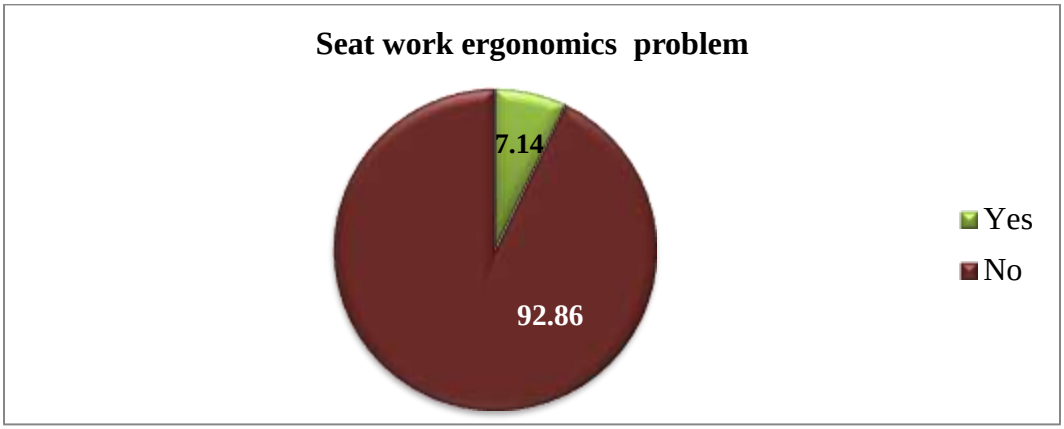

Figure 4.7:- In appropriate seating position, table and chair (Source: Field Visit)

The chair is a critical piece of equipment for sewing machine operators who work in a seated position. It has a very large impact on the comfort of the worker, reduce production efficiency and work motivation and can affect the risk of muscle pain and injury. As shown in figure 4.7, operators are provided with chairs like stacking chairs. These chairs do not provide

back support and has no castors, so it does not make operators slide away from their work place. The incorrect posture of sitting on stitching machine also causes trouble for spinal cord as a result of bending forward constantly. It also occurs due to lack of training and education to the workers. The existing chair height is 46 cm, width 30 cm and length 45.7 cm. It is out of the standard sated by ANSI.

The measured angle of inclination of the spine in the below figure was more than 20 degrees, which is higher than the permissible limits, The angle of inclination of the spine should not exceed 20 degrees, otherwise it will cause back pain. By continua ting this situation while stitching; workers in the leather industry will be led to many troubles, which will affect their health.

2. Assembly tasks are very repetitive and provide the operators with little opportunity for rest. Many operators perform only one operation with no job rotation. The repetitive nature of the job was made worse by other workers delivering unfinished fabrics to the operators.
3. Standing position of operators

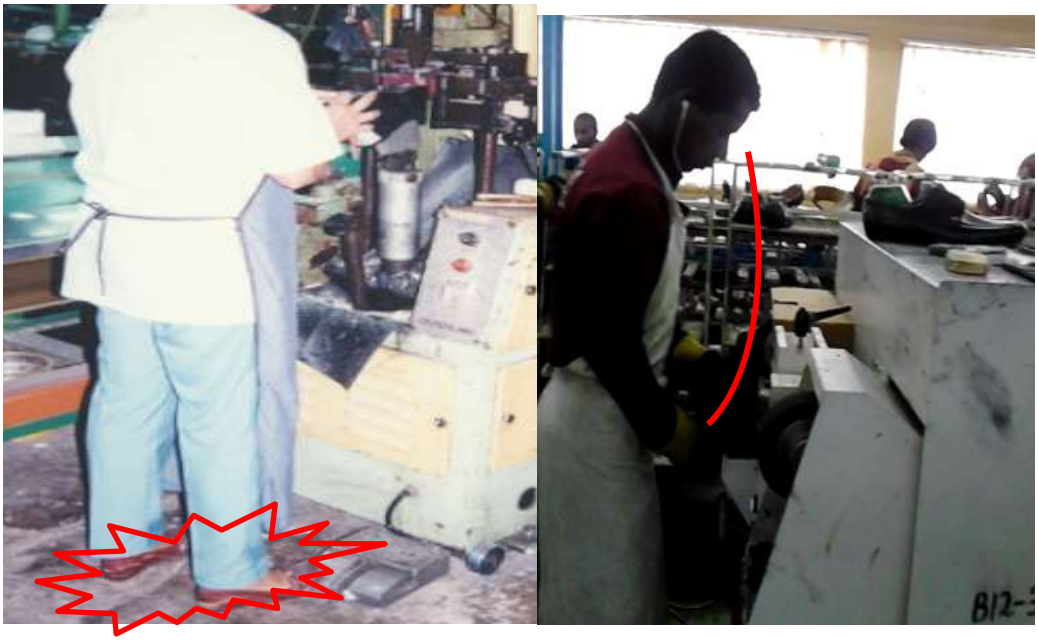

Figure 4.8:- Poor standing position of operators (Source: Field Visit)

Appropriate standing position is critical for lasting machine operators who work in a stand position. As figure 4.8 the way of operating affect the operator health condition mostly neck and foot. The company is not considering standing position of operator not comfortable for worker and acceptable in ergonomically. Based on the current situation of company questioner developed and fill by relate work involve worker and analyze the current agronomical problem.

The overall worker involve in the standing operations mostly the lasting process more operations are done by stand so this questioner include the all stand work done. But from the stitching process two operations are done by stand so included. The number of operator which answers the question is 48 from two stations. From those worker 64.4% who work in stand answer yes, this means there is high ergonomically problem and not comfortable for the task done. Workers performances can be affected by ergonomic problem and reduce their speed and quality of product.

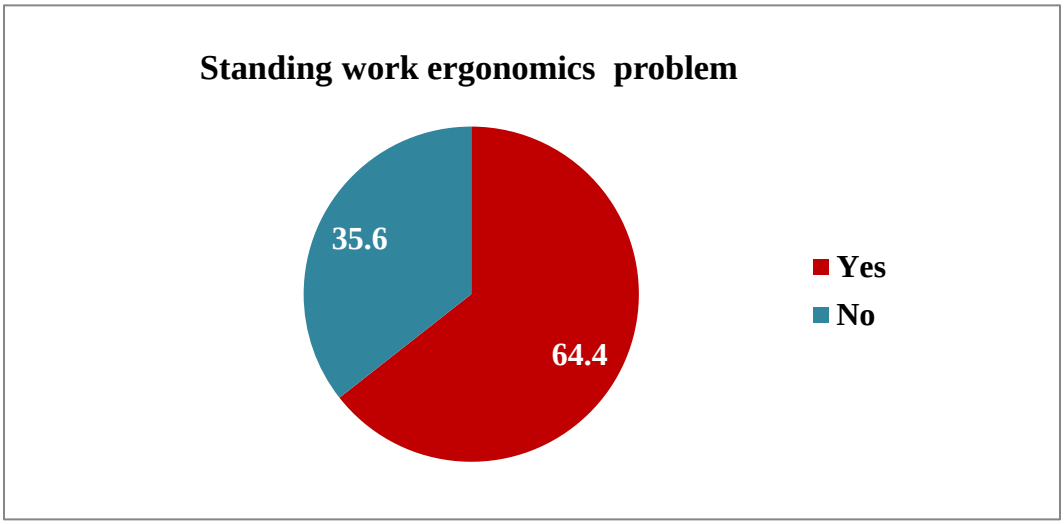

Figure 4.9:-Ergonomics problem of standing work

Health Effect due to Ergonomic Risk from Standing Work

Inappropriate design of standing workstation may create risks to the operator's body system due to:

A. Localized fatigue that can cause pain and discomfort to the muscles of the back, neck and shoulders; and the joints of the knees, ankles, hips, shoulders, and elbows.
B. General fatigue that results in reduced physical ability to perform a task and reduce the concentration level of employees.
C. Overexertion to the musculoskeletal system.
D. Injuries to the employee such as slipped disc, tendonitis, sprained back, and others,

Identifying common hazards

The study of ergonomics has identified a number of tasks and positions that are most likely to lead to cumulative trauma disorders and other physical problems. Among the risk factors for cumulative trauma disorders of the arm and hand are:

- ✓ Repetitive activities – making the same motion over and over. The longer you repeat the same movement, the greater the risk.
- ✓ Forceful exertions, particularly with the hands. The combination of repetitive motion and force, such as pushing on a tool over and over, is a particular risk.
- ✓ Staying in the same position, whether seating or standing, for an extended time.
- ✓ Awkward body postures, such as reaching above your shoulders or behind your back or twisting your wrists to perform tasks.
- ✓ Continued physical contact between hands or arms and a work surface or surface edge.
- ✓ Excessive power tool vibration.
- ✓ Hand tools that either don't fit the job or don't fit the hand.

Poor ergonomics can also injure the back. Among the factors that raise the risks of back injury are:

- ✓ Bending continually from the waist.
- ✓ Lifting from below the knees or above the shoulders.
- ✓ Twisting at the waist, especially while lifting.
- ✓ Lifting or moving objects that are too heavy or awkward.
- ✓ Seating for long periods of time, especially if you have poor posture.

4.5.3 Working Area/ Environment

The quality and amount of product produced by employees are influenced by the work environment while poor environmental conditions can cause inefficient worker productivity as well as reduce their job satisfaction. The work environment plays a big role if the organization would like to maintain better productivity as many employees spend most of their time on generating activities in the organization.

In the production section poor working environment affects quality of row material and finished product and made scrap on the row material. Working environmental factors contribute to employee's productivity, quality output, level of wastage and rate of turnover.

Figure 4.10:- Disorganized work place (Source: Field visit)

Working place is poor and not attractive for employees this affects their motivation the main cause of this problem there is no 5S implementation within the production section. Other causes are the company has high customer order and the defected products are high, and management decision is not fast on defected product either to rework or to transfer in the store. The rework product mostly the upper part and final product. The rework product characters in the shoe factory disassemble the defected upper part and that rework product start from the cutting up to the lasting and finishing process. The company not committed for all this rework process this caused the defect product stayed in the production line and it affects work place. at the end company doesn't meet customer delivery date by different reason at this time the finished product wait in the production line so this system made the line missed work place and not attractive to work for worker.

Mostly the finished products are waited more time in the production area this made lack of free space and poor workplace management. The other thing is material of shoes are not placed properly so working environment not comfortable for transportation of the raw material and working in process parts.

Generally, the place arrangement of company is very poor, the employees gives different reason for the absence of 5s implementation there is high customer order so we are busy to implement 5S. But the absence 5S implementation caused different types of waste in the process. Wastes are affect product quality, productivity of employees and increase operation time this affects deliver date of customer and increase the production cost.

Figure 4.11:- Unnecessary materials around machine and poor working table (source: field visit)

As it is illustrated in figure 4.11 working table is not attractive and motives for work. The working environment affects the work motivation and operator efficiency this means decreases the production efficiency. Working environment is directly related to production efficiency and operator productivity.

4.6 Proposed Solution

4.6.1 Improvement Model

Based on literature review and company review or data analysis productivity improvement model were developed. The model shows the relationship between causes of work overload and job stress, its impact on quality of products and delivery time and productivity of company. The proposed solutions below are focused on area of main causes to solve and to enhance the productivity of company.

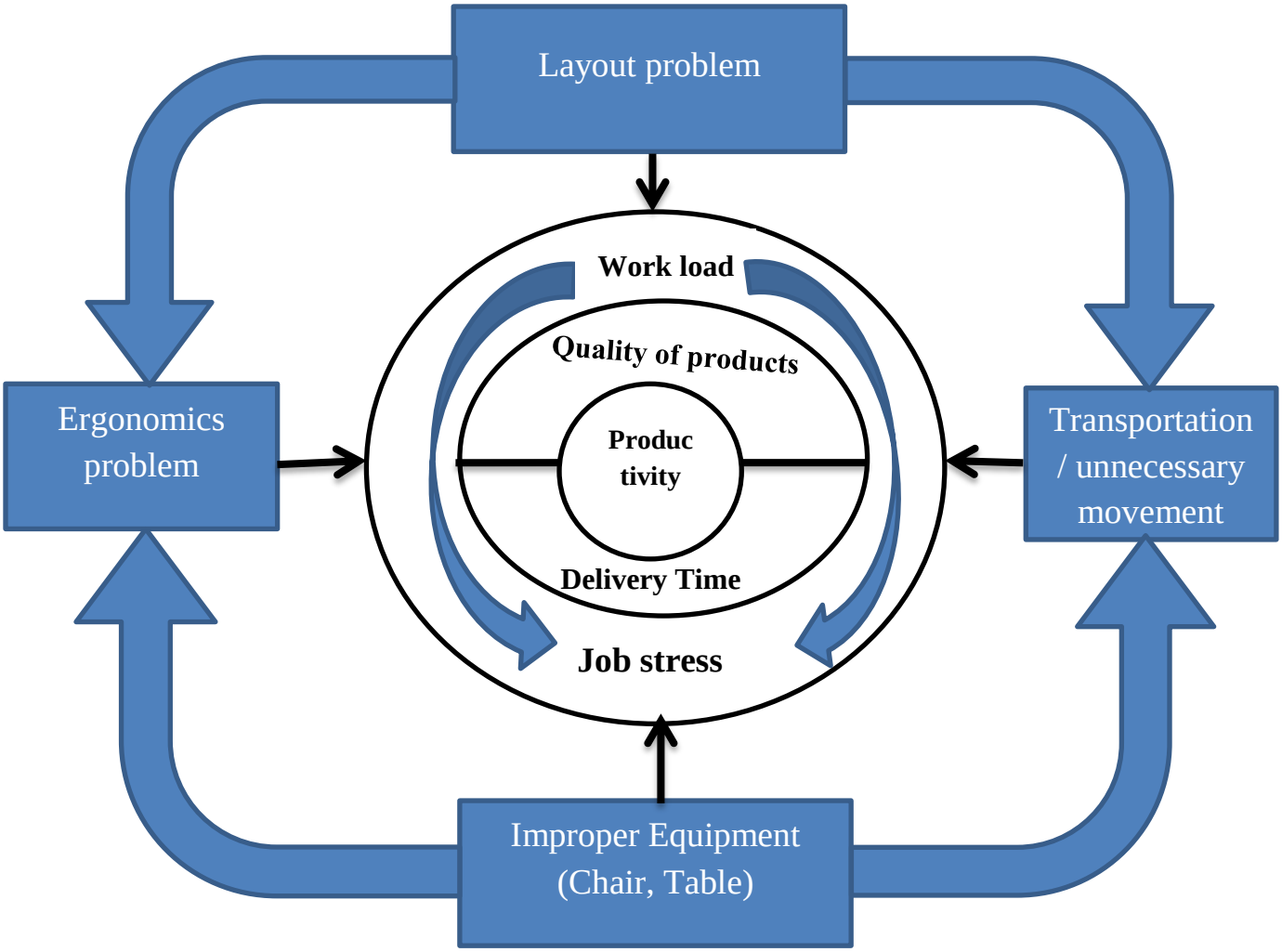

Figure 4.12:- Proposed model for productivity improvement

As illustrated in figure 4.12 layout and ergonomics problem, transportation or unnecessary movement and improper equipment which are chair and table are the main causes for work load and job stress. These work overload and job stress have an impact on product quality and

delivery time because employees are not comfortable and they cannot be productive within existing environments. In other way working environment and equipment affect employee's health condition these also contrary with context of "employees are a big resource for company". Within this condition the produced product cannot fulfill customer's requirement, increase defect rate and it affects delivery time or punctuality of company, also affect employees efficiency and company productivity.

4.6.2 Improved Layout

Plant layout is one way to reduce the cost of manufacturing and increase the productivity. Also increases good workflow in production route. The principle of ECRS was adapted to reduce the waste and arrange the repeated steps, resulting in changes in plant layout and staff workload. Facility layout design has major influence on plant production. The purpose of layout design is to find the most effective facility arrangement and minimize material handling cost. Plant lay out is one way to reduce the delivery time this means increase production time. The efficiency of production depends on how well the various machine, production facility located in a plant. Good plant layout is facilitate production process, minimize material handling, time, cost and allows flexibility of operations, easy production flow, makes economic use of the building, promotes effective utilization of manpower, and provides for employee's convenience, safety, comfort at work, maximum exposure to natural light and ventilation. It is also important because it affects the flow of material and process, labor efficiency and control.

The layout problem is affecting the company productivity. The improved (alternative) layout is more benefit according to the reduction of transportation, motion waste and to minimize the work load of employees. To rearrange the machine company use different kinds of layout or machine arrangement depends on the product type. Improved layout is greater than the existing one by machine arrangement is more consider the worker ergonomics more comfortable.

Layout improvement

Proposed layout sorted out machineries which are not necessary for current production system and temporary storage of fished product are placed in specified and appropriate. The benefits of the propose layout reduce the distance of transportation and unnecessary movements from 28 m to 14 m, this means the company gates 4 m^2 free space from the overall transportation distance and reduced the transportation time from 40 min reduce to 17min, and the delays time because of transportation or unnecessary movement is minimized form 17.5 min. The operation time of employees is increased by 23 minute and 17.5 minutes total saved time is **40.5 minutes** these also increase the output of company by **38** pieces of shoes per day.

Table 4.4: Comparison of layouts

Alternatives	**Constraints**			
	Distance	**Time**		**Free area**
		Movement /transport	**Delays**	
Alternative one (Existing layout)	28m	40 min	17.5 min	-
Alternative two	14m	18min	0	$4m^2$
Outcome	14 m	23 min	17 min	

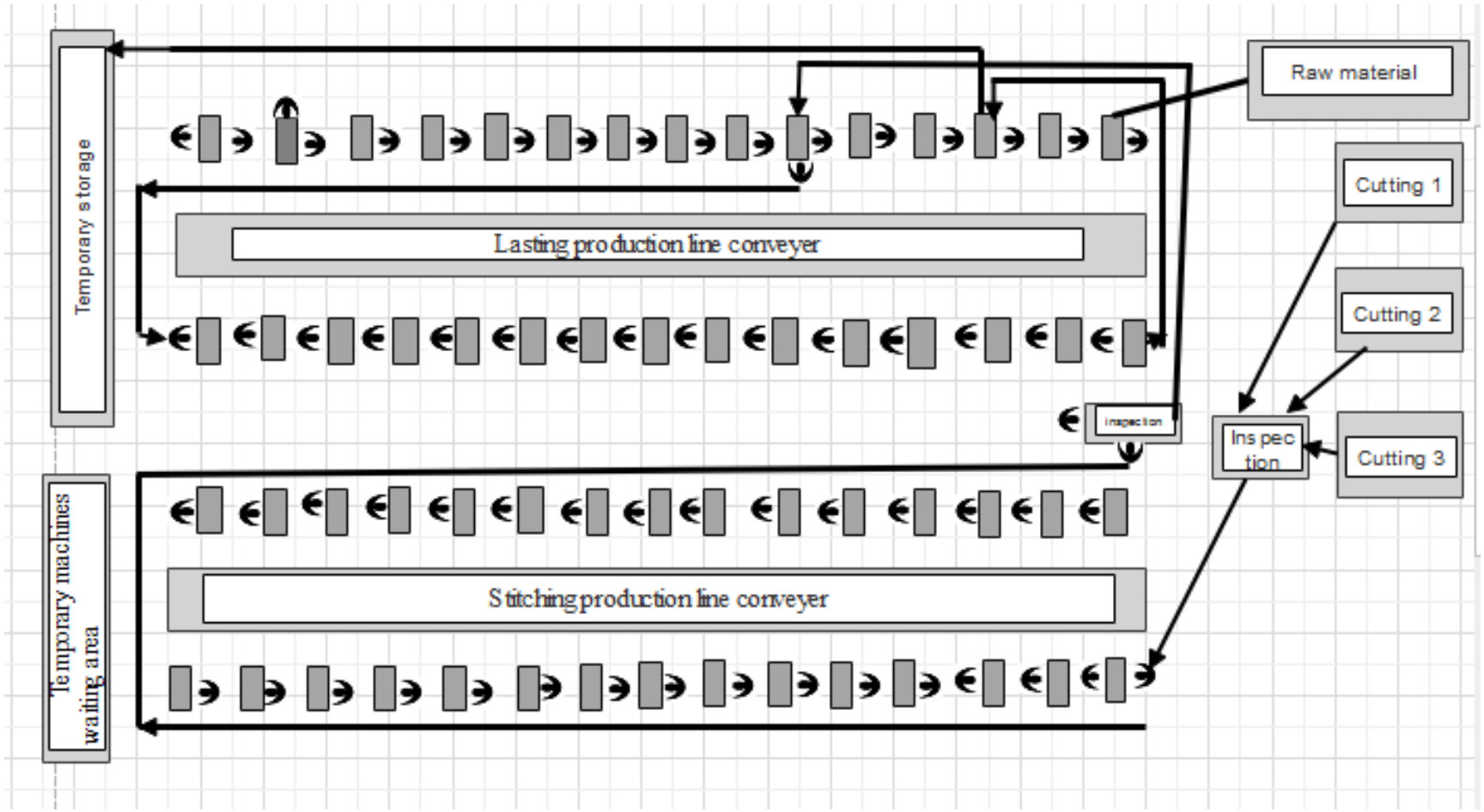

Figure 4.13: Proposed layout for stitching and lasting station

4.6.3 Ergonomically Designed Workstation and proposed Chair and Table

In this case company employees encounter several risk factors at stitching workstations such as awkward arm, neck, trunk, and leg postures. These postures are influenced by the size of the worker and the design of the workstation. This section proposes ergonomically designed workstation to eliminate work related problems of the existing system.

Workspace Design

The research used a universal anthropometric data for designing a work-space for representative of the population. There are three principles for applying anthropometric data to specific design problem. Each applies to a different type of situation - design for individual, designing for an adjustable range, designing for average. In case of Tikur Abay Shoe Company both male and female workers are working so; the design is for the average workers.

Workstation design

As discussed in section 4.5.1 in stitching section the operators perform their job out of the working area. They also live and go far their work to take materials for their work. It crates musculoskeletal disorders on worker health.

As illustrated in figure 5.5 the research designed the stitching work station based on OSHA recommendation. The actual work should be done in normal work area. In maximum working area the work cannot be done but it used for locating materials and tools. In the proposed work station materials and equipment place within maximum working area. So these proposed work stations eliminate this awkward movement and transportation of workers.

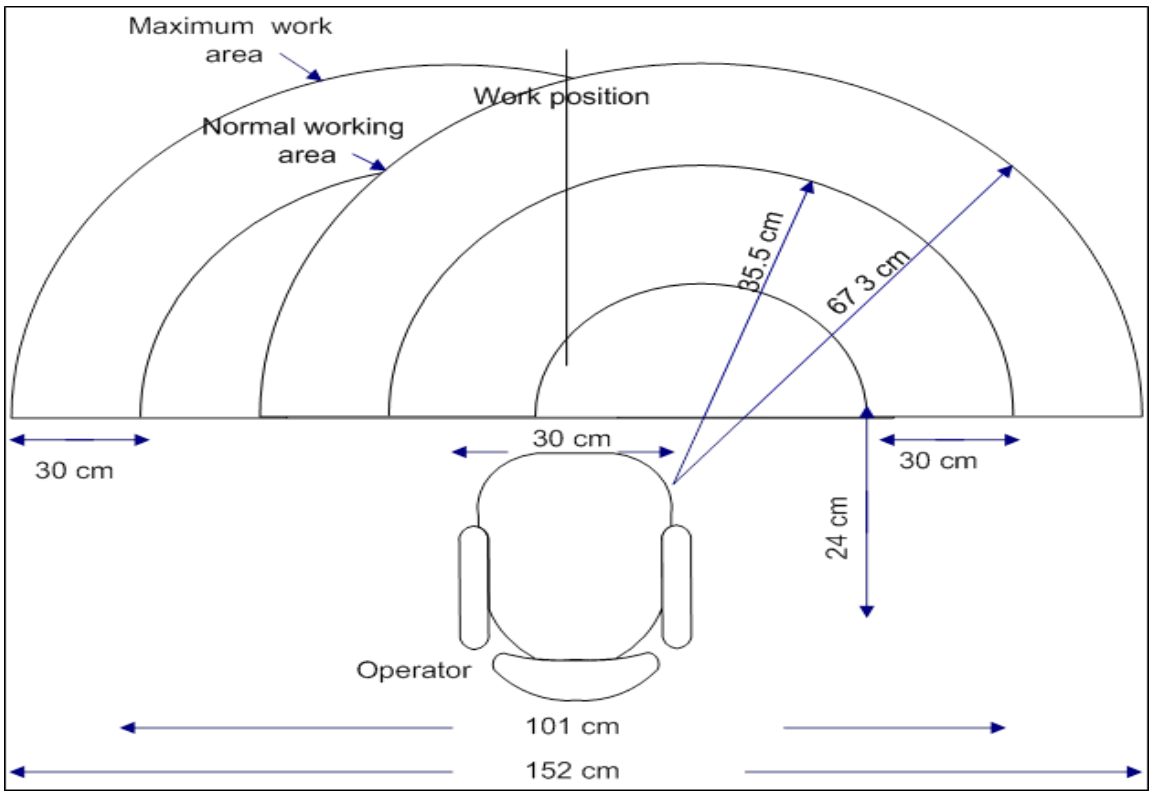

Figure 4.14:-Proposed Stitching Work Station

Stitching chair design

Ergonomically comfortable chairs and tables are very important to increase productivity and worker motivation. Seating work ergonomics materials designed and suggests the right position of workers and to reduced workers health problems and work load.

Seat pan height and Slope

According OSHA 85% of the stitching section workers are females. So the design of seat pan height is the 5th percentile female popliteal height. But at that height a female of near 95th percentile could feel discomfort, so the height is 95th percentile female height. Hence, 95th percentile Female popliteal height dimension is 46cm. This is within the ANSI recommendation and should be a good design choice.

Seat depth and width

The 5th percentile female buttock to popliteal length is 54.1 cm. The width should be set to be suitable for large persons. As, female have higher hip breadth than male, so, 95th percentile Hip Breadth Female, 45.72cm was taken.

Seat back

While designing seat back, the factor of supporting the lumber vertebras comes first. But the location of the lumber support with respect to the level of lumbar spine (L1-L2 or L4-L5) does not seem to be of importance. This finding suggests that a height adjustable lumber is not necessary since the height of a fixed lumber support can be optimized to contact the lumber spines of a wide range of users. So, ANSI recommendation for the lumber support can be followed. The support should be 16 to 22 cm in height as recommended by ANSI, which will work both as lumber and limbo-thoracic support, 30cm in width (ANSI recommendation is minimum 30 cm) and should be 16cm (ANSI recommendation is 15.2 to 25.4cm) above the seat reference point. ANSI recommended seat pan angle range is 90^0 to 105^0. More than 90^0 angles should be only used when used with a tilted work-surface.

Correct lumber support can be achieved by using extra cushioning to form a lumber pad (slight softer than the seat pan cushion) or, by contouring the back rest. Back rest should be protruded to 4 to 5 cm forward to support the lumber region perfectly. So, a 4cm thick non-contoured cushion serves just as perfect and at the same time cost saving.

Hand rest and foot rest

No hand rest is needed as the hands are always at the work surface, which is just as the elbow height. Again foot rest is also not needed as working table provides a pedal (to operate the sewing machine by foot), that automatically serves the purpose of foot-rest.

Back Support: -A back rest should be added with the existing set-up, which will support the lumber region of the operator. It can be made at a low cost by bending a pipe to a desired shape, which have a cushion of approximately 4cm thick attached with it and then by attaching the structure with the existing set-up

I. Stitching table design

Table height

Stitching table height should be sitting elbow height plus sitting popliteal height of 95th percentile male (29.5+49.5=79cm) suggested that the height should be reduced by 4cm. Tilting Sewing Table should be 15^0 tilted towards the worker (ANSI recommended). So that he or she can maintain the correct trunk posture. This is also helpful to get relief from neck and lower

back pain. Stitching Table width and length is not concerned in the discussion, as the machine position is fixed in the table and operator has only put his hand there for sewing.

Table angle: - Stitching tables that used in case company were not tilted towards the operator. Stitching table can be tilted up to 15^0 by inserting wedge shaped blocks or by using strips under the legs of the table.

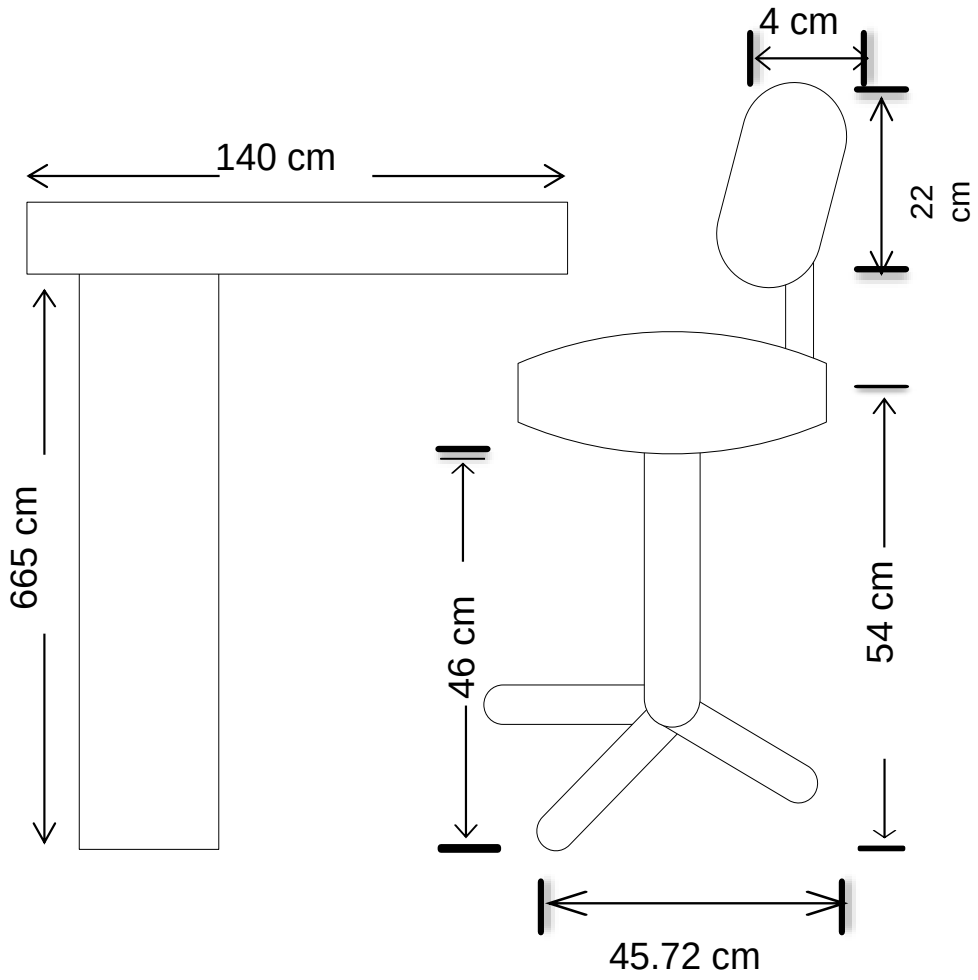

Figure 4.15:- Designed stitching table and chair

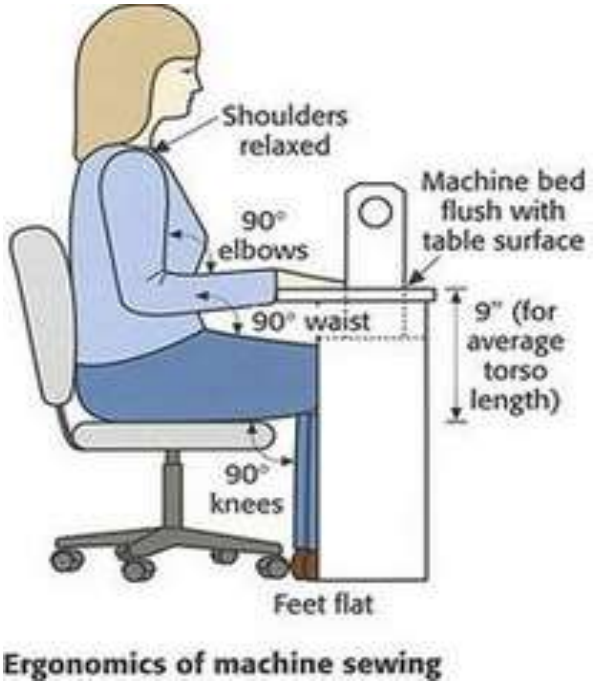

Figure 4.16:- Correct position of sewing operation (source: websites)

II. Standing work

The main problem of the standing work is employees stay for long period of time to perform their task within uncomfortable environment. But the company doesn't support the employees regarding too comfortable materials especially for standing operators. So recommendable footwear for standing work is,

- ✓ Your feet can only be as comfortable as the footwear permits.
- ✓ Choose the shoes that provide a firm grip for the heel. If the back of the shoe is too wide or too soft, the shoe will slip, causing instability and soreness,
- ✓ Wear shoes that allow freedom to move your toes, Pain and fatigue result if shoes are too narrow or too shallow.

Recommended regarding floors in a workplace

Keep work areas clean, Avoid standing on concrete or metal floors, appropriate materials for standing work is wooden, cork or rubber covered floors, ensure that the floors are level and non-slippery, and cover concrete or metal floors with mats. Slanted edges on mats help prevent tripping and do not use thick foam-rubber mats. Too much cushioning can cause fatigue and increase the hazard of tripping.

Different tasks require different work surface heights:

Precision work, such as writing or electronic assembly – about 5cm above elbow height; elbow support is needed, Light work, such as assembly-line or mechanical jobs – about 5-10 cm below elbow height and Heavy work, demanding downward forces – from 20-40 cm below elbow height.

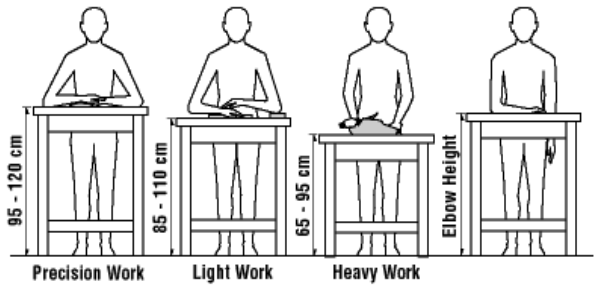

Figure 4.17: Correct standing position

Figure 4.18: Proposed seat- standing chair for standing work

The above figure 4.17 shows more comfortable to design for lasting process quality controller, adhesive ironing, creaming and brushing and others similar activity considering this designing standard. The other important point is the chair ergonomics to recommend for simple and standing operation. This type of chair is adjustable and rotates 360^0 to comfortable for operators, they can use by their interest height and inclined degree. The leg part of the chair made from rubber and weight is light makes it easy to move.

4.6.4 Working Environment

Work place arrangement of the company is poor and not comfortable for operator. Uncomfortably of worker decreases their motivation and it affects work efficiency this means indirectly increase or decrease production efficiency of company. The other problem is layout or current machines arrangement does not facilitate high productivity. Whilst some machines are located close to each other, others are scattered either within the workshop or between different locations.

Therefore main solution for disorganize work place is implementing kaizen philosophy within organization. KAIZEN can be built in and run with an integrated and company-wide approach through the collaboration of all the levels of the organization that are top management, middle managers and front-line employees. To implement kaizen philosophy we use implementation

methods and technical tools. The technical tool is 5s, is the foundation, the building blocks, for a "Kaizen" approach to incremental improvement. 5S focuses on the elimination of wastes in the work environment. Basically 5S activity is very important to organize and to keep workplace comfortable.

Implementing the philosophy isn't warranty because in previous three years the company was starts the implementation but not sustained. The main thing is not about starting the implementation sustaining is the major activities. To restart the implementation it needs motivation and commitment of management and workers.

Steps of kaizen implementation

1. To give training for management and worker.
2. Organizes kaizen promotion team:- include high level and middle level managements
3. Implement through implementation step.
4. Sustaining: by giving motivation and recognition for each activity.

4.7 Productivity of proposed solution

As explained in equation 1, productivity is the relationship between the output of an enterprise and its required inputs.

Current input time 7 Hr. or 420 min within this time they produced 398 pieces of shoes, so time saved from proposed layout 23 min and by eliminating delay time 17.5 min is saved, total time saved 40.5 min. Within this time operators produced 38 pieces of shoes per day,

In proposed solution the output of company increased by 38 pieces of shoes per day and minimizing or eliminating 33.6 % of defected product which is caused by operators. 33.6 % of defect is 123 pairs of shoes is eliminated, total increased 161 pieces of shoes. The productivity of line comes,

$$productivity = \frac{out\ put}{Input}$$

So, productivity is

$$productivity = \frac{934\ pair\ of\ shoe}{48\ workers * 7\ hr} = 3\ pairs\ of\ shoe\ per\ workers\ per\ day$$

Production efficiency becomes 88.9 %, it increased by 28.19 %.

Productivity increase can achieved by improving the output and improving/eliminating defected product; that is, by producing more output, or better output, with a given level of input resources.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The main objective of this research was to identify the major problems that caused Work overload and assess the impact of work overload on employee's productivity in Tikur Abbay Shoe S.CO and to propose solution that minimize the work overload.

The literature explains the various aspects of the methodology and the importance of each step to get the insight of the production process and Observing existing working condition and defected product flow process chart were the core methods to collect the necessary data and to enrich at analyzing and discussing the results. The analysis and discussion addressed the objectives of the study. According to the pre-study and analysis, the results shows that there is poor work place design, unbalanced work load, high fatigues on workers, poor work motivation and not attractive work station in the stitching and lasting section of the company.

The design of workstation must consider ergonomics and law of motion economy. By redesigning the work station non value adding task like searching selecting, transportation and motion waste others. By improving the current layout reduce work load of operators, operation time & fatigue. Poor ergonomically designed work station lead to fatigue in effect may reduce the productivity and efficiency.

Finally, improved process layout, working equipment and working environment reduced unsecured motion this also improved work load of employees and amount of defected product. The transportation distance is reduced from 28m to 14m and improved working equipment's such as the table and chair reduced workers fatigues. Using ergonomics principle improves the current company using chair and table and reduced workers health problem, work load and working environment become comfortable. These also improve 33.6 % of defected product which is caused by man and labor productivity are become 3 pairs of shoes per worker per day and production efficiency increased by 28.19%, therefore, it can be concluded that the proposed solutions are valuable to the factory.

5.2 Recommendation

The research assessed the working environment method of the company as well as company production efficiency problem finally concluded by proposing new working method and developed by applying elimination, combination, and rearranging techniques and improved layout new work method propose as a solution in the above section. The following recommendations are proposed for Tikur Abbay Shoes Share Company based on the outcome of the paper.

- Improve the production area layout, daily update accordingly the product type and use machinery.
- Implement the research agronomical proposes materials; it needs more attention by management level because it does require some investment.
- In order to have improvement in the company working environment comfortable and attractive. Implement Quality Environment properly by following the kaizen implementation techniques. This implementation requires commitment all company community and continuously implement.
- Company must be developing motivation method this means prepare bounces, over time and other worker motivation system apply.

Therefore, based on the conclusion drawn the researcher recommends the implementation of proposed layout and using proposed ergonomic equipment's minimize work load of employees and increase quality of products and productivity of the company.

5.3 Future work

Realizing the possible benefits of the study, the research can go further to conduct an analysis on the whole production lines and product types on the company. The study has been conducted for Harber model shoe process flow. In the future the study can be deployed for different models of shoe. As illustrated in fishbone diagram there different causes which are not addressed in this research so addressing others cause such reducing complexity of process and developing SOP etc. are future activities.

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APPENDIX

Appendix 1- Interview Questions

Addis Ababa University

Addis Ababa Institute of Technology

School of postgraduate in Industrial Engineering

Interview for Tikur Abbay Shoe S.co

I would like to express my gratitude for your committed cooperation. The interview is part of my research paper for the requirements of MSc in Industrial Engineering. I am conducting a thesis work under the idea of productivity by assessing impacts of work overload on employees therefore, I assure you that the information obtained from this interview will be kept confidential and also will not be transferred to other parties for any other purpose.

Generally the production plan per day, types of shoes model, number of process for each shoes model, defect rate or rework information products in two station, number of shifts per day, working condition of production section are specific questions which has been asked are shown below,

A. Questions for Company Managers

1) What is the total number of employees in the company?
2) How many hours per shift your employees work?
3) What are the main factors that influence the employee's productivity?
4) What is the daily production plan and actual production for each shoes model?
5) Which product model is more demanded in export market?
6) How do you try to achieve a daily/ annual production plan without customer compliant?
7) What are the major quality problems which occur in each Product model?
8) What are the major causes for quality problem products in your company?
9) How much does it covers?
10) Is there employees turn over from production section? Do you study problem of turnover?

B. Questions for employees

1. What is the number of employees in two stations?
2. Which product model has complex process?
3. Please explain the impacts of working condition on employee's performance and productivity?

……

……

4. Does the actual production meet the target per person? If your answer is no Why?

☐ Yes ☐ No

……

……

5. Did you complete your task during an average time? If your answer is no Why?

☐ Yes ☐ No

……

……

6. Does work environment/ condition is comfortable to perform your task? If your answer is no why?

☐ Yes ☐ No

……

……

C. Questions for Ergonomics problem

Table 5.1: Ergonomics Questions for Seat and Standing Work Performed

No.	**Question for seat work performed**	**Yes**	**No**
1.	Are the armrests suitable for the task and work station?	19	37
2.	Does the backrest adjust sufficiently in height and depth to allow the user to gain support?	-	56
3.	Is the height adjustable to allow work to be carried out at or below elbow height?	-	56
4.	Is the lower back adequately supported?	-	56
5.	Are the footrests required and, if so, are they suitable?	5	51
6.	Is the chair comfortable for the intended period of use?	-	56
	Total	24	312
No	**Question for standing work performed**	**Yes**	**No**
1.	During the work cycle, does the employee perform a particular work continuously without releasing the physical stress of the body such as in the calf muscles either through rest	28	20

	breaks or leg movement or task variability?		
2.	Does the employee stands on a hard surface without any proper floor mat when performing standing work?	48	-
3.	Is the arrangement of job not within easy reach?	16	32
4.	Does the employee have to maintain an awkward posture of the upper body, for example back, elbow?	25	23
5.	Is the duration of standing position at work exceeding 10 minutes without possible leg movement?	45	3
6.	Are shoe provided with improper sole to support the body weight?	10	38
7.	Is the work bench fixed or not adjustable?	48	-
8.	If yes, is work table or machine height too low or too high?	43	5
9.	Are the items arranged in the standing work station not within reach?	15	33
	Total	**278**	**154**

THANK YOU FOR YOUR PARTICIPATION!

Appendix 2- Data collection for quality problems

Table 5.2: Daily Quality Data Recording Format to Identify Defect Type

No.	Defect type	No. of pair	Reject	No.	Defect type	No. of pair	Reject
1.	Loose leather			8.	Wrong cutting direction		
2.	Open grain			9.	Growth marks		
3.	Drawn grain			10.	Under substance		
4.	Fat packets			11.	Poor nap no buck		
5.	Scratches			12.	Cuts/flaws		
6.	Shade Variation			13.	Wrong size		
7.	Wrong color			14.	Heel grip grain side not buffed		

Table 5.3: Quality Recording Sheet for Stitching Process

No.	Defect type	No. of pair	Reject	No.	Defect type	No. of pair	Reject
1.	Uneven stitch length			7	Top tension tight		
2.	Skipped stitches >1 or < 1			8	Wrinkles I binging		
3.	Wrong needle /thread used			9	Closed seam with uneven thickness material		

4.	Stitch too far or too close to edge			10.	Improper reinforcement		
5.	Stitch not as per marking			11.	De-shaped eyelets		
6.	Broken Stitch			12.	Bobbin thread not matching lining color		

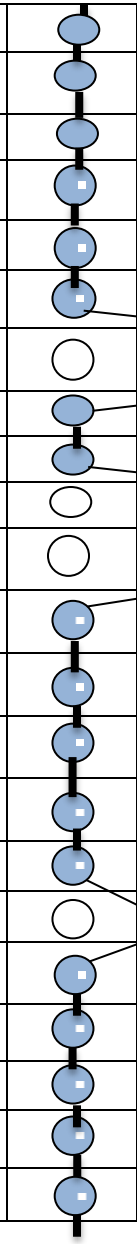
Table 5.4: Quality Recording Sheet for Lasting Process

No.	**Defect type**	**No. of pair**	**Reject**	**No.**	**Defect type**	**No. of pair**	**Reject**
1.	Back seam crooked			8.	Improper roughing		
2.	Back height not pair wise			9.	Insufficient lasting margin		
3.	Wrong back height			10.	Nails protruding inside the sole		
4.	Toe vamp crooked			11.	Incorrect toe spring		
5.	Inside quarter must be 2-3mm higher than outside quarter			12.	Quarters not in line		
6.	Wrinkles I lining			13.	Counter not sticking well to upper &lining		
7.	Poor sole adhesion			14.	Improper skiving of counter &toe puff		

Appendix 3: Activities Involved on the Production of Harber Shoe Model

Table 5.5: Stitching activities performed for one pair of Harber production

No.	Stitching activities performed for one pair of Harber production	operation	Inspection	Transportation	Delay	Storage	By	Quantity	Average time of 2wks (sec)	Distance (m)
1.	Temporary storage						Man	1		
2.	Transport to stitching						Man	1	493.2	5m
3.	Select and loading						Manual	1	44.3	
4.	Marking						Man	3	43.9	
5.	Transporting to skiving machine						Man	1	271.3	2.3m
6.	Skiving 1						Machine	1	18.5	
7.	Skiving 2						Machine	1	56.4	
8.	Reinforcement attaching 1						Manual	1	50.1	
9.	Adhesive attaching						Manual	2	57.9	
10.	Adhesive on reinforcement 2						Manual	4	53.7	
11.	Stitching 1(lining)						Machine (flat bade 1needl)	1	133.5	
12.	Waiting						-	-	103.5	
13.	Stitching 2(front part)						Machine (flat bade 1needl)	1	30.5	
14.	Waiting until front part stitching finished						-	-	38	
15.	Stitching 3(upper)						Machine(flat bade 1needle)	1	55.4	
16.	Adhesive						Manual	1	60.0	
17.	Alcohol rubbing						Manual	1	61.9	
18.	Transport to zigzag machine						Manual	1	106.3	1.5m
19.	Stitching 4 (zig zag)						Zig zag m/c	1	34.9	
20.	Folding						Machine	1	60.4	

21.	Stitching 4(side and vamp)						Machine	1	43.0	
22.	Stitching 5 (quarter)						(Post bed 1 needl)	1	54.9	
23.	Adhesive						Manual	1	55.4	
24.	Folding						Manual	1	22.1	
25.	Adhesive (foam 1)						Manual	1	42.3	
26.	Adhesive(foam 2)						Manual	1	49.0	
27.	Waiting until adhesive foam finished						-	-	60.0	
28.	Hammering stitched side						Machine	1	98.6	
29.	Reinforcement attaching 3(front)						Manual	1	144.2	
30.	Transporting						Manual		150	3m
31.	Waiting until reinforcement attachment comes						-	-	83.2	-
32.	Stitching 6 and plastering marking						Post bed two needle	2	35.4	
33.	Stitching 7						Flatbed one needle	1	84.8	
34.	Stitching 8						Flatbed one needle	1	115.6	
35.	Adhesive 1 (vamp, lining, quarter)						Manual	1	26.5	
36.	Adhesive 2						Manual	1	40.6	
37.	Inspection						Manual	1	77.0 in	
38.	Stitching 9(tough)						Flatbed one needle	1	44.4	
39.	Folding (quarter)						Machine	1	81.6	
40.	Adhesive						Manual	1	8.9	
41.	Turning						Manual	1	17.9	
42.	Hammering						Manual	1	48.8	

43.	Stitching 10						Post bed two needle	2	74. 2	
44.	Delay until trimming								70.0	
45.	Trimming						Machine	1	32.1	
46.	Delay until eyelet								49.0	
47.	Eyelet						Machine	1	21.5	
48.	Stitching11(vamp, quarter)						Post bed one needle	1	112.4	
49.	Stitching 12(lining)						Post bed one needle	1	60.0	
50.	Stitching13(internal part)						Manual	1	45.3	
51.	Remove yarn & stitching						Manual	1	110.0	
52.	Waiting until yarn and stitching removed						Manual	2	67.53	
53.	Quality check						Machine	1	28.9	
54.	Attaching toe puff						Counter mold	1	60.0	
55.	Waiting until toe puff finished								93.2	
56.	Back part molding						Manual	2	69.9	
57.	Adhesive(toe puff) and gluing						Post bed one needle	1	56.3	
58.	Stitching						Manual	2	64.3	
59.	Transport to yarn insertion place						Manual	2	127.9	2.5m
60.	Insert yarning the hole						Post bed one needle	1	60.0	
61.	Transport						manual	1	377.23	3.7m
62.	Temporary storage						-	-		
	Total	**43**	**3**	**7**	**8**	**2**				**18 m**
		2635 sec.			**564.43 sec**					**1525.93 sec**

Table 5.6: Lasting activities performed for one pair of Harber production

No.	Lasting activities performed for one pair of Harber production	Operation	Inspection	Transportation	Delay	Storage	By	Quantity	Time (sec)	Distance (m)
63.	Transport to lasting station						Man	1	203.9	3.0m
64.	Insole tack						Manual	2	105.33	1.7 m
65.	Cleaning outsole						Manual	1	25.8	
66.	loading (upper & last)						Manual	1	6.3	
67.	Attach last and insole						Manual	1	45.1	
68.	Adhesive on upper						Manual	1	67	
69.	Adhesive on last						Manual	1	56.2	
70.	Transport						Man	1	159.3	0.5m
71.	Heat activating (upper)						Machine	1	142.1	
72.	Waiting until m/c finish						-	-	108.9	
73.	Toe lasting						Machine	1	33.2	
74.	Heel adjust						Manual	1	37.7	
75.	Side attach						Manual	1	50.6	
76.	Waiting until heel adjust finished						-	-	63.75	
77.	Heel lasting						Machine	2	43.4	
78.	Cleaning and removing plaster						Manual	1	76.5	
79.	Waiting								73.38	
80.	Pounding						Machine	1	43.5	
81.	Heat setter						Machine	2	49	
82.	Hammering						Manual	2	50.3	

83.	Heat supplier						Machine	2	46.6	
84.	Creaming						Manual	1	52.7	
85.	Transport						Manual	1	63.5	1.5m
86.	Upper ironing						Machine	1	74.6	
87.	Waiting						-	-	28.7	
88.	Brushing 1						Manual	2	55.2	
89.	Roughing						Machine	2	53.6	
90.	Adhesive on upper1						Manual	2	56.9	
91.	Adhesive on sole						Manual	1	54.8	
92.	Adhesive on upper 2						Manual	1	62	
93.	Heat activator (upper &sole)						Machine	1	258.2	
94.	Waiting						-	-	107.53	
95.	Attach sole and upper						Manual	1	54.3	
96.	Attach sole and upper or pressing						Machine	1	46.5	
97.	Transport to chiller						Manual	2	123.7	1m
98.	Chiller						Machine	1	200.1	
99.	Waiting until chiller finished						-	-	105.9	
100.	De lasting						Machine	1	20.4	
101.	Attaches sock line						Manual	2	52.3	
102.	Outside cleaning						Manual	2	60.9	
103.	Waiting						-	-	17.9	
104.	Inside cleaning						Manual	2	60.6	
105.	Heat supply						Machine	1	57.5	

106.	Creaming						Manual	1	44.3	
107.	Brushing 2						Manual	1	46.7	
108.	QC						Manual	1	45.2	
109.	Shoe lace						Manual	1	96	
110.	Transport to temporary storage							2	217.9	3.0m
111.	Packaging						Manual	1	20 sec	
112.	Transport to store						Machine	1		
	Total	33	**4**	**5**	**7**	**1**			**2263.7**	**10.2 m**
		2263.7 sec.			**488.16 sec.**					**891.53 sec.**

Appendix 4 –Anthropometrics Data of US

Table 5.7: Anthropometrics estimates for US adults age 19-65 year

(All dimensions in mm except body weight, given kg)

	Men				Women			
Dimension	5th %ile	50th %ile	95th %ile	SD	5th %ile	50th %ile	95th %ile	SD
1. Stature	1640	1755	1870	71	1520	1625	1730	64*
2. Eye height	1595	1710	1825	70	1420	1525	1630	63
3. Shoulder height	1330	1440	1550	67	1225	1325	1425	60
4. Elbow height	1020	1105	1190	53	945	1020	1095	47
5. Hip height	835	915	995	50	760	835	910	45
6. Knuckle height	700	765	830	41	670	730	790	37
7. Fingertip height	595	660	725	39	565	630	695	40
8. Sitting height	855	915	975	36	800	860	920	36
9. Sitting eye height	740	800	860	35	690	750	810	35
10. Sitting shoulder height	545	600	655	32	510	565	620	32
11. Sitting elbow height	195	245	295	31	185	235	285	29
12. Thigh thickness	135	160	185	16	125	155	185	17
13. Buttock–knee length	550	600	650	31	525	575	625	31
14. Buttock–popliteal length	445	500	555	33	440	490	540	31
15. Knee height	495	550	605	32	460	505	550	28
16. Popliteal height	395	445	495	29	360	405	450	28
17. Shoulder breadth (bideltoid)	425	470	515	28	360	400	440	25
18. Shoulder breadth	365	400	435	21	330	360	390	19

19. Hip breadth	310	360	410	30	310	375	440	39
20. Chest (bust) depth	220	255	290	22	210	255	300	28
21. Abdominal depth	220	275	330	32	210	260	310	31
22. Shoulder–elbow length	330	365	400	21	305	335	365	18
23. Elbow–fingertip length	445	480	515	21	400	435	470	20
24. Upper limb length	730	790	850	36	655	715	775	35
25. Shoulder–grip length	615	670	725	33	560	610	660	30
26. Head length	180	195	210	8	165	180	195	8
27. Head breadth	145	155	165	6	135	145	155	6
28. Hand length	175	191	205	10	160	175	190	10
29. Hand breadth	80	90	100	5	65	75	85	5
30. Foot length	240	265	290	14	220	240	260	13
31. Foot breadth	90	100	110	6	80	90	100	6
32. Span	1670	1810	1950	84	1505	1625	1745	73
33. Elbow span	875	955	1035	48	790	860	930	44
34. Vertical grip reach (standing)	1950	2080	2210	80	1805	1925	2045	73
35. Vertical grip reach (sitting)	1155	1255	1355	61	1070	1160	1250	55
36. Forward grip reach	725	785	845	35	655	710	765	32
Body weight	*55*	*78*	*102*	*14*	*41*	*65*	*89*	*15**