ANALYSIS OF THE IMPACT OF WORKER FATIGUE ON PRODUCTIVITY FOR APPAREL INDUSTRY- A CASE STUDY

by

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I hereby declare that no part of this thesis has been submitted elsewhere for the award of any degree or diploma.

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Table of Content

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT

Improving productivity is the main concern of an apparel companies There are many problems in apparel companies which obstacle the higher productivity. Unskilled workers. physical fatigue from extended working hour without rest, misplacement of worker at workstation, lack of training, absence of engineering knowledge and engineering management to utilize optimum efficiency of worker. which are directly related to production Lack of interest of higher authority to implement the engineering management and technique to increase productivity impede to accelerate the productivity in apparel industry.

As the overall daily performance of each worker is not same and the change in their performance defer from one worker to another worker In this thesis, a study has been carried out to find out the effect of fatigue on productivity and to form a framework to improve the productivity based on the overall performance of workers During the investigation attention is concentrated on how physical fatigue of workers influences the daily production rate and way to optimize the productivity of apparel industries. It has been found that if performance of workers are observed regularly and these results are properly implemented then daily production rate increase up to a satisfactory level with the same efficient workers, same machineries and same technical facilities Even if physical fatigue exists, loss due to fatigue can be reduced to a remarkable label

CHAPTER-I
INTRODUCTION

1.1 Introduction

A major movement within the rapidly emerging global market has involved a shifting focus from low cost products to high quality, high value products. Specifically in the garment industry where competition is high. In addition to customer driven demands, companies are being made more responsible for good working conditions on the floor by government regulations, tight labor markets, and recognition of the value of a good employee. To meet these demands, garment manufacturers must find a manufacturing method that meets or exceeds quality standards while decreasing costs through optimizing manufacturing productivity, efficiency. and safety Fatigue plays an important role in designing systems and tasks Design of successful working method helps to utilize the human capabilities with job demands A mismatch of this interface can increase expenses, thus affecting the net profit by causing human operators to make mental mistakes, work inefficiently, or work beyond their physical capabilities to the point of injury Workers fatigue research has been employed where highly repetitive and low to moderate force levels Accumulation of muscle fatigue that results in chronic muscle pain is commonly considered a causative factor [8].

Fatigue as a major problem in the Bangladesh workforce, and one with a major impact on productivity and costs Workplace conditions for which fatigue is a major symptom such as depression or anxiety accounted for only a small part of the productivity losses Far more of the costs were thought to result from a wide range of other physical and mental health problems that may occur when fatigue is also present Fatigue reduced work performance mainly by interfering with concentration and increasing the time needed to accomplish tasks

There is a clear relationship between quality and productivity Generally, when quality increases, so will productivity, because waste is eliminated. The amount of inputs required to produce outputs is reduced So productivity increases This can happen as long as the individual or group of individuals is willing to exert effort and has the capability to achieve the quality productivity levels desired It is the operation manager's task to provide the facilities. tools and desire or motivation to do so [5]

1.2 Problem Statement

During the last decade, there have been several changes in the international trade agreements for apparel products, which are generating new challenges and opportunities for the export-oriented apparel industry of Bangladesh Bangladesh economy in association with low labor productivity, a low efficiency of the workers. lack of efficient infrastructure , low level of investment, lack of opportunities on the job training, lack of knowledge and awareness of the management about productivity and quality are intensifying the internationally originated challenges So it is necessary for the readymade garments industry of Bangladesh to develop a standard framework for some functions of quality and productivity to maintain the international level of standards of quality to meet the changing needs of all the customers.

Today, the Bangladeshi garments industry is facing a fierce competition in global market, where price is order qualifier whereas excellent service, high quality of goods and timely delivery are order winners Increased competition. product diversification and excellence in service have forced garment manufacturers to increase productivity, to reduce costs. adapt to demand cycle and improve quality Only those units will survive which are competitive and efficient in all respect For the last decade, increasing global competition in manufacturing has forced companies to focus on enhancing the efficiencies and economies of scale in all of their business processes There is a growing trend towards downsizing to decrease the labor costs of manufacturing and assembling products. One result of this trend is that downsized companies are forced to produce more using fewer resources To compensate for the fewer workers, overtime hours worked by industrial hourly workers have been on a steady increase for years. Unfortunately, this increase in physical fatigue can lead to a decrease in the quality of the produced goods because of the reduced accuracy of workers' movements [11]

Application of industrial engineering techniques such as time study, method study, line balancing and fatigue study is totally absent. though by using those techniques productivity can be improved Although there are several reasons behind these, all can be attributed to lack of knowledge and awareness of the management about productivity improvement tools and techniques Higher official or owner of the garment company should be aware and take necessary measure for improving their existing production capacity. The main issue is to analyze the case-specific situation of productivity issue that is affecting a particular case.

1.3 Objectives

The objectives of the study are:

1 Finding the effect of fatigue on worker's per hourly production rate with time interval and how does it change
2 Finding the effect of fatigue on labor utilization which is the ratio of productive time and cycle time or bottleneck time, idle time and cycle time of worker
3 To categorize worker according to their performance
4 Determine the most probable period of fatigue of worker
5 Developing a framework to improve productivity.

The main outcomes of this study are: (1) Relationship among productivity, utilization, idleness, line efficiency, fatigue loss of assembly line and worker's fatigue (2) A set of guideline for improving productivity.

1.4 Methodology

The methodology of the study:

1 Data collection from the sewing floor of each worker of each time segment of an assembly line throughout the shift by splitting the entire shift into 24 equal time segment

2. Calculating the performance of workers by comparing processing time and standard processing time, calculating machine utilization by comparing productive time of a cycle with cycle time.
3. Calculating idleness from idle time of a cycle and cycle time throughout the shift of individual worker
4. Investigating productivity loss due to fatigue based on maximum production capacity considering no fatigue and actual production capacity.
5. As production capacity of assembly line depends on the bottleneck point, therefore efficient worker should be placed at the bottleneck point Hence, Identifying and replacement of most efficient worker at bottleneck point to optimize productivity
6. Unnecessary extra worker leads to increase production cost. Hence, releasing inefficient worker from the workstation if unnecessary extra worker is assigned at the bottleneck point where production capacity is more than two times than bottleneck point.
7. Analyzing productivity capacity of each time segment throughout the shift
8. Suggestions for implementation based on the outcomes of the study for improving productivity.

1.5 Assumptions

1. Continuous flow of material through the assembly line
2. Worker will show the same performance while performing at any workstation, i.e. no change in efficiency due to variation of operation
3. There is no effect on performance due to change in weather, variation in working environment
4. No effect of fatigue of data collector in collecting whole day data

1.6 Conclusion

To organize assembly type of production successfully, and having unbroken material flow, it is necessary to be familiar with performance of worker, as a basis for defining optimal methods of work, more favorable structure of the operation in question, machine utilization ratio, worker load, worker and hourly production. To be able to establish a optimum assembly line, it is necessary to have an overall view of all worker's label of skill posses, fatigue In this study, it has been tried to maximize the utilization of worker's efficiency. By placing worker properly at the workstation in assembly line, production capacity has been aimed to be increased.

CHAPTER-II
WORK FATIGUE

2.1 Introduction

Fatigue is a physical and/or mental state caused by over exertion. It reduces a person's capabilities to an extent that may impair their strength, speed, reaction time, coordination, decision making, or balance. A level of fatigue is a natural response to the mental and physical effort of everything we do. Normally, good quality sleep reverses the imbalance, allowing the body and the brain to recover. However, working long hours, working with intense mental or physical effort, or working during some or all of the natural time for sleep can all cause excessive fatigue. All of these have obvious implications for workplace and public safety. Fatigue can also have longer-term effects on health. Fatigue is defined as a state of being tired. It can be caused by long hours of work, long hours of physical or mental activity, inadequate rest, excessive stress, and combinations of these factors. The signs, symptoms and affect fatigue has on workers varies from one person to the next, however fatigue may affect the individual worker's ability to perform [2].

Fatigue is further defined as when a target force can no longer be generated and therefore resulting in a gradual fall in maximal force. This reduction in maximal force can be in part dependent on a person's state of fitness, muscle fiber type and composition, and the type of exercise being performed. The onset of localized muscle fatigue is detrimental to productivity as decreased strength and loss of precise motor control can have negative effects on performance in terms of speed and quality [1].

2.2 Possible Indicators of Workplace Fatigue

- feeling drowsy/relaxed:
- feeling tired or sleepy, or not feeling refreshed after sleep,
- blurred vision:
- increased irritability,

- finding it difficult to keep your eyes open,
- taking more frequent naps during leisure hours. or falling asleep at work:
- finding it hard to concentrate and/or making more mistakes than usual,
- excessive head nodding or yawning,
- increased absenteeism,
- repeatedly moving off track while driving vehicles and plant: and
- near misses

This list is not exhaustive and the presence of these indicators does not necessarily mean that fatigue is a risk. Management of fatigue should not just rely on workers recognizing these symptoms, as the symptoms on their own have been found to be unreliable indicators of fatigue The employer must assess the risk and implement control measures as required [4]

2.3 Some Possible Performance Impairments

- Slowed reactions - physical reaction speed and speed of thought
- Failure to respond - to stimuli, changes in the surroundings, information provided
- Incorrect actions - either physical or mental
- Flawed logic and judgment and an increase in memory errors, including Forgetfulness
- Decreased vigilance
- Reduced motivation
- Increased tendency for risk-taking

2.4 Factors which have an Influence on Fatigue

The issue of stress levels in the workplace is of growing interest in the field of occupational health Stress has been defined as a continuous averse situation, the evasion of which is subjectively or objectively important to an individual In situations of stress, the individual is not totally in control. In the setting of a work environment, the main sources of occupational stress are organizational factors (job demands, rank, etc) and work hazards, the most common of which are air pollution, noise, vibration, physical and psycho physical strain, visual exertion, and inadequate working posture Occupational stress consistently been related to the incidence of psychosomatic disorders and mental stress In figure2 1. the factors has been demonstrated which affects the output of worker [6].

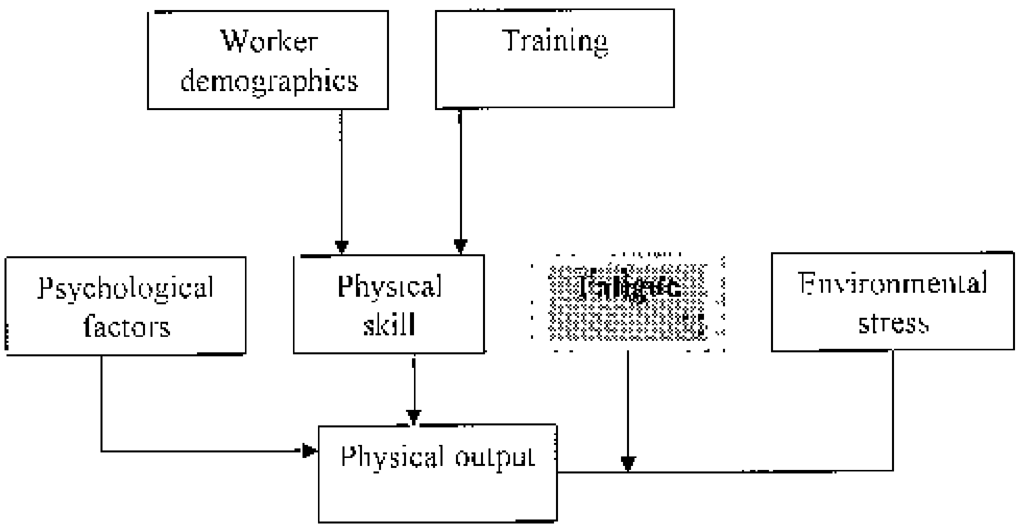

Figure 2 1 Components that affect physical output [7]

(a) Shift Work

In terms of work hours, shift work is defined as work that starts before 8 00am and finishes after 6.00pm A biological definition of shift work would be any work pattern that causes a change in normal sleep patterns

Shift work (in particular night work) can be a powerful cause of fatigue when it.

- Limits a person's opportunities to get adequate sleep
- Requires them to work in the early hours of the morning, when people are normally at their sleepiest and least functional.

(b) Extended Work Hour

Shift that last longer than 8 hours are classed as long or extended. People may work long hours on a short-term basis to deal with a major emergency or an unexpected situation, or they may work long hours regularly for financial or other reasons. The effects of working long hours depend on how long the work periods are, are how often they occur, and at what time of day. Sleep restriction has clear negative impact on human performance. It suppresses the immune system, increase appetite, and makes the body increasingly resistant to insulin. Several nights of restricted sleep create a sleep debt which has clear effects on performance.

(c) Effects Accumulate

The combined effects of sleep restriction and extended hours of work has a short-term impact on performance, and in the long term may affect cardiovascular health , mental health, safety, and productivity

(d) Night Work

All the statement above refers to day work. Working at night has a greater impact than working the same number of hours in the day time, and the impact is even greater when the work hours are extended. On average, shift workers lose 1-1.5 hours of sleep for each 24-hour period. This build up a sleep debt of 6 hours after 4 nights. Working more than three or four nights in a row is likely to cause a significant sleep debt, with serious consequence for safety. Night-work hours should be limited [7].

(e) Noise

Excessive exposure to loud noise can irreversibly damage the ear, resulting in noise-induced hearing loss. 'Nuisance' noise can be annoying and distracting and result in reduced job performance and satisfaction. Noise may also be unsafe if it impairs communication in the work environment, such as by overpowering auditory alarms

(f)Lighting

Lighting levels need to be appropriate to the task and must comply with Australian Standard 1680. Working in dim or overbright work environments can result in eyestrain, headaches, irritability and, inevitably, reduced productivity. Light sources, including the sun, can create unwanted reflections, glare and shadows in the workplace that can cause discomfort and distraction, and can interfere with the performance of visual tasks. Low levels of lighting can cause depression, which for some people may be severe

(g)Ventilation, Air Quality and Thermal Comfort

Ventilation is important for the control of dust, fumes, gases, aerosols, climate and thermal comfort factors. Exposure to different types of dust can result in fibrosis of the lung, allergic reactions and asthma attacks. Various vapours, gases and aerosols have the ability to cause respiratory and skin damage. Extremes of heat can reduce concentration and motivation and cause a number of heat-related illnesses. Extremes of heat can also reduce tolerance to chemical and noise exposure, and increase the risk of heart attacks.

(h)Vibration

Whole body vibration, e.g. from riding a mower, can affect comfort and performance even at low levels and can cause damage to the spine, stomach pain and gastrointestinal complaints. Hand-arm vibration, such as from hand tools, can have negative effects on muscles and the skeleton, and can contribute to carpal tunnel syndrome, low-back pain and vibration white finger, for example.

(i) Radiation

Exposure to ultraviolet radiation from the sun can induce potentially lethal skin cancers. Exposure to direct sun, particularly between the hours of eleven and two, can result in sunburn, headaches and fatigue. Different people have varying degrees of sensitivity to the sun, e.g. fair freckled skin often burns more quickly than olive skin. Precautions for avoiding sun exposure should be followed diligently by everybody [9].

(j)Ergonomics

Ergonomics and human factors have been around for approximately 60 years. During World War II there was a need to deal with employee fatigue, stress, injuries, and poor performance due to mismatches between people and technology, unusual work schedules, and demanding and threatening working conditions. Over the ensuing 60 years ergonomic researchers and practitioner of ergonomics have learned that the best way to address ergonomic concerns is to take a broad view of the problems encountered combined with focused solutions. The broad view of a work process and improvements addresses the need to make sure that improvements in one area do not lead to problems in another area. It accounts for the issues that often occur elsewhere in the work system when just a focused approach is used in one area. This has led to the understanding that a bigger view allows the ergonomics practitioner who is trying to solve a problem to address both the specific problem (the "micro ergonomics"), and to also deal with the ramifications in the entire work process (the "macro ergonomics") Micro ergonomic factors deal with design characteristics of tasks, or tools/technology, or the environmental conditions, or the capacity/knowledge of each individual employee It addresses the specific ergonomic risk factors in a particular task, job or operation Macro ergonomic factors deal with larger issues such as the organization of the work process, the coordination of tasks and activities among employees, the supervision of processes and employees, and how people, technology, tasks and environmental features are integrated Ergonomic improvements and interventions must account for both levels and their effects on the work system to be successful [8]

2.5 Fatigue Management

The physical aspects of a workplace environment can have a direct impact on the productivity, health and safety, comfort, concentration, job satisfaction and morale of the people within it. Important factors in the work environment that should be considered include building design and age, workplace layout, workstation set-up, furniture and equipment design and quality, space, temperature, ventilation, lighting, noise, vibration, radiation, air quality Ergonomics is the study of the relationship between people, the equipment they use and the physical environment in which they work. Applying ergonomic principles to the design, modification and maintenance of workplace environments, has a benefit on people's work performance and short- and long-term health and safety When people are working in situations that suit their physical and mental abilities, the correct fit between the person and the work task is accomplished People are then in the optimum situation for learning, working and achieving, without adverse health consequences, e.g injury, illness

When assessing the workplace environment, consideration should be given to individual human characteristics such as age, sex, experience, physical stature etc., and how well these human characteristics match the physical environment Appropriate design of workplace environments will ensure that they accommodate a broad variety of human characteristics The work environment should satisfy the physical and mental requirements of the people who work within it. The necessary adjustments to the work area, in terms of the heights and angles of furniture and equipment, should be made for the comfort and safety of each person

The four main categories of physical characteristic that need to be considered in the work environment are:

- Clearance, e.g. headroom, legroom, elbow-room, access,
- Arm reach, which has a bearing on storage of materials,
- Posture, which has a bearing on the location of materials/equipment, heights of working surfaces,
- Strength

Physical environmental factors can have an adverse impact on people. The specific physical factors that limit performance will vary depending on both the work environment and individual differences. Those people who are working within an environment are the ones best able to identify factors that affect their work. It is important to involve these 'hands-on' people in consultations with supervisors, managers and occupational health and safety personnel when considering options for controlling the risks in question

The stressors of monotony, boredom, and mental fatigue are a progressive set beginning with monotony, which has been described as "an environment in which there is either no change or change occurs in a repetitive and highly predictive fashion over which the individual has little or no control." Determining factors related to the development of boredom and monotony are training and uniformity in work conditions is especially conducive to the development of boredom, one study in 1914 showed, the higher the training level the higher resulting level of monotony and boredom experienced resulting from a lack of stimuli. These people belong in design functions, which would supply the required stimuli and challenge to avoid boredom. Humans require stimulation to perk their interest rather than uniformity in working procedure which is conducive to boredom, however when the stimulation becomes predictable and uncontrolled humans tend to feel monotony which leads to boredom also considered an emotional state, the eventuality is mental fatigue where staff simply no longer expresses and interest in performing the task at hand, if the environmental condition that induced the boredom is allowed to continue and the staff experiences continuous exposure adaptation evolves making the work tolerable but never enjoyed[7].

Ideally, a predictive model can be generated that would allow job designers to estimate when workers will reach unsafe levels of fatigue. This would allow work rest schedules to be created that prevent fatigue from decreasing productivity and quality, and/or allow jobs to be designed that do not cause significant fatigue during the expected shift length.

Company recognizes that fatigue is a factor, which may affect a worker's ability to perform mental and physical tasks All management and supervisory personnel must be able to recognize and respond to the signs and symptoms that might impair the worker's performance due to fatigue. Training will be provided to recognize and respond to fatigue issues in the field. The following segments of the fatigue management system are general guidelines. which may be adopted in whole or in part for individual companies Each company must determine which aspects are operationally and structurally feasible for their situation and implement them accordingly [2].

2.6 Responsibility for Managing Fatigue

1. Management

- To ensure the FMS (Fatigue Management System) is implemented throughout the company
- Provide the necessary information about fatigue
- Provide instruction and training
- Communicate employer expectations
- Monitor the effects of extended work hours
- Support employees who are experiencing concerns with fatigue
- Assist and advise line Supervisors
- Investigate any problems and/or concerns

- Inspect the workplace and review FMS with employees
- Review the FMS

2. Supervisors

- Ensure all crewmembers understand the FMS
- Conduct safety meetings discussing fatigue and the FMS
- Promote the FMS
- Ensure tasks are performed in safe and healthy manner
- Be aware of the possible risks associated with extended hours and/or consecutive days of work
- Give workers as much notice as possible if extended hours are anticipated
- Observe and record how individuals respond to extended hours
- Recognize symptoms of fatigue
- Get feedback from individual crewmembers and the crew as a whole
- Take prompt action if a risk develops
- Relay information to and from management & employees
- Report any FMS problems, concerns and/or issues

3. Employees

- Actively participate in FMS training
- Recognize symptoms of fatigue
- Promptly report any fatigue related concerns
- Report any individual medical or personal situations, which may have an affect on fatigue
- To get proper rest during time off
- Identify personal stress and seek assistance if required [6]

2.7 Conclusion

Worker's physical fatigue is common issue in the garment companies. Processes of garment production belong to the so called piece-type of production processes (assembling type), while the work is performed on production lines, including a number of technological operations. In garment physical fatigue grows from incontinent workplace to work. Insufficient lighting, ventilation, ignorance of ergonomics consideration, insufficient space allocation, highly repetitive operation leads to grow fatigue. It is significant to take necessary measure to remove those sources of fatigue where possible.

CHAPTER III

LITERATURE REVIEW

3.1 Introduction

Production capacity of assembly line not only depends on the capacity of machine, smooth flow of materials through the successive machine but also depends on the capability of worker. From working long hour, worker becomes tired and can not perform with his or her maximum efficiency. In addition, performance of each worker is not same. Therefore, assembly line should be designed based on the performance of worker where productivity is triggered by capability machine and worker. There are many thesis has been conducted to find the effect of fatigue and found a promising result.

3.2 Historical Background

In one study has been conducted to find the effect of rest period on hand fatigue and productivity. In order to achieve the research objectives, an industrial hand task was simulated in the field. The experimental task consisted of collecting hand strength measurements and recording the number of drilled screws. Sixteen study volunteers were randomly assigned a number of one through sixteen. The participants having numbers one through eight were assigned to the control group while participants nine through sixteen were assigned to the experimental group (i.e., eight participants to each group). Recovery time was used as the main treatment effect under the experimental condition. For the purpose of this experiment, the participants of the control condition worked without having recovery time (breaks or stretching) versus the experimental condition participants receiving recovery time (breaks or stretching). The experimental group received two, two minute rest periods. A rest period was given after ten minutes of continuous drilling and the other was given after the second ten minutes of drilling. The control group received no rest periods and was required to drill for 20 minutes continuously. After 20 minutes of control group and 24 minutes of experimental group including rest periods of drilling, post-test hand strength measurements were collected. The mean number of screws of control group is 157.5 and mean number of screws of experimental group is 162.5 The mean hand strength of control group is 83.4 pounds and mean strength of experimental is 89.4 pounds. Collected data shows a very significant impact of intermittent rest period on recovery of fatigue and productivity [2].

Standard processing time of an operation should be enough to cope with the stress of work which generate from environment of workplace personal needs and ergonomics. While calculating the standard processing time of operation some coefficient should be considered such as temperature, ergonomics, personal allowance, physical fatigue etc. In one study carried out to examine the standard time norm of garments engineering, they found that normal time of sewing of a length of 52 cm is 15.5 seconds but considering the coefficient of other factors the processing time is 16.7 seconds. It seems some factors directly regulate the productivity of assembly line. But this can not meet with the individual time demand. Physical fatigue that generate from long time of working does not same for each worker. It depends on physical stamina of human beings. If extra time is added to the normal processing time, the production capacity reduces and directly triggered by the individual capability [7].

Physical workload standard for different task should be consistent with the ability of assigned worker. Standard workload differs from one type of task to another type. It depends on the nature of task. But excessive workload and improper posture of working leads to musculoskeletal disorder and reduces effort of worker to work. To get problem from musculoskeletal disorder, ergonomic factors should be considered while designing the workstation [3].

Operation of garment is highly repetitive. Every successive operation takes very shorter duration which leads to generate physical fatigue. Therefore worker becomes tired and feels averse to work. One another thing that in assembly line of garment industries, workers are at the same workstation which reduces attention to work. Along with monotony from working at the same workstation, highly repetitive work may directly damage tendons through repeated stretching and elongation, as well as increased likelihood of fatigue and a decrease in the opportunity for tissues to recover. Workers on repetitive jobs had more than a fivefold greater risk of developing upper extremity cumulative trauma disorders and fatigue when compared to workers on lower repetition, low-force jobs one of the first effects of working long hours is fatigue. It seems intuitively obvious that working long hours will make an individual tired or fatigued. Fatigue can be viewed in two ways: either by measuring it directly as an end in itself, or indirectly in terms of performance or health effects that are thought to be associated with fatigue [6]

There are many factors that affect productivity such as product and system design, machine and equipment, skill and effective ness of worker and production volume. But the label of skill does not same. Therefore most efficient worker should be motivated to be productive [11]

From the above discussion, it is clear that the label of physical fatigue reduce the productivity of a worker and the label of fatigue is not same for all worker as it is triggered by the physical ability of individuals. Misplacement of worker at the workstation in assembly line reduces the maximum production capacity of an assembly line. Sometimes it increase the production cost of production. This variation in the performance of individuals leads to follow a clear outline while placing worker at the workstation. As the performance of each worker is not same

So by analyzing the physical ability and overall daily performance of each worker, their position at the workplace should be allocated so that they can perform with their maximum ability.

3.3 Importance of the Study

For the last decade, increasing global competition in manufacturing has forced companies to focus on enhancing the efficiencies and economies of scale in all of their business processes. There is a growing trend towards downsizing to decrease the labor costs of manufacturing and assembling products. One result of this trend is that downsized companies are forced to produce more using fewer resources. To compensate for the fewer workers, overtime hours worked by industrial hourly workers have been on a steady increase for years. Unfortunately, this increase in physical fatigue can lead to a decrease in the quality of the produced goods because of the reduced accuracy of workers' movements. From a research perspective, the link between fatigue and quality has not been adequately investigated. No quantitative guidelines exist that would enable a manufacturer to compare labor costs and quality costs to determine the level of labor needed to maximize the tradeoff between performance of worker and productivity. Some investigation has focused on changes in movement time due to the mass of parts and one applied study has contemplated the relationship between fatigue and production efficiency, however, no usable models have been developed. On the other hand, companies gravely need this information to guide their staffing priorities. Many critical business decisions are based on expected costs and revenues of manufactured products. If costs can be reduced or revenues can be increased through better scheduling practices, companies can achieve a significant increase in profitability.

3.4 Conclusion

In conclusion, to compete with the global open market, every garment company should set a clear guide line to examine their productivity regularly. From physical fatigue they are not only losing production but also increase in the production cost. By studying fatigue of worker, they can improve their production capacity, utilization, line efficiency. It is not only for the shack of improving productivity but also it is important for selection workload of a worker.

CHAPTER-IV

PRODUCTIVITY ANALYSIS

4.1 Introduction

Productivity may be defined as the ratio between output and input Output means the amount produces or the number of items produced and inputs are the various resources employed. e g , land and building, equipment and machinery, materials, labors, etc. Therefore. productivity measurement shows how well a company is doing This does not, however, tell anything about why the company is performing the way it is There are many factors affect productivity of assembly line such as product and system design, machine and equipment. skills and effectiveness of the worker, production volume In the true sense, the productivity can be said as increased if more products can be obtained from the same amount of resources Indoor environmental quality may affect physiological and psychological processes that. in turn. may affect performance of tasks that may interact with other factors to affect overall productivity The objective of the study is to determine the real capacity of the existing line, improving the productivity of the assembly line, reducing the idle time of work station. finding a means of comparing output forecasts with actual output at selected intervals and finding a means of adding resource usage data and associate productivity in a meaningful fashion related to outputs to reduce the details in reports as data go to higher-and higher level managers.

4.2 Analysis of Productivity

To calculate productivity, utilization, idleness, line efficiency of assembly line, the following equations and terms has been used.

4.2.1 Observed Time

Observed time is the time require for a single operation which is collected by using stop watch. From receiving from previous workstation to the delivery to the next workstation is the observed time for an operation. Observed time an individual operation defers from one operation to another operation

4.2.2 Bottleneck Point

A bottleneck is defined as ant resource whose capacity is less than the demand placed upon it. A bottleneck point is a constraint within the system that limits the throughput. It is that point in the manufacturing process where the flow thins to a narrow stream. A bottleneck point may be a machine. Scarc of highly skill labor, or a specialized tool. Observations in industries show that most plants have few bottleneck operations. If there is no bottleneck point, then excess capacity exists and the system should be changed to create a bottleneck point.

4.2.3 Production Capacity

Maximum daily production capacity is the ratio of available time and cycle time. Available time means the time of the shift. For example, if an operation runs for one 8-hour shift each day, the available productive time each day is 28.800 seconds. The daily production capacity can be found as follows

Maximum daily actual output $P = \frac{T}{C}$ .... (4.1)

Where, T= Available time, second

C= Cycle time (second/unit)

4.2.4 Performance Rating or Efficiency

Performance of worker means how efficiently a worker can do his operation. Operator performance or efficiency is the ratio of units of work actually produced by worker and units of work which could be produced at standard performance

Performance rating or efficiency = $\eta_k = \frac{P_a}{P_s} \times 100\%$ .. .. (4 2)

η_i = Performance rating or efficiency of worker

K=A,B,C . .. L

P_a = Units of work actually produced by worker

P_s = Units of works which could be produced at standard performance

4.2.5 Utilization and Idleness

Utilization means the productive time of the available time of a cycle At the non bottleneck point, the productive time is less than the cycle time and some portion of the cycle time is not used. Waiting line formulas generally require an arrival rate or the number of units per period Assuming number of workstation in the assembly line is n. The productive time of each workstation is expressed as follows

$T_1, T_2, T_3 \ldots \quad \ldots \quad \ldots \ldots T_n$

The relationship between productive time and cycle time C is given as follows

$T_j \leq C$

Utilization (%) = $\frac{\sum_{j=1}^{n} T_j}{nC} \times 100\%$ .. ..(4 3)

T_j = Productive time of each workstation. second

nC = Total line capacity, second

n= Number of workstation

c= Cycle time. second

Idleness is the portion of available time which remains unproductive. At the non bottleneck point. time requires for an operation is less than bottleneck point and remains idle. This is also called balance delay. Idleness of worker reduce maximum utilization of available time.

$$\text{Idleness (\%)} = \frac{\sum_{i=1}^{n}(c - T_i)}{nc} \times 100\% \quad \ldots \quad (4.4)$$

4.2.6 Line Efficiency

In contrast of balance delay, there is another equation which is designed to indicate how effectively the line is used in term of line capacity. This is called line efficiency. Line efficiency is the ratio of average productive time of each workstation and total line capacity and expressed through the following equation.

$$\text{Line efficiency, E (\%)} = \frac{\sum_{i=1}^{n} T_i}{nc} \times 100\% \quad \ldots \quad (4.5)$$

[14].

4.2.7 Line balancing

Line balancing is a manual planning and scheduling technique and similar in nature to material resource planning. It is most appropriate for assembly line operations involving a number of distinct components. In essence, it employs the principle of management by exception through a comparison of progress of individual components with the time schedule for completed assemblies. Regular progress checks reveal the future effect of any current delays and indicate the degree of urgency for corrective action. Line balancing is not directly concerned with the resources expanded but it is utilize in determining production progress in terms of percent tasks completion. Major bottleneck in the production is emphasized. The objective of this technique is to study the progress of job at regular intervals, to compare progress on each operation with the progress to satisfy the eventual delivery requirement, and to identify those operations in which progress is unsatisfactory.

η_t = Target line efficiency

Center line $(CL) = \dfrac{\sum_{i=1}^{n} T_i}{n}$ ....(4.6)

Upper control limit $(UCL) = \dfrac{\sum_{i=1}^{n} T_i}{n\eta_l}$ ....(4.7)

Lower control limit $(LCL) = 2 \times \dfrac{\sum_{i=1}^{n} T_i}{n} - UCL$ ....(4.8)

Theoretical minimum number of workstation, $n_c = [\dfrac{T_c}{C}]$ ....(4.9)

[14].

4.3 Conclusion

Productivity improvement is the main vision of any company to increase the profit margin. By using the formulas explained above, cycle time can be reduced and productivity can be improved. For light work, efficiency of assembly line should be 85% or more than 85%. This study aims to improve the existing production capacity of the assembly line and to form a set of guide line for garments industries by improving cycle time and line efficiency by using skilled worker at more time consuming workstation.

CHAPTER-V

FATIGUE STUDY

5.1 Introduction

Manufacturers follow assembly/ line/ throughput manufacturing system Because of labor intensive, skill based industry it is absolute necessary to have efficient assembly/ line production system. In this case output of one process become the input of other process and delay in any one operation will result in loss of output down the line for all the operations Higher difference in skill level of the operators, heavy absenteeism and high labor turnover rate has turned nicely plan lines in to unpredictable, inefficient production systems. These will lead to decreased machine productivity and the system efficiency, increased throughput time and WIP level, increased delivery time and production cost and what not to make the business unviable and inefficient [10]

Throughout the whole shift, no worker can perform his or her optimum efficiency as they become tired due to physical fatigue. Performance of worker is not only an inherent ability but also a matter of physical stamina As level of physical stamina of each worker is not same, therefore placing worker with higher stamina loss due to fatigue can be reduced The main objectives of the study are to determine the trends of fatigue, identifying the point from when fatigue grows up among the worker, investigating the level of individual skill, identifying the most efficient worker, obtaining an evaluation standard for order receiving planning

5.2 Investigation of Fatigue Loss

To produce products, manufacturing processes are divided into several workers and each worker carries out the same work allotted to him/her in a short period of time. To increase efficiency of production line and check weather assembly line working with its optimum performance or not, performance of workers are rated. This is called the rating of worker. The rating of worker helps to achieve simplification, specialization and standardization for rationalization to Increase in production. A method to allot the workload evenly to each worker so that products are produced at a consistent speed is called "flow production system." To successfully carry out the flow production system, synchronization in the rating of workers is necessary to create the situation where required goods are provided at required time by required quantity. To calculate the performance rating of worker or efficiency and loss due fatigue, the following equations has been used.

Performance or efficiency has been discussed in the previous chapter. To calculate the loss due to fatigue, two terms has been considered. Those are maximum production capacity and actual production capacity.

Maximum production capacity is the number of unit would have produce if there is no fatigue. We know that at the beginning of the day worker can not work with their maximum performance due to a physical rigidity, but it reduce with time and increase performance. After sometime, from becoming tiredness their performance starts to reduce. Throughout the whole shift, after getting rid from rigidity, worker shows the maximum performance. Considering no fatigue, the maximum production capacity has been calculated of the shift.

Actual production capacity is the amount of work which has produced actually. From the observed time of worker, dividing available time by cycle time the actual number of unit has been calculated. Productivity loss due to physical fatigue does not depend on each workstation but it depends on the worker at the bottleneck point. Therefore, in this study, loss due to fatigue has been calculated based on the loss of worker at the bottleneck point after each iteration

Performance rating or efficiency $\eta_k = \frac{P_a}{P_s} \times 100 \times \%$ .. .. (5.1)

η_k = Performance rating or efficiency of worker

K=A,B,C....... . .L

P_a = Average units of work actually produced by worker

P_S – Units of works which could be produced at standard performance [14]

Number of unit loss= Maximum production capacity without considering no fatigue of worker at bottleneck point – Units of work actually produced by worker

Number of unit loss = $P_m - P_a$ .. ..(5.2)

Loss due to fatigue (%) = $\frac{P_m - P_a}{P_a} \times 100\,\%$ . .. .(5.3)

P_m - Maximum production capacity without considering no fatigue of worker at bottleneck point

P_a = Actually number of unit produced by worker.

5.3 Conclusion

Due to long time working worker becomes tired and loss their performance. It is important for any garments industry to minimize their loose which comes from long time working of worker. This study aims to analysis the productivity loss and to developing a frame work to analysis the productivity loss due to fatigue

CHAPTER-VI

PRODUCTIVITY AND WORK FATIGUE

6.1 Introduction

While designing position of worker at workstation, it should be kept in mind about reducing the bottleneck processing time as much as possible Higher efficient worker take less time to complete an operation than other If a less efficient worker is placed at the bottleneck point, it is not wise for improving productivity. utilization, minimizing loss due to fatigue Hence to improve productivity, most efficient worker should be placed at the bottleneck point. Therefore, overall daily efficiency should be considered when reduction of cycle time is thought But the label of overall performance does not remain constant throughout the whole shift The variation of performance of worker and fatigue results a reduction of productivity But it is necessary to improve the existing production capacity of assembly line for each garment company. By using proper optimization technique this can be done.

6.2 Optimization Techniques

There are several optimization technique are used, such as liner programming, network optimization model, transportation and assignment model, genetic algorithm etc Each optimization model is suitable for some distinctive situation A brief about those models is cited below

6.2.1 Linear Programming

Linear programming is a mathematical modeling technique designed to optimize the usage of limited resources In linear programming, there are two types of objective functions. One is maximization and another is minimization Generally, problem is considered as maximization when the aim of the objective function is to increase the profit and when the aim of the objective function is to reduce the cost then it is considered as minimization problem Both cases help to improve the profit linear programming has three basic elements Such as decision variable, objective function and constraints The element, decision variable is which seek to determine, objective function is which is aimed to optimize and constraints is that is need to satisfy [12].

Linear programming helps to determine the most feasible solution from infinite solution This model is not applicable when characteristic of the resource is distinctive. In this study, the efficiency of the workers is distinctive i e. there is no way to use a portion of the efficiency of worker In assembly line, worker will be must working with their performance As the decision variable of the study is the performance is known and there is no way to use any fraction of the worker's efficiency, thus optimization technique is not applicable.

6.2.2 Network Optimization Model

There is a multimode of operations research situations that can be conveniently modeled and solved as networks (nodes connected by branches) In network optimization model, there are many paths to reach at the destination from the starting point To minimize the length of road, pipeline, determine the time schedule, this model is used The solution of those situations, and others like it, is accomplished through a variety of network optimization algorithms There are five types of algorithm to solve the network models The models are minimum spanning tree, shortest route algorithm, maximum flow algorithm, minimum-cost capacitated network and critical path algorithm [13].

In assembly line, the direction of material flow is distinctive and it can be violated because of the sequence of operation Moreover, every operation must be carried out on the material for completion In network optimization model, there are many paths to follow and sometimes there has a provision to skip any path. In network optimization model. the provision of skipping any path and provision of follow a predetermined in assembly line impedes to apply in the problem

6.2.3 Transportation Model

The transportation model is a special class of liner programming problem. It deals with the situation in which a commodity is shipped from recourse to the destinations. The objective is to determine the amount of shipped from each source to each destination that minimize the total shipping cost while satisfying both the supply limits and the demand requirements. The model assumes that the shipping cost on a given route directly proportional to the number of units shipped on that route. In transportation model there is a provision to follow any path to reach from source to destination [13]

In assembly line production system there is a distinctive path to follow and there is no provision of skipping any operation for the shack of completing a finish product. Sequence of operation must have to be maintained. For this reason transportation model is not applicable in this situation

6.2.4 Assignment Model

The assignment problem is a special type of line programming problem where assignees are being assigned to perform task. In assignment problem, number of worker and number of task should be same and one worker should perform only one operation. Transportation model is used to minimize the total cost

In garment operation, there is a variety of operation and number of worker and number of operation can not be kept same to meet with the smooth flow of materials through the line. It is not important to minimize the cost of each operation in terms of time of a assembly line to improve productivity. Because production capacity of assembly line does not depends on several points but depends on the bottleneck point. Therefore this type of model is not suitable for this situation.

6.2.5 Genetic Algorithm

Genetic algorithms provide a third type of methaheuristic that is quite different from the first two. This type tends to be particularly effective at exploring various parts of the feasible region and gradually evolving towards the best feasible solution In genetic algorithm a new trial feasible trial solutions affect the next feasible solution Human performance differs from one person to another person and has no impact on other In garment, as there is a assembly line production system and there is not impact of one worker to other this type of algorithm is not applicable[12]

As those above model impede to be utilized in that situation, the following model is developed to optimize the existing productivity of the assembly line The model is developed based on the overall daily performance of each worker.

6.3 Description of the Proposed Approach

Due to the physical fatigue of worker, performance of worker change with time and the label of performance of each worker do not remain same To optimize production capacity of the existing line the following steps has been followed

Step-1

By using stop watch. the observed processing time of each operation has been collected. Then the average of the observed processing time of each time segment is calculated dividing sum of total observed time of a time segment by number of data collected In this study, frequency of data collection at each time segment is six Therefore. average processing time of a operation has been found. Standard processing time of each operation is collected from the work study department

Step-2

After collecting average processing time of each operation of each time segment, the performance of individual worker has been calculated by dividing average processing time by standard processing time of their operation. Standard processing time of each operation is different which is designed based on the length of operation

Step-3

Next step is assigning worker randomly at different workstation without considering their level of performance As in another situation and while designing a new assembly line, the optimum placement of worker is unknown and unpredictable, for this reason, while placing worker at their workstation assigning of worker should be random before iteration Number of worker at each workstation should be counted based on the standard time of the corresponding operation. In this thesis, number of worker is counted depending on the number of worker of existing assembly line in each workstation.

Step-4

Processing time of every workstation is not same and it defer from one workstation because of their length of sewing seam and nature of operation Among those workstation. the workstation has been identified which takes maximum time for a single operation of the corresponding workstation which is termed as bottleneck point

Step-5

Overall efficiency of the worker at bottleneck point has been compared with other worker of the assembly line. If the efficiency of the worker who is placed at the bottleneck point is less than any other worker then the most efficient worker has been replaced at the bottleneck point and the bottleneck point worker has been replaced to the replaced worker position

Step-6

Again the new bottleneck point has been identified and the efficiency of the worker at bottleneck point has been compared with other worker If the efficiency of the bottle neck worker is less than any worker, more efficient worker is placed at the new bottle neck point again But if this iteration increases the processing time than previous position of worker, then stop. This iteration has been continued until efficient worker is placed at the bottleneck point

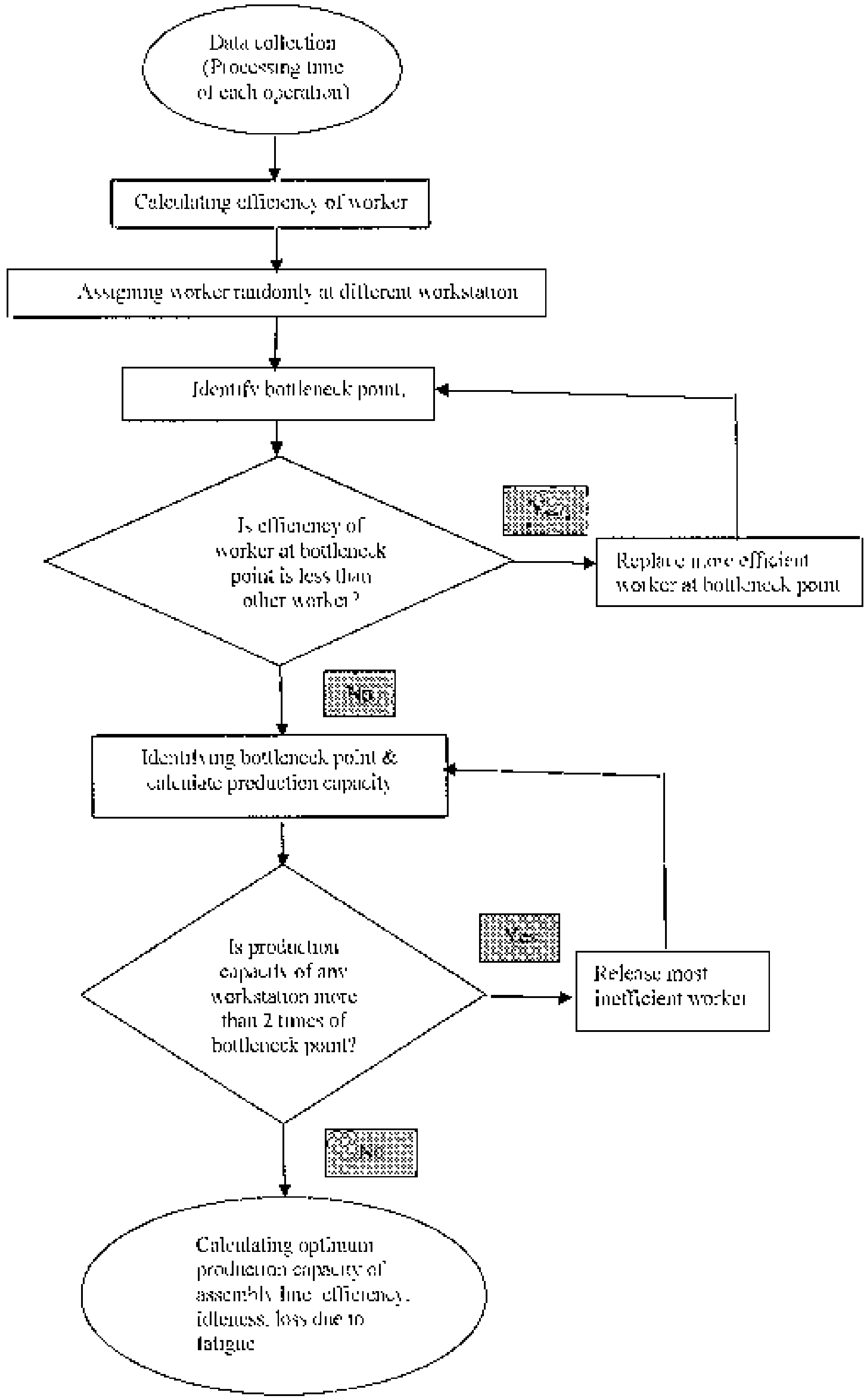

Figure 6.1: Steps necessary for optimizing productivity

Step-7

At this step, a new bottleneck point is identified which takes less processing time than all previous situation. The production capacity of each workstation of each time segment has been calculated based on processing time of bottleneck point.

Step-8

Unnecessary worker increase the production cost and the worker has no contribution in improving production capacity. Therefore inefficient worker has been released if production capacity of a workstation is two times or more than two times than bottleneck point and more than one worker is assigned at the workstation. That will help to reduce unnecessary workforce and cost of production.

Step-9

New production capacity, loss due to fatigue, line utilization, idleness, and line efficiency has been calculated.

6.4 Conclusion

The above steps will help to generate an efficient assembly line and will increase production capacity. Moreover, this model is a unique where traditional optimization models are not suitable to be employed. Not only production capacity, this model will help to improve utilization of assembly line and efficiency.

CHAPTER-VII

CASE STUDY

7.1 Introduction

In Bangladesh. there are numerous number of garment factories A major part of foreign currency comes from this sector But every company is not so encouraged to provide the permission to visit their company Because of their internal weakness, they feel it threatening for themselves to give permission. But it is not wise for the shake of improving their existing production capacity by studying their resources The company under consideration, located at Kashimpur, Gazipur, is a big garments organization, having partial vertical integration This project aims to analyze worker fatigue and subsequently suggesting appropriate techniques, and providing guidelines as to how to approach implementation

7.2 Location

Jinnat Fashions Limited, under this study is situated at Shardaganj, Kashimpur on Gazipur in Bangladesh.

7.3 Description of the Company

Jinnat Fashions Limited-01 established in December 2005 and Jinnat Fashions Limited-02 in may 2006.It is a 100% export oriented garments manufacturing company with a mission to be best export in providing from the Bangladesh to our valued customers around the world Jinnat Fashions Limited has concentrated all it's strength and resources in developing and producing a wide range of quality garments for the international market. Management believes on professionalism and ensure hard working and sound man is committed to deliver quality garments to it's customer well in time. It has capability to handle substantial volume of orders with reasonable time. This company is committed to produce high quality, sophisticated products and continuously try to improve in quality management with every year to come

This factory adheres to all of major merchandising as per local & abroad, factory certification and labor compliances as per local law or buyer requirements Utmost importance has been given to production layout and the quality control department, which gives 100% quality assurance with inventory check, in-line inspection & final inspection before final inspection / shipment by Buyer. Jinnat Fashions Limited is one of the leading garment factory in Bangladesh where we providing local law facilities, dining facilities, prayer room & medical facilities for workers on time. Even their factory is giving a wonderful circumstance facility for worker Also they are providing some facilities for Buyer / representative

7.4 Company Profile

Name of the Company: Jinnat Fashions Limited.

Address: Shardaganj, Kashimpur, Gazipur, Bangladesh

Key persons: 1. M.A Jabbar
Managing Director
2. M. A Kader Anue
Operation Director
3. Hassan Imam
Production Director

Year of Establishment: Jinnat Fashions Limited-01, December 2005
Jinnat Fashions Limited-02, May 2006

Banker Name: Islami Bank, Exim Bank
Bangladesh

Employees: Staff 54

Cutting: 35

Sewing: 540

Finishing: 30

Total Machinary: Cutting: CNC cutter (Gerber)-2

Sewing: 540

Finishing: 30

Total: 572

Production Capacity: 24500 PCS per day

Business type: Manufacturer and Exporter

Annual Sales Range: US$ 1.6 Million – US$ 1.8 Million

Geographic Markets: World wide

7.5 Factory Specification

Jinnat Fashions Limited is a four storied building but only second and third floor are under of Jinnat Fashions Limited. Jinnat Fashions Limited-01 is situated on second floor and Jinnat Fashions Limited on third floor. Cutting section for two floors are situated on second floor. Raw material and finished product are stored in store. Second and third floor are allotted for sewing section, finishing, section. Finishing section of each floor are situated separately on second and third floor. At the end of each assembly line, there has a quality control department.

There are two permanent doctors for first treatment. All types medicine for are provided without any payment if any worker get accident while doing his duty. Compliance department is very strong and aware looking for worker interest and problem. There is child care center to look after kid of worker.

It tries to meet all fire code regulations. Salary payment date is 5^{th} on every month. It provides free factory uniform to workers. It has five wash rooms for workers in factory floors.

7.6 Products Description

Jinnat Fashions Limited produces men's, ladies and children's wear. The garment produces T-shirt, Pique Polo shirt, Auto stripe, Long sleeve Tuttle neck shirt, Shorts, Tank top, Vest etc for men's, children's, ladies. Knitted night dress, Sweet shirt. Roll neck T-shirt etc.

7.7 Description of Operations and Processes of a T- Shirt

There are twelve operation are carried out on a T- shirt. Each operation is performed at different workstation. All material handling is carried out by helper. No conveyor or belt is used for transportation material from one workstation to another workstation. Description of those operations is stated at below.

7.7.1 Shoulder Join Right Side

This is the first operation of a T-shirt carried out on the right side of shoulder. Over lock machine is used for this operation. Front part and back part of the right side of shoulder is attached by this operation. In figure7.1, 2 is the location of the operation.

7.7.2 Size Label Attach at Left Seam

This is the second operation of T-shirt. It is a very small operation. Label is a small part which contains some information about the size of a T-shirt. Label is just attached at left side of the seam. Label is collected from store department. There is no preceding task on the label in assembly line. Plain machine is used for this operation. In figure 7.1,2 indicates the location of this operation.

7.7.3 Neck Binding

This operation is carried out on the top part of T-shirt. The edge of the neck is closed with binding so that any thread can not be loosed out. Interlock machine is used for this operation. For binding, a different narrow part is used and fold over the open neck. In figure 7.1, 3 indicates the location of the operation

7.7.4 Neck Close

This operation is carried out after neck binding. To close the ends of neck, this operation is performed. Plain machine is used for this operation. This operation figures the throat as a round. In figure 7.1.4 indicates the location the operation

7.7.5 Shoulder Join Left side

This operation is alike of shoulder join right side. After carrying out neck close operation, this operation is done. But this operation is done on the left side of shoulder. The front and back part of shoulder is attached by this operation. Like shoulder join right side, over lock machine is used. In figure 7.1,5 indicates the location of the operation.

7.7.6 Sleeve Hem

There is no previous operation of the operation in the assembly line. Both right and left part of hand comes from the cutting section. The end of the both left and right hand is fold by the operation. Interlock machine is used for this operation. In figure 7.1,6 indicates the location of this operation

7.7.7 Sleeve Join

This operation is done on both hand sides. The input for this operation comes from two previous workstations. The previous operations are shoulder join left side and sleeve hem. This operation is carried out to attach both hands with the body of T-shirt

Overlock type machine is used for this operation In figure7.1,7 indicates the location of the operation

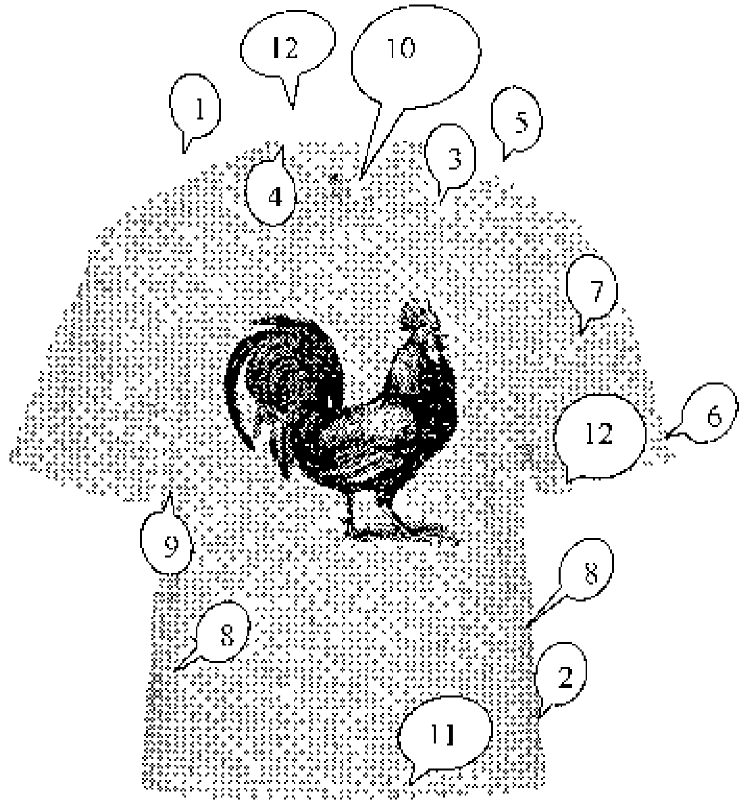

Figure 7.1: Location of operation on a T-shirt

7.7.8 Side Seam

This operation closes both side of the body The seam length of the operation is greater than other previous operation. The whole body gets as a round from this operation Overlock machine is used for this operation. In figure7 1,8 indicates the location of the operation.

7.7.9 Sleeve Opening Close

This operation is very small carried out on the sleeve to close the opening after side seam operation This operation is done to ensure a strong end of the sleeve Plain machine is used for this operation. On both left and right side the operation is done In figure7 1,9 indicates the location of the operation.

7.7.10 Main Label Attach at Back Neck Center

This operation is alike of size label attach at left seam but it is carried out on the center of back neck No previous operation is done on the label in the assembly line The label comes from store Main label contains some data about the T-shirt In figure7.1, 10 shows the location of the operation

7.7.11 Bottom Hem

This operation is done on the bottom side of the main body. To close the end of the body, this operation is carried out The edge of the bottom part is fold and sewing operation is done along the fold. This operation ensures any losing out of threads from the body part Interlock machine is used for this operation In figure 7 1,11 indicates the location of the operation

7.7.12 Neck and Sleeve Opening Chap Tack

This is final operation of a T-shirt This operation is carried out on the sleeve and neck This operation ensures a strong end of neck and sleeve The outer part of the edge is attached by folding Plain machine is used for this operation In figure7 1,12 indicates the locations of the operation

Table 7.1. Name of operations carried out on a typical T-shirt

Serial no	Abbreviation	Full Name	Serial no	Abbreviation	Full Name
1	Sh R	Shoulder Join Right side	7	SJ	Sleeve Join
2	SLA	Size Label attach at Left Seam	8	SS	Side Seam
3	NB	Neck Binding	9	SOC	Sleeve Opening Close
4	NC	Neck Close	10	MLA	Main Label Attach at Back Neck Center
5	Sh L	Shoulder Join left Side	11	BH	Bottom Hem
6	SL H	Sleeve Hem	12	N&SOCT	Neck & Sleeve Opening Clap Tack

The sequence of operation of figure7.1 and the meaning of the abbreviation is shown in table 7.1

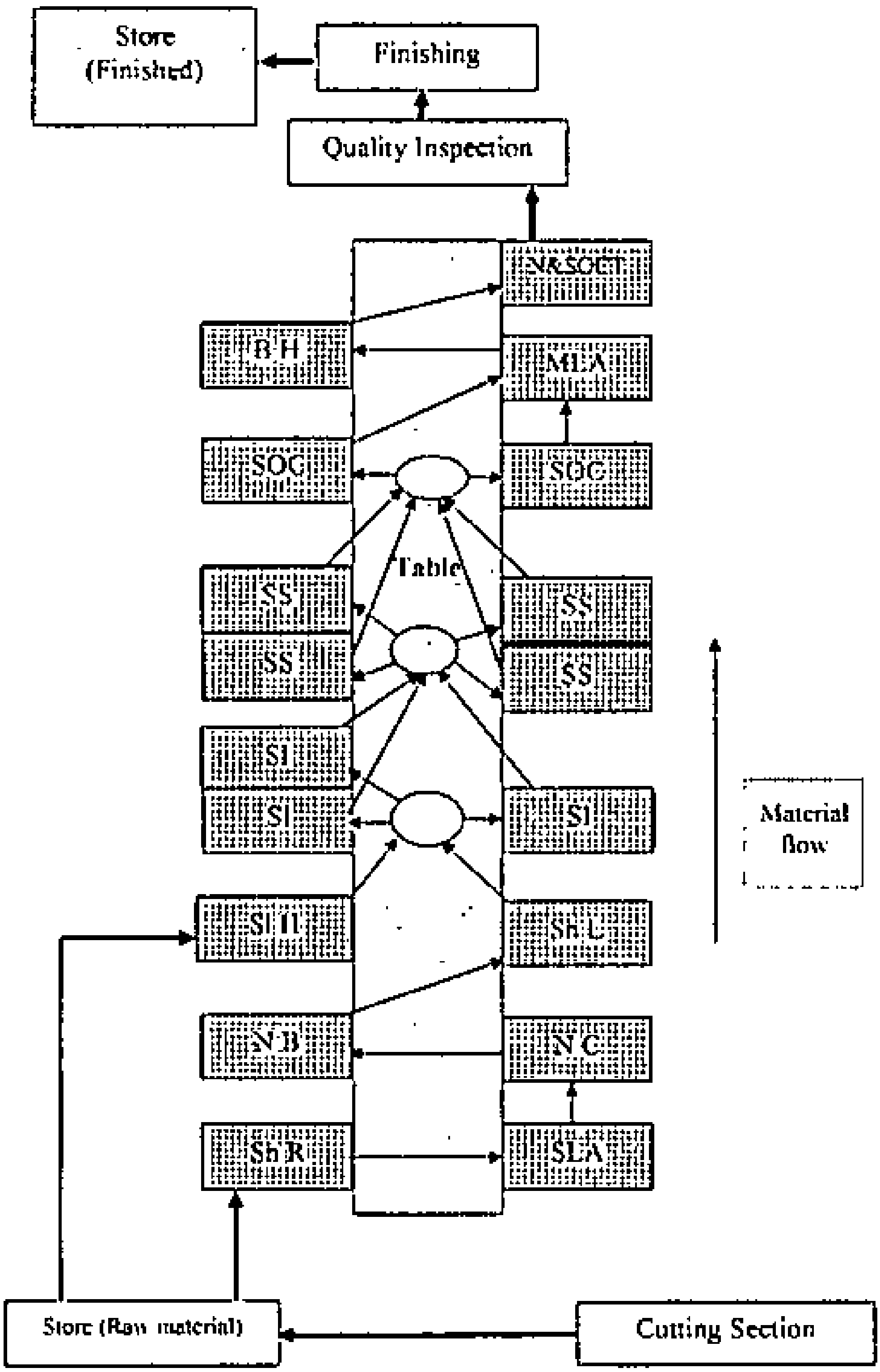

Figure 7.2: Layout of the assembly line

Figure 7.3: Process flow chart of a T-shirt assembly line sewing section

Description of process	Name of machine	Name of operation	Process systems					
			Operation	Transpo-rtation	Storage	Delay	Quantity Inspection	Quality inspection
In cutting section			○	⇨	▽	D	□	◇
To machine with hand			○	⇨	▽	D	□	◇
Joining right side of shoulder	Over lock machine	Shoulder join right side	○	⇨	▽	D	□	◇
To machine with hand			○	⇨	▽	D	□	◇
Attaching size label at left side	Plain machine	Size label attach at left seam	○	⇨	▽	D	□	◇
To machine with hand			○	⇨	▽	D	□	◇
Binding neck	Interlock machine	Neck binding	○	⇨	▽	D	□	◇
To machine with hand			○	⇨	▽	D	□	◇
Closing neck	Plain machine	Neck close	○	⇨	▽	D	□	◇
To machine with hand			○	⇨	▽	D	□	◇
Joining left side of shoulder	Over lock machine	Shoulder join left side	○	⇨	▽	D	□	◇
To machine with hand			○	⇨	▽	D	□	◇
On sleeve hem	Interlock machine	Sleeve hem	○	⇨	▽	D	□	◇
To machine with hand			○	⇨	▽	D	□	◇
Joining both sleeve with body	Over lock machine	Sleeve join	○	⇨	▽	D	□	◇
To machine with hand			○	⇨	▽	D	□	◇
Join both side	Over lock machine	Side seam	○	⇨	▽	D	□	◇
To machine with hand			○	⇨	▽	D	□	◇
Closing open of sleeve	Plain machine	Sleeve opening close	○	⇨	▽	D	□	◇
To machine with hand			○	⇨	▽	D	□	◇
Attaching main label at back neck	Plain machine	Main label attach at back neck	○	⇨	▽	D	□	◇
To machine with hand			○	⇨	▽	D	□	◇
On bottom hem	Interlock machine	Bottom hem	○	⇨	▽	D	□	◇
To machine with hand			○	⇨	▽	D	□	◇
Chap tack on neck& sleeve	Plain machine	Neck& sleeve opening chap tack	○	⇨	▽	D	□	◇
To the quality section with hand			○	⇨	▽	D	□	◇
Quality inspection			○	⇨	▽	D	□	◇

7.8 Conclusion

In garment assembly line. there is a constraint of preceding task The sequence of operation is strictly maintained. There is no change to skip or violate any sequence of operation At workstation 1, raw material comes from the store department and successive operation is carried out at distinct workstation At workstation 6, the raw material comes from the store department. No previous operation is carried out of the operation There is no conveyor or belt to transport material from one workstation to another workstation Helpers are assigned to shift to the forward workstation from previous workstation after completing operation. After carried out operation at workstation 12, finish product is transferred to quality department to check quality If there required any rework on any part of finish body, full body is taken to the right workstation to perform operation that deserve for rework

CHAPTER-VIII

ANALYTIC VIEW

8.1 Introduction

By utilizing maximum performance of worker at the assembly line, the productivity status of an assembly line can be improved. In an assembly line, optimum utilization worker effort should be ensured. There has no meaning to assign efficient worker at a less time requiring workstation but the worker should be assigned at more or most time requiring workstation.

8.2 Trend of Productivity with Time

The average production capacity does not remain constant with time interval. The trend of productivity is explained in figure8.1.

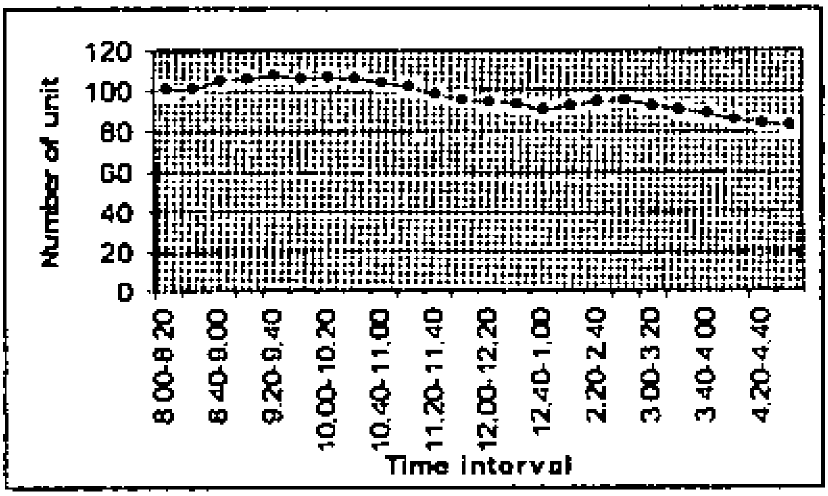

Figure 8.1: Trends of productivity with time interval

From annexure-iii, at very beginning of the day, the production capacity per 20 minutes is 110 units. But it is reduced with time interval. The maximum production capacity can be fuund at 9.20- 9.40 time segment. At this time segment, the average production capacity is 107 units. Due to physical fatigue of worker. this trend is reduced to 90 units at 12.40-1.00 time segment.

Having a break for one hour, the performance of workers is increased and productivity is also increased. At 2.00-2.20 time segment, the average production capacity of the assembly line is 92 units. This increase continues for 2.40-3.00 time segment then it is reduced again. At 2.40-3.00 time segment, the production capacity of the assembly line is 96 units.

Continuing the reduction of productivity, at 4.40-5.00 time segment, the production capacity per twenty is reduced to 83 units.

From the above trend of average productivity, it is clear that due to physical fatigue, the production capacity does not remain constant and this reduction is a very significant amount. At the beginning of the shift, the production capacity per twenty minute was 110 units but it is reduced to 83 units at the end of the shift.

8.3 Productivity Analysis

In twelve workstations the operation are carried out. Location of operation has been demonstrated in figure 7.1. The process flow chart shows the consequent operation and activity of a typical. The transportation is carried out by worker, no conveyor or belt has been used in the workstation for transportation of raw materials. Process flow chart of assembly line is shown in figure8.4.

At starting point1. full body part of a T-shirt is entered and successive operations are carried out at different workstation. Transportation of each part is carried out by hand. No automatic conveyor or belt is used in the assembly line. At workstation number 6, operation sleeve hem is carried out on two sleeves.

At workstation number 7. two sleeves from workstation 6 are attached with the body part which comes from workstation number 5. Then another sequence of operations are performed on the T-shirt. After neck & sleeve opening chap tack operation, a finished T shirt is found. The standard processing time of those operations is shown in table 8.1.

Table 8.1: Sequence of operation, position of worker at existing line & standard processing time of each operation

No of Work Station	Task Assigned	Workers Assigned	Machine Name	Task Require Predecessor	Standard Processing Time (Sec)	Standard Number of units / 20 min (P_{ij})
1	Shoulder Join Right side	A	Over Lock M/C	None	8.40	143
2	Size Label attach at Left Seam	B	Plain M/C	Shoulder Join Right side	9.60	125
3	Neck Binding	C	Interlock M/C	Size Label attach at Left Seam	9.00	133
4	Neck Close	D	Plain M/C	Neck Binding	9.00	133
5	Shoulder Join left Side	E	Over Lock M/C	Neck Close	8.40	143
6	Sleeve Hem	F	Interlock M/C	None	12.00	100
7	Sleeve Join	G_1, G_2, G_3	Over Lock M/C	Shoulder join Left Side, Sleeve Hem	30.60	39
8	Side Seam	H_1, H_2, H_3, H_4	Over Lock M/C	Sleeve Join	37.20	32
9	Sleeve Opening Close	I_1, I_2	Plain M/C	Side Seam	11.40	105
10	Main Label Attach at Back neck Center	J	Plain M/C	Sleeve Opening Close	16.60	71
11	Bottom Hem	K	Interlock M/C	Main Label Attach at Back neck Center	12.00	100
12	Neck & Sleeve Opening Chap Tack	L	Plain M/C	Bottom Hem	15.00	80

Collecting data of each operation, average processing time of each operation is calculated to find the efficiency of each worker. Average processing time of each worker at each time segment is explained in annexure-i. Based on the average processing time of each worker and standard processing time of each operation, efficiency of each worker is calculated. Overall performance of each worker of each time segment is explained in annexure-ii. In figure 8.2, the overall efficiency of worker is demonstrated

From table 8.1, it seems that standard processing time of operation side seam is maximum and the standard processing time is 37.20 second Shoulder join right side and shoulder join left side has same standard processing time The standard processing time of operation shoulder join is 8 40 second per operation

In workstation 7. three workers are assigned at the workstation to meet with the smooth flow of materials through the assembly line In workstation 8, maximum number of workers is assigned at the station Four workers are assigned at the station Workstation 9 is occupied with three workers At other workstations, one worker is assigned at each station.

Overall efficiency of worker that demonstrated in figure 8 2 is calculated using equation (5.1) and actual production capacity of each worker is collected from table 8.2 Standard production capacity for each operation is explained in table8 1 Performance of each worker with time interval is explained in annexure-ii.

Table 8.2: Production capacity of each worker with time interval

	Sh.R	SL.A	NB	NC	Sh.L	S.H	Sleeve Join			Side Seam				S.O.C		M.L.A	B.H	N.S.O.C.T
T.I	A	B	C	D	E	F	G_1	G_2	G_3	H_1	H_2	H_3	H_4	I_1	I_2	J	K	L
8.00-8.20	120	106	98	107	116	79	35	41	35	28	28	28	26	81	83	52	79	68
8.20-8.40	131	105	100	110	119	82	36	41	35	28	26	28	28	83	81	57	79	73
8.40-9.00	128	119	100	115	119	82	35	44	35	28	28	29	26	82	82	56	78	75
9.00-9.20	123	113	99	122	123	85	35	44	34	28	28	28	26	80	83	55	86	72
9.20-9.40	126	110	99	129	129	87	37	44	36	29	28	28	26	81	84	56	84	73
9.40-10.00	117	105	87	131	136	88	37	43	36	29	26	29	26	80	83	52	85	72
10.00-10.20	112	113	93	131	138	90	37	44	36	29	28	29	27	79	88	50	87	73
10.20-10.40	106	109	84	133	135	92	37	43	36	29	26	29	27	80	89	50	89	70
10.40-11.00	102	105	92	128	130	89	35	44	35	29	28	29	27	79	89	51	86	66
11.00-11.20	91	105	88	127	131	86	35	43	34	29	26	29	27	79	88	50	87	65
11.20-11.40	85	91	87	125	126	87	34	41	32	28	28	29	27	81	87	48	81	66
11.40-12.00	83	89	79	119	124	80	33	40	33	28	26	28	27	79	87	47	81	63
12.00-12.20	81	85	79	122	120	81	32	39	32	28	28	28	26	80	85	46	78	59
12.20-12.40	81	84	80	122	120	80	32	39	32	28	26	28	26	79	85	45	74	57
12.40-1.00	79	79	80	125	114	77	31	38	32	27	28	28	25	78	84	47	72	53
2.00-2.20	82	81	80	128	114	75	32	38	32	27	28	26	26	78	84	47	69	60
2.20-2.40	84	96	80	122	116	81	33	39	33	28	28	28	26	79	84	48	75	56
2.40-3.00	82	93	77	126	116	78	34	39	33	28	28	28	26	80	85	47	80	65
3.00-3.20	78	100	75	123	105	76	32	38	33	27	26	28	26	79	87	43	71	57
3.20-3.40	78	96	75	119	99	74	32	37	33	27	28	28	27	80	86	43	70	55
3.40-4.00	77	104	74	110	94	71	31	37	33	27	28	28	27	78	86	41	65	54
4.00-4.20	77	98	71	103	87	68	31	36	32	27	28	28	26	77	86	40	65	49
4.20-4.40	80	88	71	99	91	64	31	36	31	27	28	28	25	76	81	39	63	48
4.40-5.00	76	90	74	101	85	62	30	35	31	27	28	27	25	77	81	38	60	47
Average, P_a	94	98	84	119	116	80	34	40	33	27	28	29	26	79	85	48	77	60

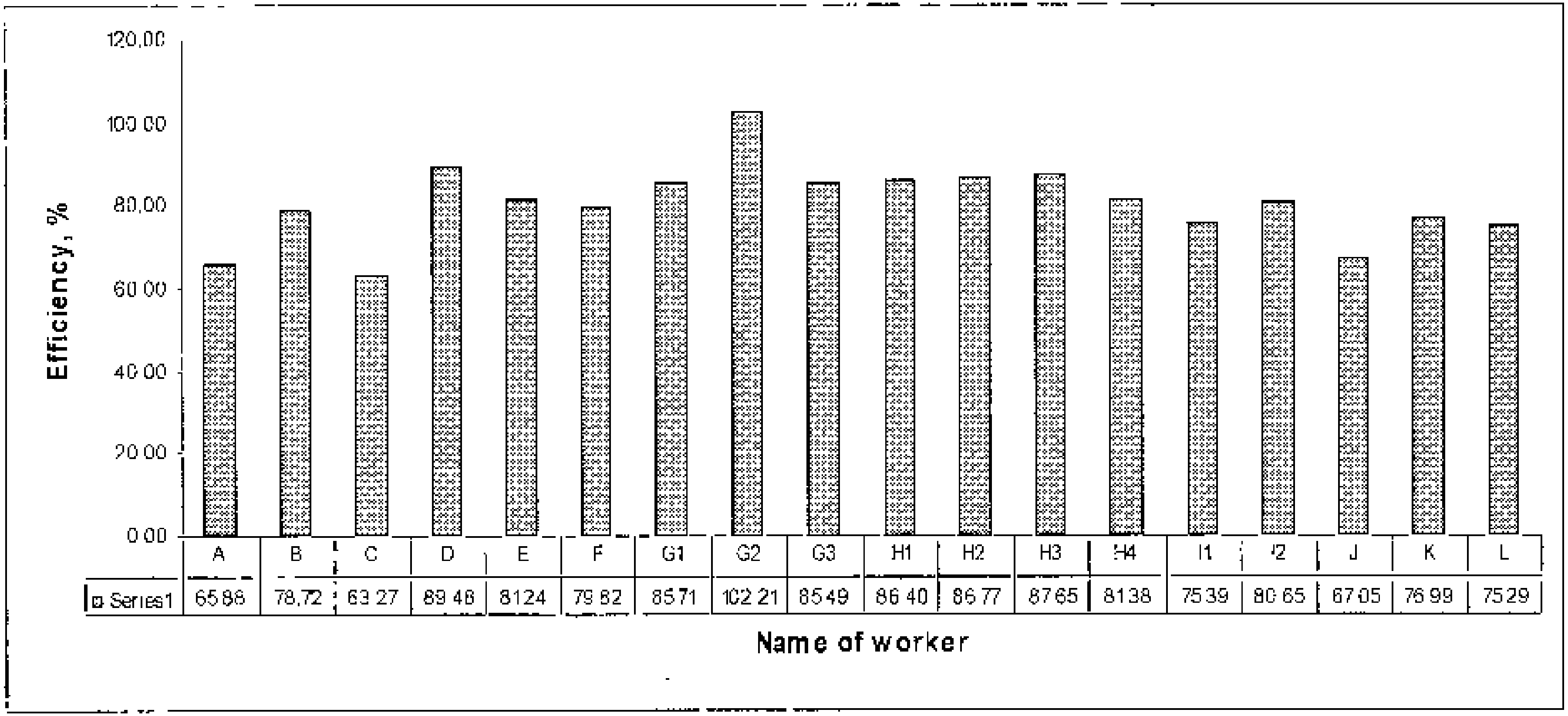

Figure 8 2 Overall efficiency of worker

From figure 8 2, it seems that efficiency of worker differ from one person to another person with a great difference. Among eighteen workers, performance of worker G_2 is maximum and the value of performance of the worker is 102 20% On the other hand. the minimum efficiency is 63.27% of worker C The next maximum efficiency is 89.48% which is belongs to worker D The next lower efficiency is 65.88% that can be found from worker A. Those efficiency has been calculated depending the average time and standard time of their operation.

To improve productivity. most efficient worker should be placed at the bottleneck point. As efficient worker can do any operation faster than other worker, therefore a reduction on processing time can be obtained by placing more efficient worker at the bottleneck point. Garment companies always desire to reduce their processing time at the bottleneck point but they don't pay any attention on the overall performance of worker even if it is necessary to pay attention.

Among other worker, worker H_3 can perform with a 87 65%. In addition, Worker I_1 and I_2 can perform with 75 39% and 80.65% respectively The performance of worker B, H_1 and L is 78 72%. 81 38% and 75 295 respectively There is a remarkable difference between worker G_2 and C in their performance The difference of performance between G_2 and C is 38 93%.

There is a little difference in the performance of worker G_1 and H_1 The performance of worker G_1 is 85 71% and the performance of worker H_1 is 86.40% The performance of worker J and K are 67.05% and 76 99% respectively But this difference seems very significant when improving productivity is a major vision of garment industries.

Table 8 3 is calculated based on the efficiency of worker and standard processing time of the corresponding operation. By dividing standard processing time of each operation with the performance of individual worker, average processing time of the operations for individuals has been calculated

It seems that higher efficient worker takes less time to do a operation than less efficient worker The efficiency of worker G_2 is maximum and takes 8.22 second where worker C takes 13 28 second to complete a shoulder join on the right side. Like this, worker D whose efficiency is 89 48% and takes 16.76 second to complete a neck and sleeve opening chap tack operation On the other hand, a less efficient workerI_1 take 19 90 second to complete a same operation.

To complete a neck binding operation, worker G_1 take 10.50 second but worker L takes 11.95 second. This difference is not seen only for G_1 and L but also it is appear for each worker. This difference entices to design position of worker properly for the shake of improving productivity

Data of table 8 3 prescribe to assign more efficient worker at the workstation which has maximum processing time. By placing more efficient worker, the processing time can be reduced.

Table 8 3. Time requires for each operation by each worker

Sl. No.	Name Worker	Efficiency %	Average processing time, second											
			Sh R	S L A	N B	N C	Sh L	S H	SI	SS	S O C	M L A	B H	N & S O C T
1	A	65 86	12 75	14 57	13 66	13 66	12 75	18 22	46 45	56 47	17.30	25 50	18 22	22.77
2	B	78 72	10 67	12 20	11 43	11 43	10 67	15 24	38 87	47 26	14 48	21.34	15 24	19 06
3	C	63 27	13 28	15 17	14 22	14 22	13 28	18 97	48 36	58.79	18 02	26 55	18 97	23 71
4	D	89 48	9 39	10 73	10 06	10 06	9 39	13 41	34 20	41 58	12.74	18 78	13 41	15 76
5	E	81.24	10 34	11.82	11 08	11 08	10 34	14 77	37 67	45 79	14 03	20 68	14 77	18 46
6	F	79 82	10 52	12 03	11 28	11 28	10 52	15 03	38.34	46 60	14 28	21.05	15 03	18 79
7	G_1	85 71	9 80	11 20	10 50	10 50	9 80	14 00	35 70	43 40	13 30	19 60	14 00	17 50
8	G_2	102 21	8 22	9.39	8 81	8 81	8 22	11 74	29 94	36 39	11 15	16 44	11 74	14 68
9	G_3	85 49	9 83	11 23	10 53	10 53	9 83	14 04	35 79	43 51	13 33	19 65	14 04	17 55
10	H_1	86 40	9 72	11 11	10 42	10 42	9 72	13 89	35 42	43 05	13.19	19 44	13 89	17 36
11	H_2	86 77	9 68	11 06	10 37	10 37	9 68	13 83	35 27	42 87	13 14	19 36	13 83	17 29
12	H_3	87 65	9 58	10.95	10 27	10 27	9 58	13 69	34 91	42 44	13 01	19 17	13 69	17 11
13	H_4	81 38	10 32	11 80	11 06	11 06	10 32	14 74	37.60	45 71	14 01	20 64	14.74	18 43
14	I_1	75.39	11.14	12 73	11.94	11.94	11 14	15 92	40 59	49 34	15 12	22 28	15 92	19 90
15	I_2	80 65	10 42	11 90	11 16	11 16	10 42	14 88	37 94	46 13	14 14	20.83	14 88	18 60
16	J	67 05	12 53	14 32	13 42	13 42	12 53	17 90	45 64	55 48	17 00	25 37	17.90	22 37
17	K	76 99	10 91	12 47	11.69	11 69	10 91	15 59	39 75	48 32	14 81	21 82	15 59	19 46
18	L	75 29	11 16	12 75	11 95	11 95	11 16	15 94	40 64	49.41	15.14	22 31	15 94	19 92

8.2.1 Existing Assembly Line

Productivity loss, daily production capacity of assembly line depends on the performance of the worker who is placed at the bottleneck point. So it is not important to compute the production capacity of other worker rather than bottleneck point. Moreover, by minimizing unnecessary labor force from assembly line, production cost can be minimized. Therefore, unnecessary labor force should be minimized if possible. If production capacity of any workstation is more than two times than production capacity of bottleneck point, inefficient worker should be removed from the workstation as he/she has no role to improve productivity.

8.2.1.1 Daily Production Capacity

Table 8.4 shows key outcomes of existing assembly line. Annexure-i shows average time requires for an operation at each workstation. Workstation 10 takes maximum time to complete an operation main label attach at back neck. Average processing time of bottleneck point of existing assembly line is 25.37 second which is the cycle time of the line. The available time of the shift is 8 hours. Therefore,

Daily actual output $P = \frac{T}{C}$ units

Where, T= Available time, second

C= Cycle time (second/unit)

Daily Production Capacity= $\frac{8 \times 3600}{25.37}$
=1135 units

Table8.4: Key outcomes of existing assembly line.

Bottle neck point	Average processing time at bottleneck point, sec	Daily production capacity, unit	Number of worker assigned at assembly line, unit	Utilization (%)	Idleness (%)	Average time of processing time of the line, sec	Line efficiency (%)
10	25.37	1135	18	54.15	45.85	13.74	54.15

8.2.1.2 Utilization and Idleness

From annexure-iv, sum of the total productive time of each workstation of the assembly line in one cycle is 164.84 second and sum of the available time of each workstation of the assembly line is 304.40 second

$$\text{Utilization (\%)} = \frac{\sum_{j=1}^{n} T_j}{nc} \times 100\%$$

$$= \frac{164.84}{304.40} \times 100\%$$

$$= 54.15\%$$

From annexure-iv, total idle time of a cycle is 139.60 second and capacity of the line is 304.40 second. Therefore the idleness of the line is

$$\text{Idleness (\%)} = \frac{\sum_{j=1}^{n} (c - T_j)}{nc} \times 100\%$$

$$\text{Idleness (\%)} = \frac{139.60}{304.40} \times 100$$

$$= 45.85\%$$

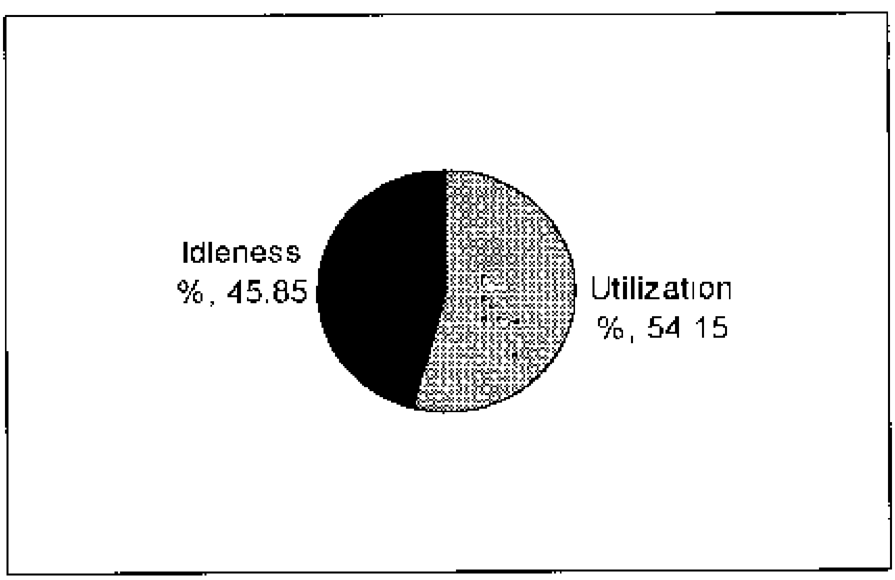

Figure 8.3: Utilization and Idleness of existing assembly line

8.2.1.3 Line Efficiency

From table 8.4, average processing time of workstations is 13.74 second and the cycle time or bottleneck processing time is 25.37 second.

$$\text{Line efficiency, E(\%)} = \frac{\sum_{j=1}^{n}(c - T_j)}{nc} \times 100\%$$

$$\text{Line efficiency, E(\%)} = \frac{13.74}{25.37} \times 100$$

$$= 54.15\%$$

To improve productivity of assembly line, iteration is applied based on their overall daily efficiency. Eighteen workers are placed in different workstation randomly as it is possible to predict which position of worker will provide optimum productivity.

Number of worker at different workstation has been counted based on the number of worker of the existing assembly line. Position of each worker is explained in table 8.6.

Three workers are placed in workstation 7 and four workers are assigned in workstation 8 to meet with the throughput of previous workstation. Two workers are assigned in workstation in workstation 9. In other workstations, one worker is placed in each workstation.

Initially, workstation 12 where neck & sleeve opening chap tack operation carried out is the bottleneck point of developed assembly line. Average processing time of bottleneck point is 22.37 second and efficiency of Worker J who working at this workstation is 67.05 %.Worker G_2 whose efficiency is 102.20% and maximum working at workstation 8.

At iteration-1, worker J is transferred from workstation 12 to workstation 8 and worker G_2 is transferred from workstation 8 to workstation 12 because the efficiency of worker G_2 is the maximum among eighteen workers. The bottleneck point is transferred from workstation 12 to workstation 10.

At iteration-2, worker G_3 is transferred from workstation 12 to workstation 10 and worker D whose overall efficiency is 89.48% is transferred from workstation 10 to workstation 12. Now the bottleneck point is transferred from workstation 10 to workstation 12. The processing time at bottleneck point or cycle time is 16.76 second which is 18.78 second at iteration-1.

After iteration-2, the daily production capacity of workstation 9 is 4150 unit and production capacity of bottleneck point is 1718 unit. Hence, production capacity of workstation 9 is more than twp times than bottleneck point and cause a huge buffer at workstation 12. To reduce buffer, worker B is released from workstation 9. Now the daily production capacity of workstation 9 is 2160 units which meet with production capacity of bottleneck point.

To check the effect of violating the steps of method has been used. Less efficient worker H_3 is assigned at workstation 12 and worker D is assigned at workstation 7. The bottleneck point is not transferred from workstation 12 but the cycle time is increased from 16.76 second to 17.11 second. Now the daily production capacity of the assembly line reduce to 1683 units from 1718 units which is not desirable for the shack of productivity.

The position of workers, processing time of each workstation and cycle time after each iteration has been explained in table 8.5

Table 8.5. Iteration of proposed combination

Number of workstation		1	2	3	4	5	6	7	8	9	10	11	12	Activity	Bottleneck point	Daily production capacity
	Operation	Sh R	S L A	N B	N C	Sh L	S H	SI	SS	S O C	M L A	B H	N & S O C T			
Initial	Worker name	H_1	C	L	K	E	I	$H_2H_3H_4$	A I_2 G_1 G_2	B G_3	D	F	J	-	12	1287
	Average processing time, sec	9.72	15.17	11.95	11.69	10.34	15.92	11.96	9.92	6.94	18.78	15.03	22.37			
	Production capacity	2962	1898	2409	2464	2785	1809	2408	2903	4150	1534	1916	1287			
Iteration-1	Worker name	H_1	C	L	K	E	I_1	$H_2H_3H_4$	A I_2 G_1 J	G_3 B	D	F	G_2	Replacement of J from Workstation 12 to workstation 8 & G_2 from workstation 8 to workstation 12	10	1534
	Average processing time, sec	9.72	15.17	11.95	11.69	10.34	15.92	11.96	12.42	6.94	18.78	15.03	14.65			
	Production capacity	2962	1898	2409	2464	2785	1809	2408	2319	4150	1534	1916	1962			
Iteration-2	Worker name	H_1	C	L	K	E	I_1	$H_2H_3H_4$	A I_2 G_1 J	G_3 B	G_2	F	D	Replacement of G_2 from workstation 12 to workstation 10 & D from workstation 10 to workstation 12	12	1718
	Average processing time, sec	9.72	15.17	11.95	11.69	10.34	15.92	11.96	12.42	6.94	16.44	15.03	16.76			
	Production capacity	2962	1898	2409	2464	2785	1809	2408	2319	4150	1752	1916	1718			
Iteration-3	Worker name	H_1	C	L	K	E	I1	$H_2H_3H_4$	A I_2 G_1 J	G_3	G_2	F	D	Releasing B from workstation 9	12	1718
	Average processing time, sec	9.72	15.17	11.95	11.69	10.34	15.92	11.96	12.42	13.33	16.44	15.03	16.76			
	Production capacity	2962	1898	2409	2464	2785	1809	2408	2319	2160	1752	1916	1718			
Iteration-4	Worker name	H_1	C	L	K	E	I1	D H_2 H_3	A I_2 G_1 J	G_3	G_2	F	H_4	Replacement of D from workstation 12 to workstation 7 & H_4 from workstation 7 to workstation 12	12	1683
	Average processing time, sec	9.72	15.17	11.57	11.69	10.34	15.92	11.87	12.42	13.33	16.44	15.03	17.11			
	Production capacity	2962	1898	2490	2464	2785	1809	2426	2319	2160	1752	1916	1683			

Table 8.6: Key outcomes of each iteration of proposed line

Number of Iteration	Number of worker assigned	Bottleneck point	Bottleneck point processing time (c), sec	Daily production capacity	Productivity improvement %	Utilization %	Idleness %	Line efficiency %
INITIAL	18	12	22.37	1287	-	59.53	40.47	59.53
ITERATION-1	18	10	18.78	1534	19.19	68.60	31.40	68.60
ITERATION-2	18	12	16.76	1718	33.49	76.74	23.26	76.74
ITERATION-3	17	12	16.76	1718	33.49	79.92	20.08	79.92
ITERATION-4	17	12	17.11	1683	30.77	75.11	24.89	75.11

8.3.2 Assembly Line after Optimization

8.3.2.1 Initial

From table 8.5, the processing time at the bottleneck point is 22.37 second and the bottleneck point lies at workstation 12. The daily production capacity of the proposed line is 1287 unit. Initially, utilization and idleness of the developed line assembly line is 59.53% and 40.47%. Worker J is assigned at the bottleneck point whose overall daily efficiency is 67.05%. Initially the assigning of worker at the workstation has been carried out randomly without considering their performance. The productivity loss due to physical fatigue is triggered by only the physical ability of the worker at bottleneck point. Line efficiency of the developed line is 59.53%. Total number of worker at the workstation is 18

8.3.2.2 Iteration-1

After iteration-1, G_2 is replaced at the initial bottleneck point and worker J is replaced at the workstation 12. Now, bottleneck point is transferred from workstation 12 to 10. Worker D is working at the new bottleneck point and average processing time of bottleneck point is 18.78 second and daily production capacity is 1534 units. From figure8.2, overall efficiency of worker D is 89.48 % which is less than worker G_2. From figure 8.10, the efficiency of the assembly line is 68.60%.

8.3.2.3 Iteration-2

After iteration-2, worker G_2 is replaced from 12 to workstation 10 and D is transferred from 10 to 12. At iteration-2, bottleneck point is transferred from 10 to workstation 12. Average processing time at bottleneck point is 16.76 second and maximum daily production capacity is 1718 units. Daily production capacity of each workstation is not more than two times than bottleneck point except workstation 9. Daily production capacity of workstation 9 is 4150 units where it is 1718 unit at bottleneck point. The efficiency of the assembly line is increased to 76.74%.

8.3.2.4 Iteration-3

From figure8.2, two workers G_3 and B are assigned at the station and their overall efficiency are 85.49% and 78.72% respectively. At iteration-3, less efficient worker B is released from workstation. From figure8.4, the processing time at bottleneck point is 16.76 second and the daily production capacity is 1718 unit. From figure 8.8 and figure 8.9, the utilization and idleness of the assembly line is 79.92% and 20.08% respectively. Now daily production capacity of workstation 9 is 2160 units And other outcomes remains same

8.3.2.5 Iteration-4

To check the effect on productivity if iteration is continued violating the steps of figure 6.1. From figure 8.4, at iteration-4, average processing time at bottleneck point increases from 16.76 second to 17.11 second and daily production capacity reduce from 1718 unit to 1683 units. As in apparel industry, daily production capacity is the major concern, therefore, after iteration-3, further iteration is not wise for the sack of daily production capacity

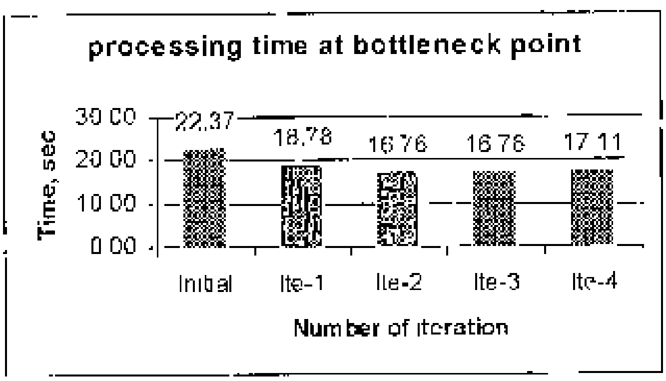

Figure 8.4 Bottleneck time of proposed line at each iteration.

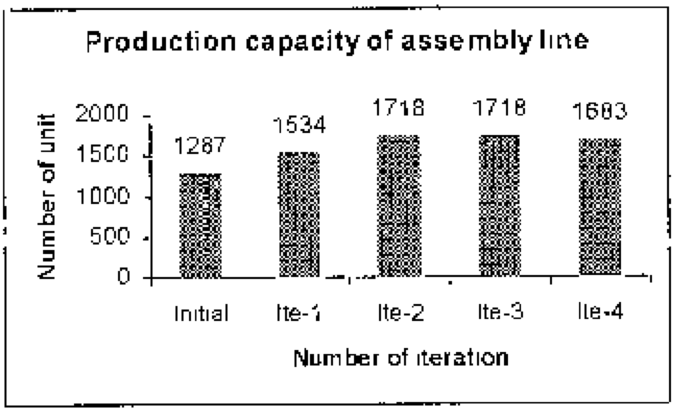

Figure 8.5: Production capacity of proposed line at each iteration

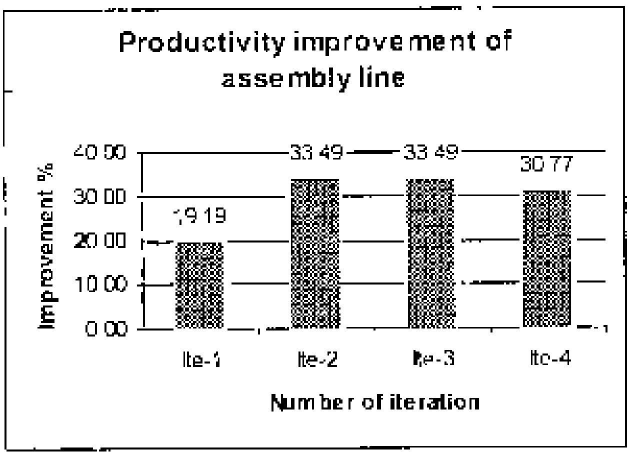

Figure 8.6: Productivity improvement of proposed line at each iteration

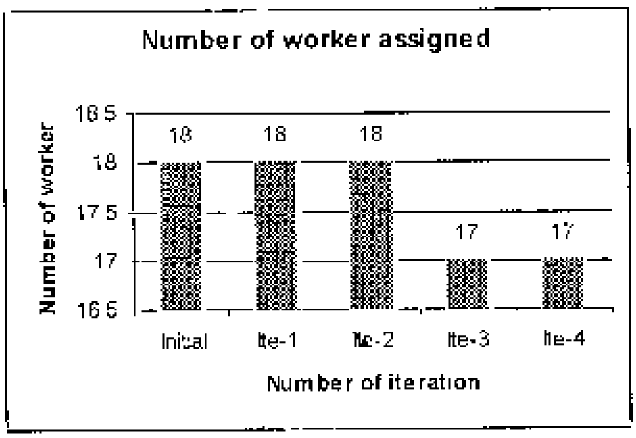

Figure 8.7: Total number of worker assigned at proposed line at each iteration

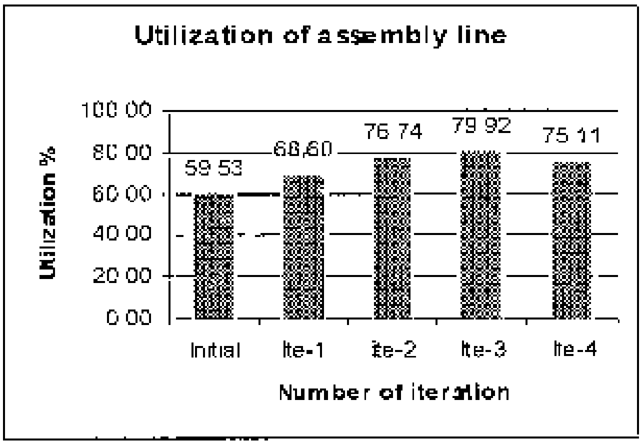

Figure 8.8. Utilization of proposed line at each iteration

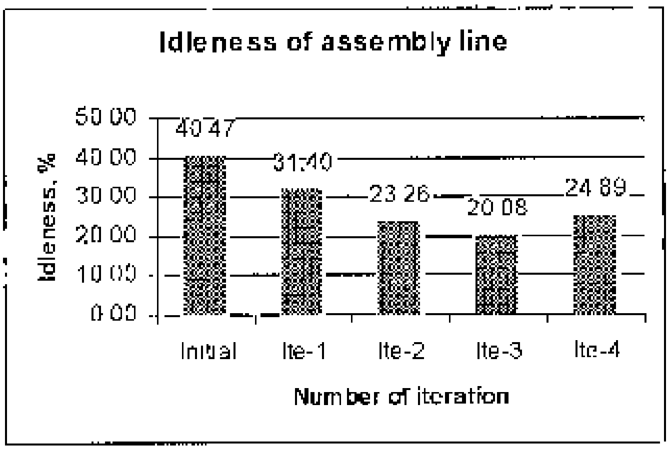

Figure 8.9. Idleness of proposed line at each iteration

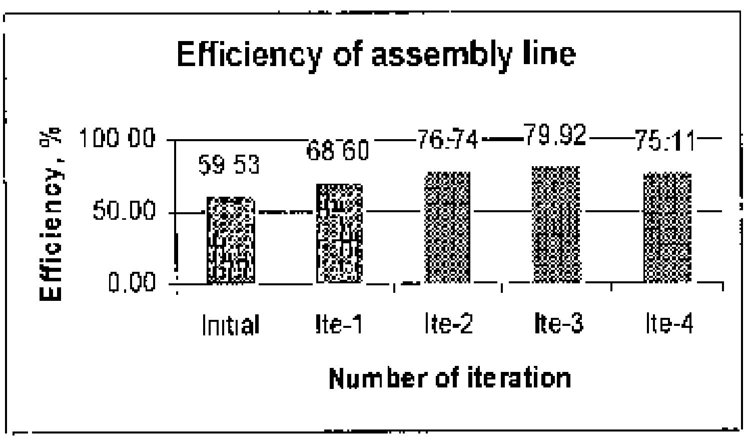

Figure 8.10. Efficiency of proposed line at each iteration.

Table 8.7: Improvement of developed line compare to existing line

Situation	Key outcomes							
	Processing time at bottleneck point, sec	Daily production capacity, unit	Number of worker assigned, unit	Loss due to fatigue,	Utilization %	Idleness %	Average of processing time of each workstation sec	Line efficiency %
Existing	25 37	1135	18	17.30%	54 15%	45 85%	13 74	54 15
Optimized situation of proposed line	16 76	1718	17	8 21%	79 92%	20 08%	13 39	79 92
Improvement	33 94%	51.40%	1 unit	52.54%	47.59%	56 21%	2 49%	47.59%

After iteration-3, production capacity is improved very significantly compare to existing assembly line. Line efficiency, utilization, idleness, loss due to fatigue also improved at iteration-3. Therefore, position of worker at iteration-3 is most feasible than iteration-1, iteration-2 and iteration-4.

8.3.3 Assembly Line after Line Balancing

In the flow production system, it is one of the principles, from mass production point of view to eliminate unnecessary transfer and hold up to achieve smooth production flow using the pitch time as the references value for synchronization. To grasp the actual condition of the line balance, it is essential to complete the work by division of labor (by worker) to arrange the results the following the normal order of process and present them in graphical form in the pitch diagram With investigating of the bottleneck process, control limit using the pitch diagram must be calculated with line efficiency 85%

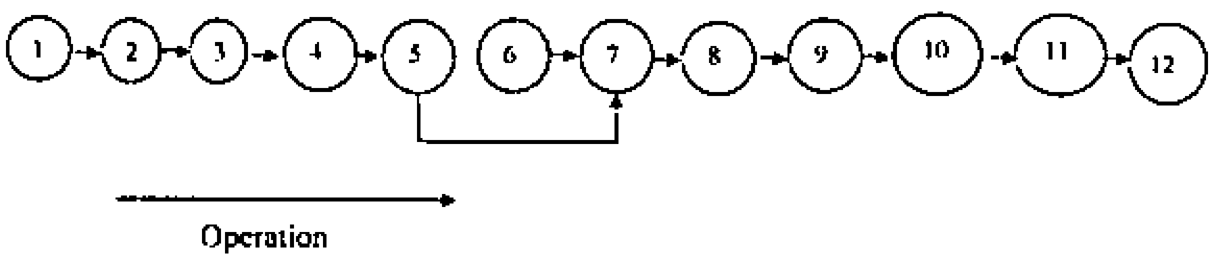

Figure 8 11: Precedence constrain for sewing

Table 8.8: Line balancing of proposed line of a T-shirt (Iteration-2)

Operation	Workstation	Preceding workstation	Task assigned	Worker assigned	Machine Name	Task required predecessor	Task time/per unit, second
1	1	-	SHR	H_1	Over Lock	-	9.72
2	2	1	SLA	C	Plain	SHR	15.17
3	3	2	NB	L	Inter lock	SLA	11.95
4	4	3	NC	K	Plain	NB	11.69
5	5	4	SHL	E	Over Lock	NC	10.34
6	6	-	SH	I_1	Inter lock	-	15.92
7	7	5,6	SL	H_2H_3 H_4	Over Lock	SHL, SH	11.96
8	8	7	SS	A I_2 G_1 J	Over Lock	SL	12.42
9	9	8	SOC	G_3	Plain	SS	13.33
10	10	9	MLA	G_2	Plain	SOC	16.44
11	11	10	BH	F	Inter lock	MLA	15.03
12	12	11	N&SOCT	D	Plain	BH	16.76

From table 8.8 which has been drawn based on the table8.5 after iteration-3. After iteration-3, the line efficiency is 79.92% and cycle time is 16.76 second Considering target line efficiency is 85%, the pitch diagram has been drawn Upper control limit, center line and lower control limit has been calculated using equation (5 6), (5.7), and (5.8)

Theoretical minimum number of workstation, $n_o = \lceil \frac{T_w}{C} \rceil$

$$= \frac{154.34}{16.76}$$

$$= 9.20 \approx 10$$

The minimum number of workstation is calculated using equation (5.9). The minimum number of workstation when cycle time is 10. It does not mean the exact number required for balancing

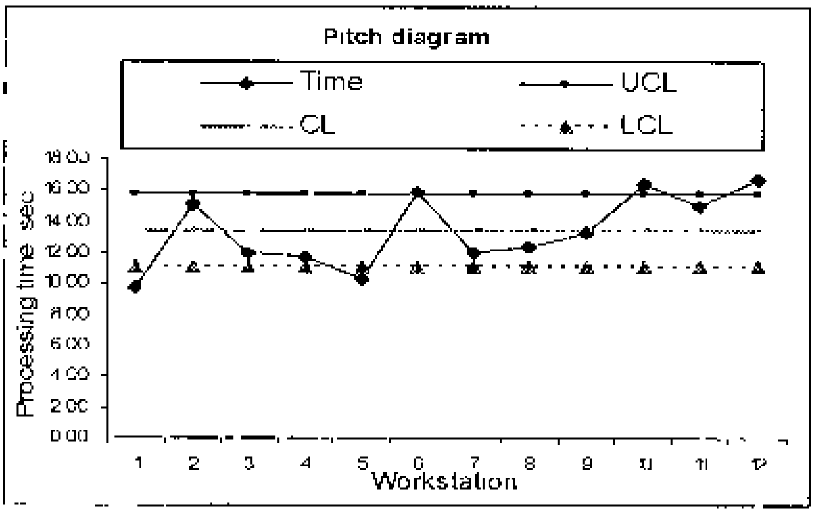

Figure 8 12 Pitch diagram of developed line after iteration-3

From figure 8 12, at workstation 6, 10 and 12, processing time for an operation goes out of upper control limit. But to improve production capacity, it is wise to reduce cycle time or bottleneck processing time To reduce processing time at bottleneck point or cycle time, iteration has been made again and efficient worker is placed at the bottleneck point. Two new workers has been assigned at the workstation whose daily overall efficiency is identical of C. Several iterations has been carried out for reducing cycle time which is explained in annexure-viii

Table8.9: Task time after line balancing of proposed line of a T-shirt

Operation	Workstation	Preceding workstation	Task assigned	Worker assigned	Machine Name	Task required predecessor	Task time per unit, second
1	1	-	Sh R	H_1	Over Lock	-	9.72
2	2	1	SLA	F	Plain	Sh R	12.03
3	3	2	NB	L	Inter lock	SLA	11.95
4	4	3	NC	K	Plain	NB	11.69
5	5	4	Sh L	E	Over Lock	NC	10.34
6	6	-	SH	C I_1	Inter lock	-	8.66
7	7	5,6	SL	H_2H_3 H_4	Over Lock	Sh L, SH	11.96
8	8	7	SS	A I_2 G_1 J	Over Lock	SL	12.42
9	9	8	SOC	D	Plain	SS	12.74
10	10	9	MLA	C C	Plain	SOC	13.28
11	11	10	BH	G_2	Inter lock	MLA	11.74
12	12	11	N&SOCT	G_3B	Plain	BH	9.14

Position of worker and processing time of individual workstation after each iteration has been explained in annexure-viii. Daily production capacity, utilization, idleness, and line efficiency has been calculated using equation (4.1), (4.3), (4.4) and (4.5)

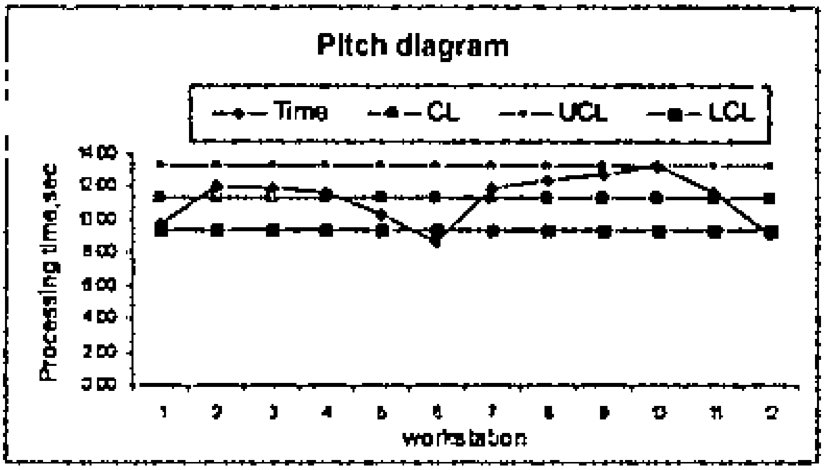

Figure 8.13: Pitch diagram of proposed line after line balance

Table 8.10: Improvement after line balancing

Situations	Total time, Sec	Average time, sec	Cycle time, sec	Line capacity, sec	Idle time sec	Daily production, Unit	Productivity Unit/worker	Utilization %	Idleness %	line Efficiency %
Existing	165.75	13.81	25.37	304.44	168.69	1135	63	54.44	45.56	54.44
Before Balancing (Iteration-2)	154.34	12.86	16.76	201.12	45.78	1718	101	76.75	23.25	76.75
After balancing	135.67	11.30	13.28	159.36	23.66	2169	108	85.15	14.85	85.15
Improvement compare to existing line (%)	18.14	18.17	47.65	47.65	85.96	91.10	71.42	56.41	67.40	56.41
Improvement compare to iteration 2 (%)	12.09	12.13	20.76	20.76	49.36	26.25	6.54	10.94	36.12	10.94

8.4 Loss Due to Fatigue

Performance of workers does not remain same throughout the whole shift. Worker becomes tired from long hour of working entirely and loss their working capability which results a loss in the production capacity of worker. A significant amount of product has been losing in garment industry due to the physical fatigue of worker This productivity loss has an impact on the profit margin. But in Bangladesh, owner of the garment companies has been ignoring.

8.4.1 Existing Line

In existing assembly line. worker J is placed at the bottleneck point at workstation. Due to a cumulative fatigue, efficiency of the worker does not remain constant At the very beginning of the day, each worker takes more time due to physical rigidity. After several minutes worker get rid from this and perform with maximum efficiency

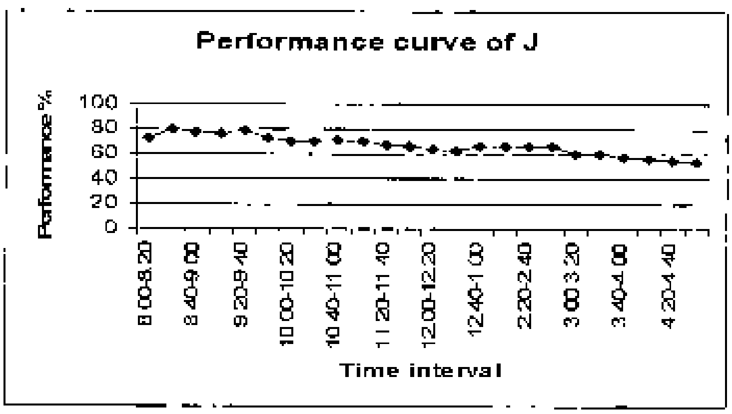

Figure 8 14 Performance curve of J

But the time for getting rid from rigidity is not same for each worker From figure 8 14. worker J can perform with maximum efficiency from 9.20-9 40 time segment and it reduced with time interval After having a break for one hour from 1 00-2.00 pm, performance of the worker increases up to a level and then it decreases with time. From table 8.2, maximum production capacity in twenty minutes is 63 units at 9:20 to 9 40 time segment then it decrease. Subtracting actual production capacity from maximum production capacity loss due to fatigue has been calculated. Considering no physical fatigue, maximum production capacity of existing assembly line is 1331 units But due to physical fatigue, actual production capacity of assembly line is 1135 units Therefore loss due to physical fatigue is 196 units

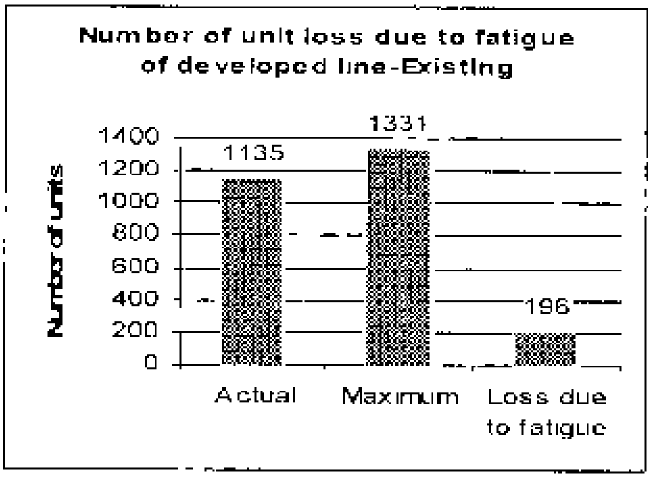

Figure8 15 Number of unit loss due to fatigue of existing line

Table 8.11: Productivity loss due to fatigue of proposed assembly line

TIME INTERVAL	EXISTING			INITIAL			ITERATION 1			ITERATION 2			ITERATION 3			ITERATION 4		
	P_a	P_m	$P_m - P_a$	P_a	P_m	$P_m - P_a$	P_a	P_m	$P_m - P_a$	P_a	P_m	$P_m - P_a$	P_a	P_m	$P_m - P_a$	P_a	P_m	$P_m - P_a$
8.00-8.20	52	52	0	58	58	0	57	57	0	64	64	0	64	64	0	70	70	0
8.20-8.40	57	57	0	64	64	0	59	59	0	66	66	0	66	66	0	70	70	0
8.40-9.00	56	56	0	62	62	0	62	62	0	69	69	0	69	69	0	71	71	0
9.00-9.20	55	55	0	61	61	0	65	65	0	73	73	0	73	73	0	70	70	0
9.20-9.40	56	56	0	63	63	0	69	69	0	78	78	0	78	78	0	70	70	0
9.40-10.00	53	56	3	58	63	5	70	70	0	79	79	0	79	79	0	71	71	0
10.00-10.20	49	56	7	56	63	7	70	70	0	78	78	0	78	78	0	71	71	0
10.20-10.40	50	56	6	56	63	7	71	71	0	80	80	0	80	80	0	72	72	0
10.40-11.00	51	56	5	57	63	6	68	71	3	77	77	0	77	77	0	72	72	0
11.00-11.20	50	56	6	56	63	7	68	71	3	76	77	1	76	77	1	72	72	0
11.20-11.40	48	56	8	54	63	9	67	71	4	75	77	2	75	77	2	71	72	1
11.40-12.00	47	56	9	53	63	10	64	71	7	71	77	6	71	77	6	70	72	2
12.00-12.20	45	56	11	51	63	12	65	71	6	73	77	4	73	77	4	70	72	2
12.20-12.40	44	56	12	50	63	13	65	71	6	73	77	4	73	77	4	61	72	3
12.40-1.00	47	56	9	53	63	11	62	71	9	69	77	8	69	77	8	68	72	4
2.00-2.20	47	56	9	53	63	10	67	71	4	75	77	2	75	77	2	69	72	3
2.20-2.40	47	56	9	53	63	10	65	71	6	73	77	4	73	77	4	69	72	3
2.40-3.00	47	56	9	53	63	10	67	71	4	75	77	2	75	77	2	70	72	2
3.00-3.20	43	56	13	48	63	15	66	71	5	74	77	3	74	77	3	70	72	2
3.20-3.40	43	56	13	48	63	15	64	71	7	71	77	6	71	77	6	70	72	2
3.40-4.00	41	56	16	46	63	17	59	71	12	66	77	11	66	77	11	70	72	2
4.00-4.20	40	56	17	45	63	18	55	71	16	62	77	15	62	77	15	70	72	2
4.20-4.40	39	56	17	44	63	19	53	71	18	59	77	18	59	77	18	69	72	3
4.40-5.00	38	56	18	43	63	21	54	71	17	61	77	16	61	77	16	67	72	5
Total unit	1135	1331	196	1297	1510	273	1534	1700	176	1719	1860	142	1718	1860	142	1693	1719	30

Number of unit loss= $P_m - P_e$

Loss due to fatigue = 1331-1135

Loss due to fatigue (%)= $\frac{P_m - P_e}{P_e} \times 100\%$

Loss due to fatigue = {(1331-1135) ×100} ÷1135
=17.30%

8.4.2 Productivity Loss of Proposed Line

To optimize the productivity of assembly line, assembly line is designed again depending on the performance of worker At each iteration of developed line, more efficient worker is placed at bottleneck point. Maximum and actual daily production capacity of assembly line is calculated based of the performance curve of worker D, and J on figure 8.17 and figure 8.14 respectively

8.4.2.1 *Initial*

As the workstation is designed randomly without considering the performance of worker so that there is no biasing occurs during placement of worker. Initially, at bottleneck point. worker J is assigned The performance curve of the worker is stated first.

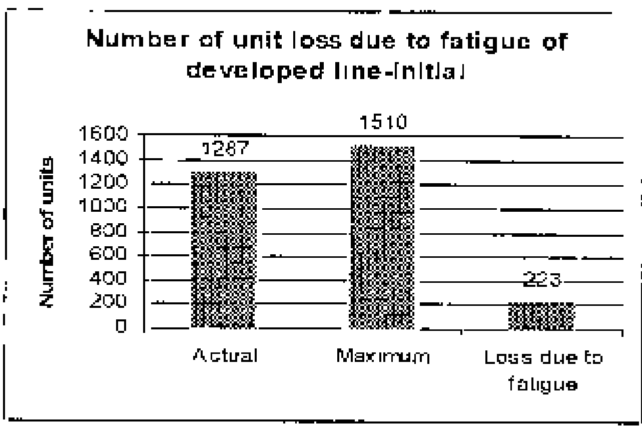

Figure 8 16 Number of unit loss due to fatigue of proposed combination line

From figure 8.14, worker J can perform with maximum efficiency from 9.20-9 40 time segment and it reduced with time interval After having a break for one hour from 1.00-2 00 pm, performance of the worker increases up to a level and then it decreases with time Number of unit loss and the percent of loss is calculated using equation (5.2) and (5 3)

From table 8.2, maximum production capacity in twenty minutes is 63 units at 9·20 to 9. 40 time segment then it decrease The bottleneck point is lies at workstation 12 where operation neck and sleeve opening chap tack is performed.

From table 8 12, the actual production capacity of the existing assembly line is 1287 unit and maximum production capacity when fatigue is not considered is 1510 units The number of 223 units is loosed due to physical fatigue which is about 17 30% Number of unit loss and the percent of loss is calculated using equation (6.2) and (6 3)

Table 8.12. Productivity loss due to fatigue of proposed assembly line

INITIAL			ITERATION-1			ITERATION-2			ITERATION-3			ITERATION-4		
P_a	P_m	P_m-P_a	P_a	P_m	P_m-P_a	P_a	P_m	P_m-P_a	P_a	P_m	P_m-P_a	P_a	P_m	P_m-P_a
1287	1510	223	1534	1660	126	1718	1860	142	1718	1860	142	1683	1719	36
17.30 %			8.21 %			8.21 %			8.21 %			2.15 %		

8.4.2.2 Iteration-1

To optimize productivity of assembly line, assembly line has been designed again depending on the performance of worker. At each iteration of developed line, more efficient worker is placed at the bottleneck point As, among eighteen workers, worker G_2 holds maximum efficiency of 102 20% Therefore, the worker is placed at the bottleneck point. But bottleneck point is transferred from workstation 12 to workstation 10 where worker D is assigned As productivity loss depends on the worker of bottleneck point. hence, at this situation, performance of worker D is studied to calculate the fatigue loss.

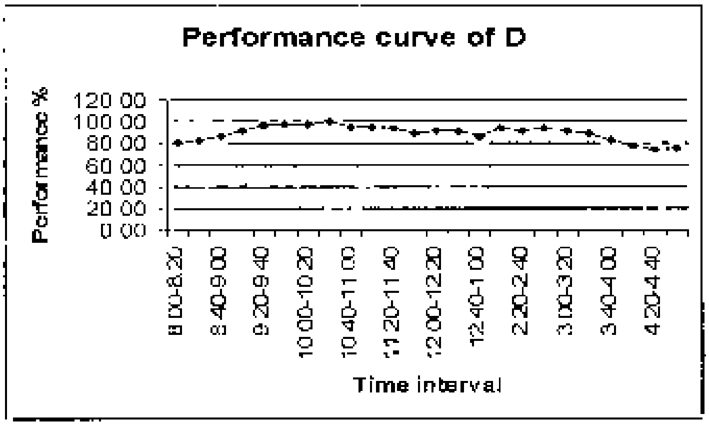

Figure 8.17: Performance curve of worker D

From figure 8 17, it is clear that performance of worker D does not remain constant throughout the whole shift Just after getting rid from physical rigidity, the efficiency of worker D reach at the optimum value of 99.80% at 10 20-10-40 time segment But it is reduce with increasing time Having a reduction to a value of 86 28% at 12 40-1 00 time segment, it is increase after a rest for one hour At the end of the day, the worker shows 75 66% efficiency

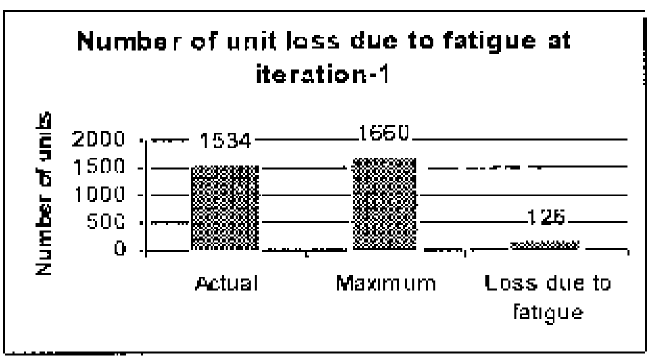

Figure 8 18 Number of unit loss due to fatigue of proposed combination line at ite-1.

From figure8.18, the maximum production capacity after iteration-1 is 1660 units without considering any physical fatigue. But the actual production capacity of the assembly line is 1534 Therefore. 126 unit is loosed due to physical fatigue which 8.21% of actual production capacity.

8.4.2.3 Iteration-2

At iteration-2. worker G_2 is transferred from workstation 12 to workstation 10 and worker D is transferred from 10 to 12 But bottleneck point exist at the workstation 12 where worker D has been assigned. Operation neck and sleeve opening chap tack is performed at the workstation at the workstation The nature of performance curve of worker D is stated previously From figure 8 19. the actual production capacity is 1718 unit and maximum production capacity of the assembly line without considering no fatigue is 1860 units Therefore. 142 units are loosed due to physical fatigue

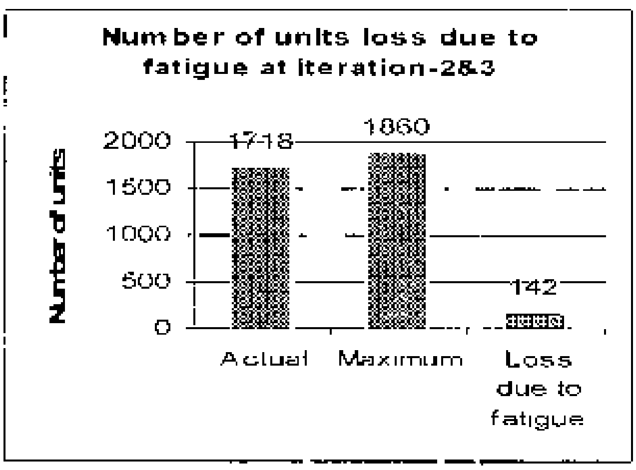

Figure 8 19 - Number of unit loss due to fatigue of proposed combination line at ite-2&3

8.4.2.4 Iteration-3

At iteration-3 no worker has been transferred from workstation because performance of worker is greater than other worker Only worker B is released from the workstation. At iteration-2, the production capacity of workstation 9 is 4150 unit but production capacity of bottleneck workstation is 1718 units Hence, production capacity of workstation 9 is more than two time compare to bottleneck point There has no meaning to assigning any unnecessary worker in the assembly line

As, production capacity of assembly line is triggering by the workstation 12 where worker D has been assigned Therefore, productivity loss will be triggered by the workstation 12. The nature of performance of worker D who is assigned at workstation 12 has been stated

As there is no interchange of workstation of worker. there is no change in the actual and maximum production capacity. The productivity loss remains same as again worker D is assigned at his/her previous workstation. 8.21% percent is loosed due to fatigue

8.4.2.5 Iteration-4

Iteration-4 has been carried out to examine whether productivity can be improved if steps if iteration is violated At iteration-4, there is a significant result for productivity loss But it is not wise for the shake of productivity Actual number of unit what can be produced in an 8 hour shift is 1683 units and maximum production capacity is 1719 units Therefore, 36 units is loosed because of fatigue. Hence, loss due to fatigue is 2 15%.

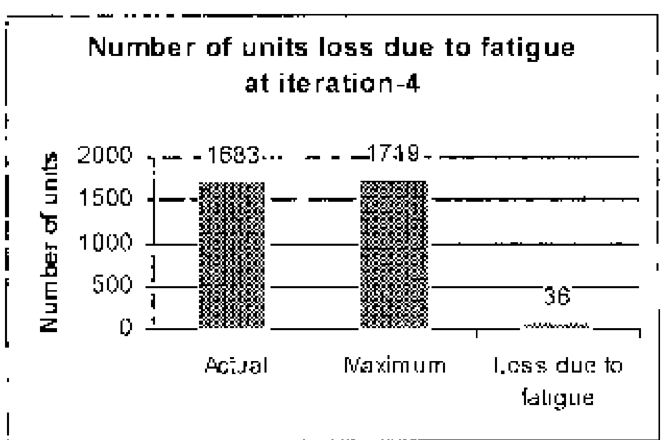

Figure 8 20: Number of unit loss due to fatigue of developed combination line at ite-4

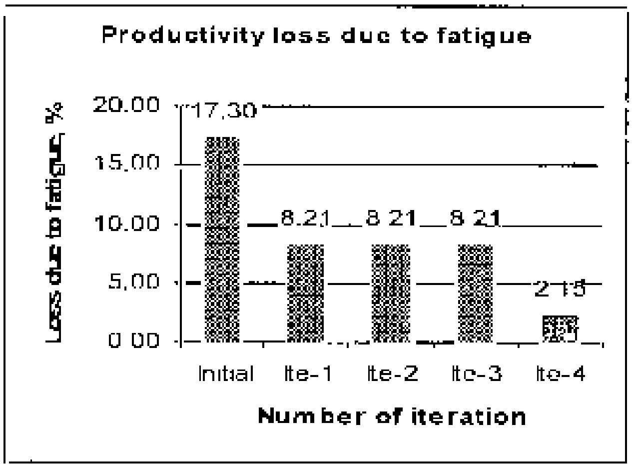

Figure8 21· Productivity loss due to fatigue

8.4.3 *After balancing the line*

Figure 8 22 shows the nature of performance with time interval of C Two workers C whose efficiency is identical, has been assigned in the workstation and cycle time is 13.28 second. The available time is 8 hours Therefore daily production capacity is 2169 unit. Figure 8 22 and table 8 13 show the nature of performance and productivity with time interval

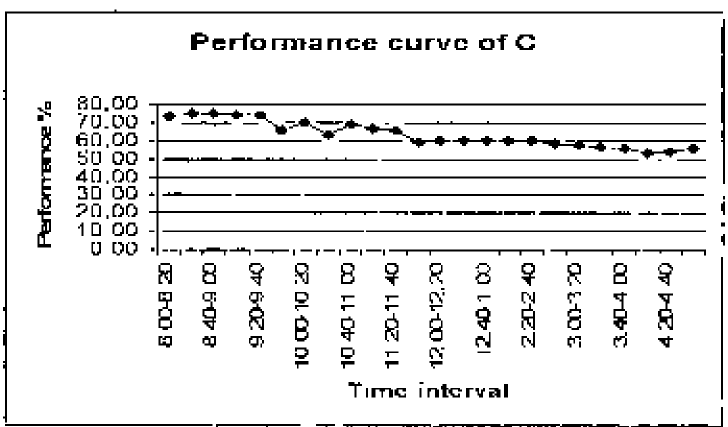

Figure 8.22 Performance curve of C.

Maximum production can found at 10.00-10 20 time segment and it is reduced with time 100 units can be produced at 10.00-10 20 time segment But at the end of the day the capacity is reduced to 79 units in twenty minute. Without considering any physical fatigue, the maximum total production capacity of the assembly line is 2425 unit Therefore. 256 units is loosed due to fatigue which is 11 80% of the actual production capacity

Table 8 13 Productivity loss due to fatigue of proposed assembly line after line balancing

Time interval	P_a	P_w	$P_w - P_a$
8 00-8 20	105	105	0
8 20-8 40	107	107	0
8 40-9 00	108	108	0
9 00-9 20	106	106	0
9 20-9 40	106	106	0
9 40-10 00	94	94	0
10,00-10 20	100	100	0
10 20-10 40	90	100	10
10 40-11 00	99	100	1
11 00-11,20	95	100	5
11,20-11 40	93	100	7
11 40-12 00	84	100	16
12,00-12 20	85	100	15
12 20-12 40	86	100	14
12 40-1 00	86	100	14
2 00-2 20	86	100	14
2 20-2 40	85	100	15
2 40-3 00	83	100	17
3 00-3 20	82	100	18
3 20-3 40	80	100	20
3 40-4 00	80	100	20
4 00-4 20	76	100	24
4 20-4 40	76	100	24
4 40-5 00	79	100	21
Total	2169	2425	256

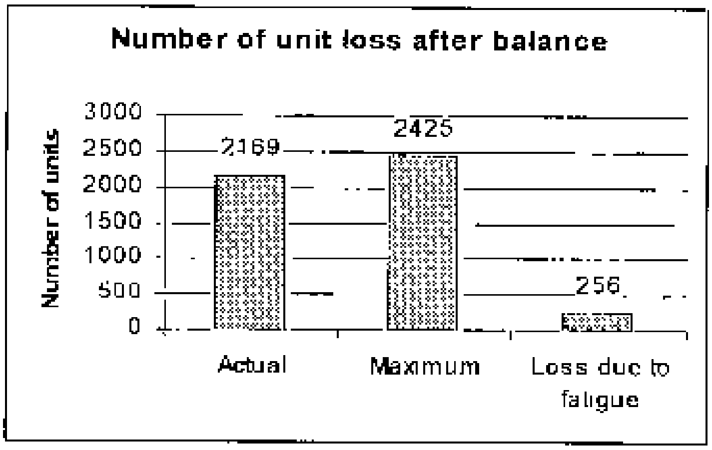

Figure 8.23: Number of unit loss due to physical fatigue after balancing

$$\text{Loss due to fatigue (\%)}=\frac{P_m-P_a}{P_a}\times 100\%$$

$$=\frac{256}{2169}\times 100=11.80\%$$

8.5 Conclusion

Production capacity of assembly line is increased with replacing more efficient worker at the bottle neck point Not only production capacity but also utilization, line efficiency, idleness has been improved after each iteration Every worker incurs a minimum space and wage which led to increase cost of production Therefore, unnecessary workforce in assembly line increase production cost and it is meaningless to assign Hence, assigning efficient worker at bottleneck point, number of total workforce can be reduced very significantly. Because of working for long time, production capacity is decreased to a remarkable amount But the level of physical fatigue of each worker does not same. Therefore, it is wise to place a worker with high physical stamina level Along with placing worker with stamina at bottle neck point, a predictive model should be generated that would allow job designers to estimates when workers will reach unsafe levels of fatigue In addition, in setting a work environment, the main sources of fatigue such as air, noise, vibration, lighting, length of shift, temperature, radiation, and ergonomics should be considered

CHAPTER-IX
RESULTS AND DISCUSSION

9.1 Introduction

Fatigue study of worker is a very significant way to design the position of worker at the assembly line Overall performance of worker changes with the increasing of time of shift Misplacement of worker results a reduction in the production capacity of assembly line Therefore worker should be placed based on their overall daily performance A very promising result can obtained from the workforce by introducing a proper way of placing Hence, every garments industry should follow an effective way while assigning worker in the assembly line

9.2 Results and Discussion

The thesis presents the results of analysis and development of a frame work for improving productivity of assembly line by analyzing overall performance of worker In this thesis time study, worker performance, utilization of assembly line, idleness of assembly line has been studied to develop a framework of improving production capacity assigning same worker at different workstation

In chapter 8 and table 8 5, existing bottleneck point time is 25 37 second and lies at workstation 10 Daily production capacity is 1135 unit From table 8.4, utilization and idleness of existing assembly line is 54 15% and 45.85 %. Efficiency of existing assembly line is 54.15%. Production capacity loss due to physical fatigue is 17 31%

To improve productivity, assembly line is rearranged and more efficient worker is placed at the bottleneck point based on their overall efficiency. From table 8.6, it is cleared that after each iteration processing time at bottleneck point is decreased and daily production capacity is increased

In chapter 8 and table 8 5, initially processing time at bottleneck point is 22.37 second of the developed combination. After iteration-3, the processing time is reduced from 22 37second to 16.76 second. If any more iteration is carried out violating steps of optimization which is explained in figure 6.1, average processing time is increased. At iteration-4, processing time is increased from 16 76 second to 17 11 second Due to increase in processing time, daily production capacity will be decreased Therefore it is not wise of violating steps. From figure 8.5, initial production capacity of developed assembly line is 1287 unit After iteration-3, daily production capacity increased 1718 unit But if further iteration is done violating steps of figure 6.1, daily production capacity is decreased From figure8 6, at iteration-3 productivity of developed assembly line has been improved by 33.49% percent but it is decreased at iteration-4 to 30.77% Therefore, for the shack productivity of assembly line, position of worker at iteration-3 is most feasible Production cost is directly related to labor cost If excessive number of worker in assembly line is assigned, production cost must be increased. From figure 8 7, at iteration-3 and iteration-4, 17 workers are required to meet with the productivity of bottleneck point Initially, eighteen workers are assigned in existing assembly line but after iteration-2 one worker is released to reduce unnecessary manpower Figure 8.8 and figure 8 9 show, utilization of assembly line is increased with decreasing idleness. At iteration-3, utilization is 79.92 % and idleness is 20.08 %. Initially utilization and idleness is 59.53 % and 40 47% respectively. Figure 8 10 shows a successive increase in line efficiency Line efficiency is increased from 59.53 % to 79.92% after iteration-3 line efficiency decrease if condition of figure 6.1 is violated

After balancing time assembly line which has been found after iteration-2. The daily production capacity is also increased to 2169 units. Not only production capacity but also line efficiency and idleness have been increased by 56 41% and 67 40 % compare to existing line The cycle time reduced from 25.37 second to 13 28 second From figure 8 13, the line is well balanced as each workstation lies within the control limit

As physical fatigue depends on the physical stamina of worker and line productivity on bottleneck point, it is wise to select higher physical stamina at bottleneck point to improve productivity. From figure 8 16, initially, maximum and actual daily production capacity of proposed line is 1510 unit and 1287 unit. Therefore, 223 units are loosed due to physical fatigue But the number of unit loosed due to physical fatigue is decreased to 101 units after iteration-3 At iteration-4 number of units loosed due to fatigue is 36 units From figure 8 22, initial loss due to fatigue of developed assembly line is 17.30% At iteration-1, iteration-2, and iteration-3, the loss is same and it is 8 21% because of same worker is placed at the bottleneck point But this loosed is decreased to 2 15 % at iteration-4

After balancing the line which has been found after iteration-2, from figure8.24, the actual and maximum production capacity is 2169 units and 2425 unit. Therefore, 256 units is loosed due to fatigue which is 11.80%

In annexure-vii, fig 1,fig 2. fig 3, fig 4, fig 5, fig 6,fig 7, fig 8, fig 9, fig 10, fig 11, fig 12, fig 13. fig 14, fig 15, fig 16, fig 17, fig 18 are the performance curve of worker A, B. C, D, E, F, G_1, G_2, G_3, H_1, H_2, H_3, H_4, I_1, I_2, I, K, L respectively Performance of workers show efficiency does not remain constant. At the beginning of day, due to physical rigidity. no worker can able to perform with their maximum ability After several minute they get rid from this rigidity and start to perform with their maximum efficiency But due to repetitive task, noisy environment of workplace. insufficient ventilation, temperature, performance of each worker reduced to a significant level till having a break for one hour. Having a respite for one hour. performance of each worker is increased But level of performance can not reach to its previous maximum position

From table 8.7, Because of decrease in average processing time at bottleneck point by 33.94%, production capacity of developed assembly line is increased at optimized situation by 51.40% compare to existing assembly line number of worker is reduced by 1 unit Utilization and idleness of developed assembly line is improved by 47 59% and 56 21 % respectively. Loss due to physical fatigue is reduced by 64 45% and efficiency of assembly line is improved by 47.59%.

9.3 Conclusion

So from these analysis, it is clear that processing time at bottleneck can be reduce by assigning efficient worker as well as productivity also As cost regarding labor is directly related to number of worker need to assign in assembly line, total production cost can be reduced by assigning efficient worker at bottleneck point Not only daily production capacity and production cost but also utilization, line efficiency, idleness can be optimized There are several operations required in apparel industry. Each operator should be trained in those operations so that they can be replaced in different workstations while assigning them at workstation By proper line balancing, cycle time can be reduced and productivity can be improve to remarkable extend

CHAPTER-X

CONCLUSSIONS AND RECOMMENDATIONS

10.1 Introduction

Because of increasing competition and demand of garments product in the global market. it is very important for garment companies maintaining the demand and deadline of shipment. But in the most company no way of improving technique has been employed. In most of the assembly line of garment in Bangladesh, inefficient worker is placed at the bottleneck point which reduces productivity Because of their ignorance about the proper utilization of worker's maximum performance in the assembly line, companies are losing to have maximum amount of product by utilizing same resources

10.2 Conclusions

The thesis is carried out for the purpose of analysis and development of a frame work for improving productivity in an apparel company based on the performance of worker. To develop a framework of improving productivity, time study, fatigue study, worker performance has been studied

It is clear that per hour production is inversely proportional to bottle neck time Bottleneck time can be reduced by placing efficient worker at the bottleneck point Number of total worker required in assembly line can reduce by placing efficient worker and productivity can be improved. It is also noted that productivity loss due to fatigue only depends on the nature of performance of worker assigned at the bottleneck point and it can not be reduced after a certain limit. Therefore, productivity loss due to fatigue is not so significant matter at optimized situation because maximum production capacity can be found with higher loss due to fatigue It is obvious that utilization in assembly line can improve and idleness can be reduced by assiguing efficient worker at bottleneck point

10.3 Recommendations for Future Work

From the above results it is clear that a promising result can be obtained by studying fatigue of worker By improving source of physical fatigue such as lighting, ventilation, sufficient space allocation, keeping lower label of noise. worker's physical fatigue can be reduce to a extent But it incurs some additional cost to the product. But the main goal of any company is not only to provide service but also profit If the additional cost is very high compare to the improvement of productivity, it is not wise to expense to develop the environment of workplace.

But the study is limited to the study of worker's fatigue It in necessary to examine the relationship between improvements of productivity and increase in cost which incurs for ventilation, multi operation training, keeping low label of noise, ventilation and others. A future study can be carried out to find the profitability comparing the improvement of productivity and increasing additional cost.

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ANNEXTURE

Table of Annexure

Annexure-I
AVERAGE PROCESSING TIME OF EACH WORKER

T1	Sh.R A	SLA B	NB C	NC D	Sh.L E	S.H F	Sleeve Join G1	G2	G3	Side Seam H1	H2	H3	H4	S.O.G I1	I2	ML A J	B.H K	N.S.O C.T L
8.00-8.20	10.00	11.28	12.25	11.2	10.36	15.11	34.32	29.44	34.56	43.41	42.46	42.37	46.70	14.85	14.74	23.20	15.25	17.57
8.20-8.40	10.78	11.39	12.05	10.9	10.43	14.65	33.66	29.23	34.40	43.29	42.70	42.26	46.71	14.49	14.79	20.96	15.21	16.53
8.40-9.00	9.36	10.07	11.95	10.4	10.06	14.56	33.91	27.26	34.26	42.78	42.59	42.03	46.11	14.51	14.61	21.51	15.30	16.02
9.00-9.20	9.76	10.58	12.14	9.84	9.77	14.15	33.92	27.32	35.04	42.32	42.66	42.29	46.03	14.93	14.39	21.66	14.00	16.60
9.20-9.40	9.51	10.92	12.09	9.27	9.31	13.78	32.74	27.35	33.39	41.94	42.17	42.76	45.60	14.79	14.25	21.27	14.23	16.35
9.40-10.00	10.30	11.42	13.72	9.17	8.80	13.57	32.81	27.68	33.01	41.88	42.28	41.74	45.62	15.04	14.40	23.15	14.20	16.70
10.00-10.20	10.73	10.59	12.90	9.18	8.71	13.32	32.60	27.46	33.77	41.80	42.24	41.68	45.19	15.18	13.68	24.13	13.77	16.49
10.20-10.40	11.32	11.05	14.27	9.02	8.91	12.99	37.48	27.62	33.10	41.63	42.35	41.40	45.02	14.98	13.52	23.80	13.41	17.13
10.40-11.00	11.72	11.47	13.04	9.39	9.21	13.43	34.43	27.46	34.28	41.57	42.34	41.37	44.51	15.26	13.51	23.44	13.89	18.21
11.00-11.20	13.18	11.45	13.59	9.43	9.16	13.96	34.57	27.17	35.37	41.82	42.66	41.39	44.14	15.26	13.58	23.90	13.74	18.47
11.20-11.40	14.20	13.13	13.77	9.63	9.50	13.80	35.39	27.63	37.02	42.11	42.78	41.92	44.56	14.86	13.74	24.76	14.74	18.13
11.40-12.00	14.48	13.53	15.28	10.1	9.68	15.01	36.72	27.83	36.82	42.26	42.91	42.62	44.58	15.25	13.86	25.42	14.83	19.13
12.00-12.20	14.87	14.13	15.15	9.83	9.96	14.80	37.35	27.86	37.21	42.43	43.22	42.61	46.20	15.08	14.05	26.18	15.41	20.47
12.20-12.40	14.80	14.27	15.03	9.86	10.01	14.85	37.23	27.85	37.31	43.24	43.26	43.23	46.62	15.15	14.06	26.84	16.18	21.15
12.40-1.00	15.16	15.95	15.03	10.4	10.53	15.51	38.26	28.25	36.99	43.65	43.40	43.63	46.71	15.38	14.20	25.54	16.59	22.52
2.00-2.20	14.62	14.75	14.96	9.55	10.48	15.92	37.54	28.45	37.42	43.71	43.37	43.26	46.75	15.40	14.36	25.27	17.28	19.91
2.20-2.40	14.35	12.50	15.09	9.87	10.32	14.86	36.91	27.68	36.20	43.43	43.43	42.85	46.23	15.18	14.29	25.17	15.94	20.82
2.40-3.00	14.70	12.92	15.56	9.56	10.32	15.30	34.80	27.47	36.13	43.28	43.30	42.68	45.68	14.97	14.01	25.46	14.94	18.47
3.00-3.20	15.34	11.99	15.70	9.77	11.39	15.74	37.12	27.52	36.30	44.11	43.10	42.42	45.59	15.11	13.86	27.89	16.79	20.98
3.20-3.40	15.35	12.49	16.01	10.1	12.11	16.33	36.93	28.04	36.13	44.25	42.82	42.35	45.09	15.09	14.02	27.72	17.23	21.92
3.40-4.00	15.64	11.56	16.15	10.9	12.75	17.01	38.69	28.61	36.55	44.54	42.98	42.63	45.20	15.30	13.90	29.35	18.37	23.44
4.00-4.20	15.62	12.20	16.84	11.6	13.82	17.76	38.60	28.86	38.08	44.56	43.40	42.62	45.47	15.50	14.01	30.07	18.39	24.73
4.20-4.40	14.94	13.67	16.81	12.1	13.20	18.63	39.14	29.20	38.36	44.68	43.43	43.11	45.62	15.72	14.82	30.53	19.04	25.02
4.40-5.00	15.73	13.38	16.20	11.9	14.16	19.38	40.21	30.12	39.26	44.84	43.24	44.17	47.47	15.63	14.87	31.52	19.92	25.68
Average time, sec	12.75	12.20	14.22	10.06	10.34	15.03	35.64	28.06	35.87	43.08	42.88	42.45	45.72	15.13	14.15	25.37	15.59	19.92

Annexure-II

OVERALL PERFORMANCE OF EACH WORKER

	Sh.R	SLA	NB	NC	Sh.L	S.H	Sleeve Join			Side Seam				SOC		MLA	B.H	NSOC T
TI	A	B	C	D	E	F	G_1	G_2	G_3	H_1	H_2	H_3	H_4	I_1	I_2	J	K	L
8.00-8.20	84.00	85.09	73.50	80.24	81.17	79.43	89.16	103.98	88.48	85.69	87.60	87.80	79.67	78.78	77.34	72.40	78.89	85.38
8.20-8.40	77.92	84.27	74.67	82.49	80.54	81.93	90.92	104.89	88.96	85.93	87.13	88.03	79.65	78.68	77.07	80.15	78.92	90.74
8.40-9.00	89.74	85.35	75.33	88.38	83.54	82.43	90.23	112.25	89.31	88.97	87.34	88.51	80.67	78.01	78.02	78.11	78.44	90.61
9.00-9.20	88.07	90.74	74.14	91.48	85.98	84.78	90.47	112.00	87.33	87.91	87.21	87.97	80.82	78.34	79.21	78.78	85.72	90.35
9.20-9.40	88.33	87.91	74.47	97.07	90.27	87.21	93.48	111.88	91.84	88.70	88.21	88.04	81.58	77.08	80.00	79.00	84.31	91.73
9.40-10.00	81.55	84.08	85.80	96.10	95.49	88.44	93.78	110.56	92.71	88.82	87.98	89.13	81.54	75.81	79.18	72.58	84.51	89.84
10.00-10.20	78.29	80.65	69.75	98.05	95.46	90.08	93.66	111.42	90.61	88.99	88.08	89.28	82.32	75.09	83.33	69.84	87.15	90.99
10.20-10.40	74.20	85.89	63.07	99.80	94.31	92.38	94.21	110.78	92.44	88.93	87.85	89.87	82.64	78.09	84.33	70.58	89.46	87.58
10.40-11.00	71.67	83.71	69.00	95.61	91.24	89.33	88.89	111.46	89.28	89.49	87.85	89.91	83.57	74.72	84.39	71.66	88.37	82.36
11.00-11.20	63.73	83.87	66.23	95.41	91.69	85.98	88.51	109.83	88.51	88.05	87.10	89.67	84.27	74.72	83.94	70.31	87.33	81.23
11.20-11.40	59.15	73.10	65.34	93.44	88.44	88.08	88.47	103.72	82.60	88.34	88.98	88.74	83.48	78.73	82.98	67.88	81.30	82.72
11.40-12.00	58.01	70.94	58.82	89.01	88.81	79.93	83.34	100.82	83.11	87.99	88.70	87.29	83.44	74.74	82.25	68.08	80.94	78.43
12.00-12.20	56.49	67.99	59.42	91.53	84.34	81.09	81.93	99.23	82.23	87.68	88.08	87.25	80.53	75.59	81.14	64.17	77.88	73.30
12.20-12.40	56.78	67.78	59.89	91.25	83.96	80.25	82.20	98.38	82.02	86.04	88.00	88.08	79.80	75.23	81.06	62.60	74.15	70.91
12.40-1.00	58.41	60.18	59.89	88.78	79.78	77.39	79.84	98.09	82.73	85.23	85.71	85.28	79.64	74.11	80.27	66.79	72.35	68.60
2.00-2.20	57.48	85.09	60.07	94.22	80.13	75.39	81.52	98.71	81.77	85.12	86.78	88.00	79.58	74.01	70.39	68.48	69.48	75.34
2.20-2.40	58.54	76.82	59.64	91.23	81.40	80.74	82.81	99.45	84.53	85.65	85.68	88.82	80.48	75.09	70.79	68.74	75.29	72.08
2.40-3.00	57.14	74.33	57.83	94.19	81.41	78.48	87.83	99.00	84.70	85.06	88.91	87.16	81.43	78.14	81.35	65.99	80.35	81.23
3.00-3.20	54.78	80.10	57.34	92.12	73.78	78.25	82.43	98.23	84.30	84.33	86.32	87.70	81.60	75.48	82.28	60.25	71.48	71.49
3.20-3.40	54.72	78.84	58.21	89.24	89.35	73.51	82.88	94.12	84.69	83.69	86.68	87.88	82.50	75.53	81.29	60.61	89.65	8.00
3.40-4.00	53.71	83.00	58.73	82.58	85.90	70.53	79.08	94.91	83.73	83.53	86.58	87.27	82.30	74.50	81.90	57.25	65.32	63.98
4.00-4.20	53.78	78.67	53.44	77.81	80.80	67.58	79.27	92.72	80.35	83.50	85.72	87.29	81.82	73.53	81.35	56.88	85.24	60.65
4.20-4.40	58.22	70.48	53.54	74.20	83.64	83.73	78.18	92.48	79.78	83.28	85.68	86.29	81.55	72.51	78.95	55.02	83.04	59.98
4.40-5.00	53.40	71.78	56.56	75.66	59.31	81.92	78.10	90.43	77.95	82.97	88.04	84.23	78.38	72.98	78.69	53.30	60.73	58.41
Overall efficiency %	65.68	78.72	63.27	89.48	81.24	79.82	85.71	102.21	86.49	86.40	86.77	87.66	81.38	75.39	80.65	67.05	76.59	75.29

Annexure-III

AVERAGE PRODUCTION CAPACITY WITH TIME INTERVAL

T I	Sh R	SLA	NB	NC	Sh L	S H	Sl J	SS	SOC	M L A	B H	N S O C T	Average (Units)
8 00-8 20	120	106	96	107	116	79	110	110	162	52	79	68	101
8 20-8 40	111	105	100	110	115	82	112	110	164	57	79	73	101
8 40 9 00	128	119	100	115	119	82	114	111	164	56	78	75	105
9 00-9 20	123	113	99	122	123	85	114	111	164	55	86	72	105
9 20-9 40	126	110	99	129	129	87	116	112	165	56	84	73	107
9 40-10 00	117	105	87	131	136	98	116	112	163	52	85	77	105
10 00-10 20	112	113	93	131	138	90	116	112	167	50	67	73	107
10 20-10 40	106	109	84	133	135	92	117	113	169	50	89	70	106
10 40-11 00	102	105	92	128	130	89	114	113	167	51	86	68	104
11 00-11 20	91	105	88	127	131	86	112	113	157	50	87	65	102
11 20-11 40	85	91	87	125	126	67	107	112	168	48	81	66	99
11 40-12 00	83	89	79	119	124	80	105	111	165	47	81	63	95
12 00-12 20	81	85	79	122	120	81	103	110	165	46	78	59	94
12 20-12 40	81	84	80	122	120	80	103	109	165	45	74	57	93
12 40-1 00	79	75	80	115	114	77	101	108	163	47	72	53	90
2 00-2 20	82	81	80	126	114	75	102	109	161	47	69	60	92
2 20-2 40	84	96	80	122	116	81	105	109	163	48	75	58	95
2 40-3 00	82	93	77	126	116	78	107	110	166	47	80	65	96
3 00-3 20	78	100	76	123	105	76	103	110	166	43	71	57	92
3 20-3 40	78	96	75	119	99	74	103	110	165	43	70	55	91
3 40-4 00	77	104	74	110	94	71	101	110	165	41	65	51	89
4 00-4 20	77	98	71	103	87	68	99	109	163	40	65	49	86
4 20-4 40	80	88	71	90	91	64	96	109	157	39	63	48	84
4 40-5 00	76	90	74	101	95	62	96	107	158	38	60	47	83

Annexure-IV

UTILIZATION & IDLENESS OF EXISTING ASSEMBLY LINE

	NUMBER OF WORKSTATION												Total time, sec	Utilization %	Idleness %
	1	2	3	4	5	6	7	8	9	10	11	12			
Worker assigned	A	B	C	D	E	F	G_1G_2 G_3	H_1H_2 H_3H_4	I_1 I_2	J	K	L			
Avg. processing time	12.75	12.20	14.72	10.00	10.34	15.03	11.19	10.87	7.30	25.37	15.59	19.92	164.64	54.15%	45.85%
Available processing time	25.37	25.37	25.37	25.37	25.37	25.37	25.37	25.37	25.37	25.37	25.37	25.37	304.4		
Idle time	12.62	13.17	11.15	15.31	15.03	10.34	14.18	14.50	18.07	0.00	9.78	5.45	139.80		

Annexure-V
GANTT CHART
(I)FOR EXISTING ASSEMBLY LINE

	Operation start		0	12.75	24.95	39.17	49.23	59.57	74.60	85.79	95.65	103.96	123.33	114.92
	Operation end		12.75	24.95	39.17	49.23	59.57	74.00	85.79	96.66	103.96	129.33	144.92	104.84
Number of workstation	Name of operation	Duration, second												
1	Shoulder join right side	12.19												
2	Size label attach at left seam	12.36												
3	Neck binding	14.4												
4	Neck close	10.13												
5	Shoulder join left side	10.54												
6	Sleeve hem	15.2												
7	Sleeve join	10.9												
8	Side seam	10.9												
9	Sleeve opening close	7.3												
10	Main label attach at back neck	25.37												
11	Bottom hem	15.78												
12	Neck & sleeve opening chain tack	13.68												

(II)FOR PROPOSED ASSEMBLY LINE AFTER OPTIMIZATION

Operation start			0	9.72	24.89	36.84	48.53	58.87	74.79	90.75	99.17	102.50	128.94	1143.97
Operation end			9.72	24.89	36.84	48.53	58.87	74.79	90.75	99.17	102.50	128.91	143.97	159.73
Number of workstation	Name of operation	Duration, second												
1	Shoulder join, right side	9.72												
2	Size label attach at left seam	15.17												
3	Neck binding	11.95												
4	Neck close	11.69												
5	Shoulder join left side	10.34												
6	Sleeve hem	15.92												
7	Sleeve join	11.36												
8	Side seam	12.42												
9	Sleeve opening close	13.33												
10	Main label attach at back neck	26.41												
11	Bottom hem	15.03												
12	Neck & sleeve opening chap tack	15.75												

Annexure-VI

UTILIZATION & IDLENESS OF ASSEMBLY LINE

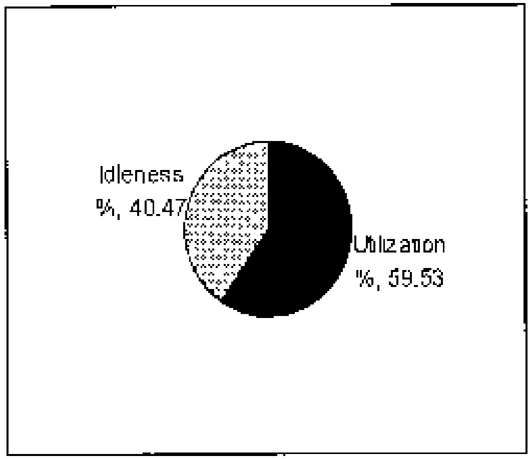


Figure1- Utilization & Idleness at initial of Developed combination

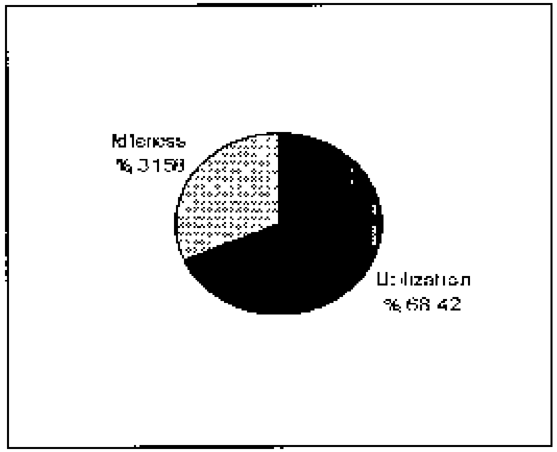


Figure 2 Utilization &Idleness at Iteration-1

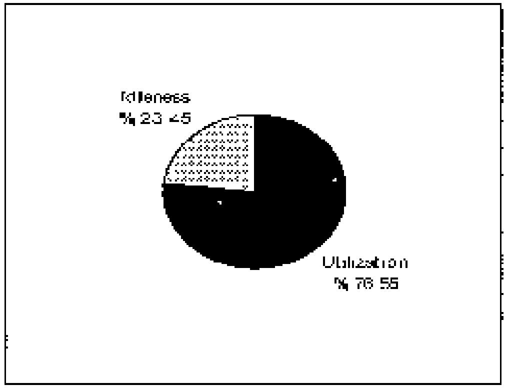


Figure 3: Utilization & Idleness at Iteration-2

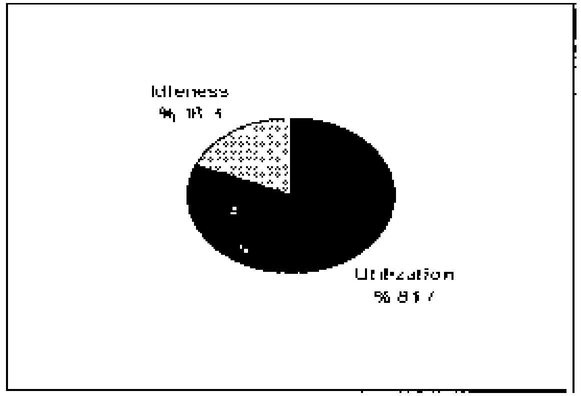


Figure 4 Utilization & Idleness at Iteration-3

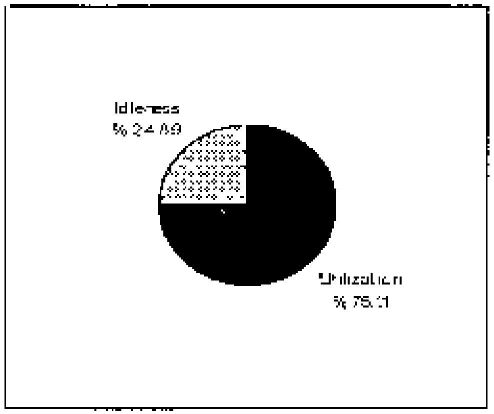


Figure 5: Utilization & Idleness at Iteration-4

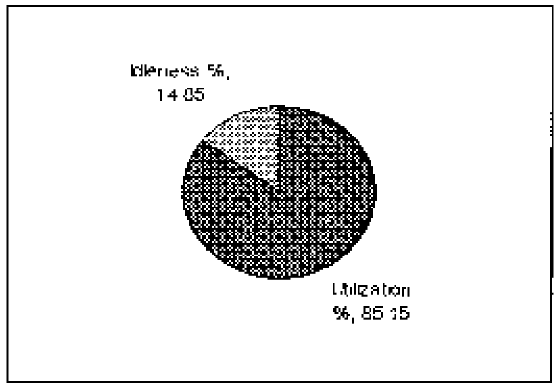


Figure 6 Utilization& Idleness after line balancing

Annexure-VII

PERFORMANCE CURVE OF WORKER

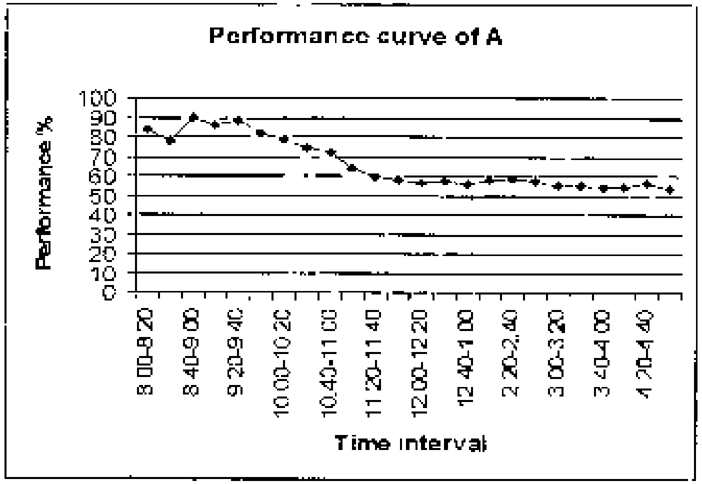


Figure 1: Performance curve of A

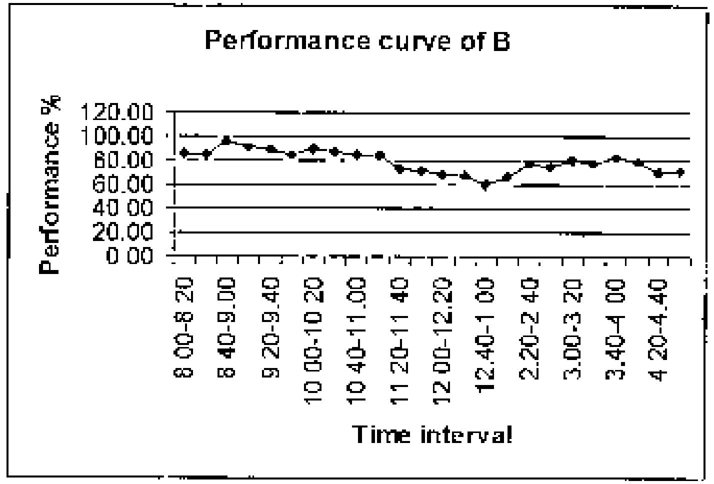


Figure 2 Performance curve of B

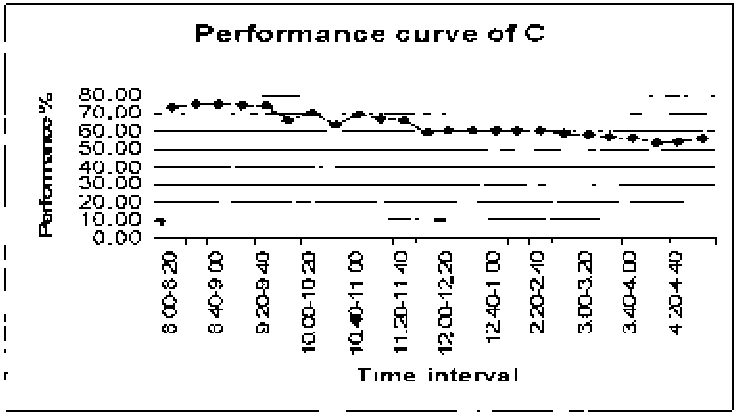


Figure 3 Performance curve of C

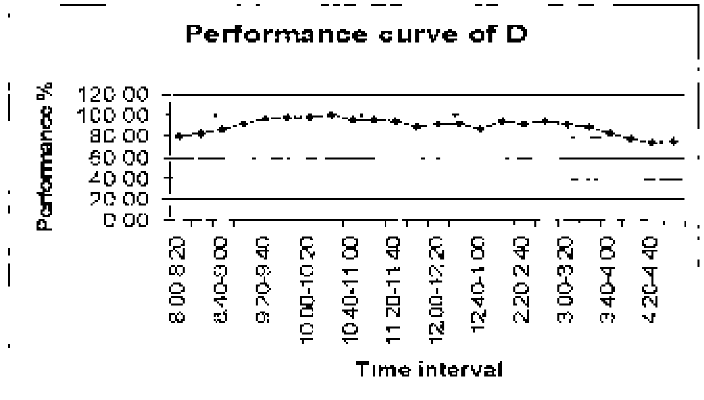


Figure 4· Performance curve of D

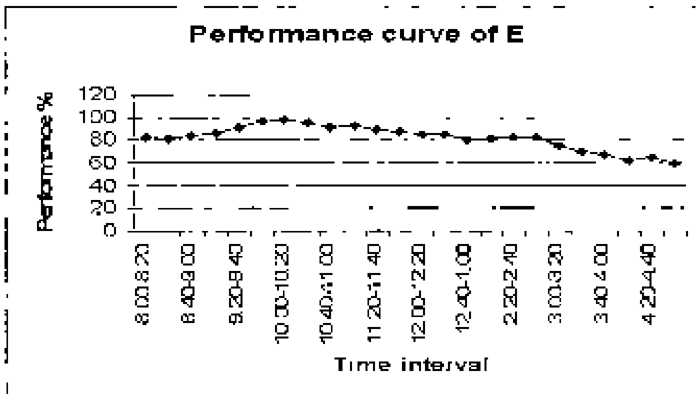


Figure 5· Performance curve of E

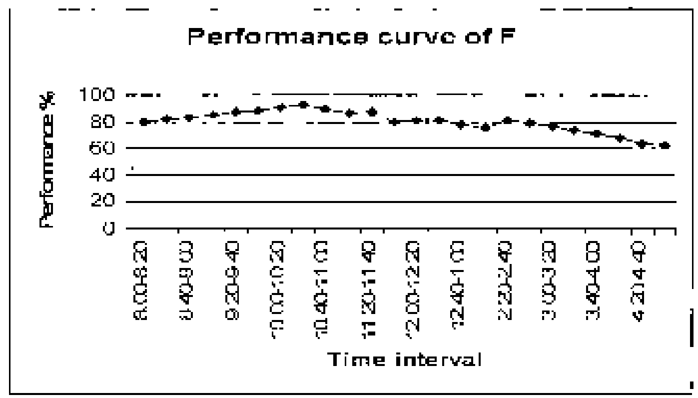


Figure 6· Performance curve of F

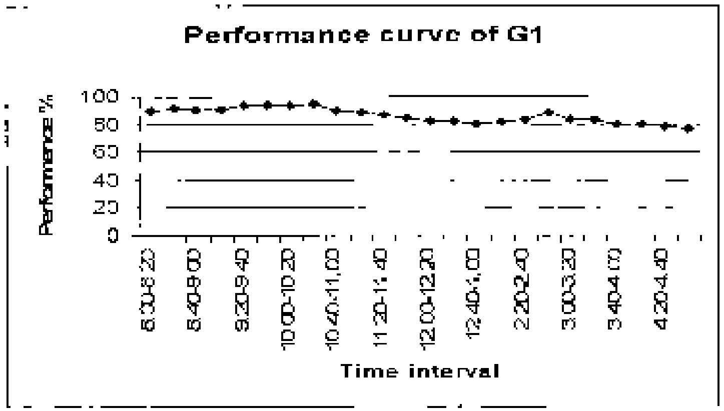


Figure 7: Performance curve of G_1

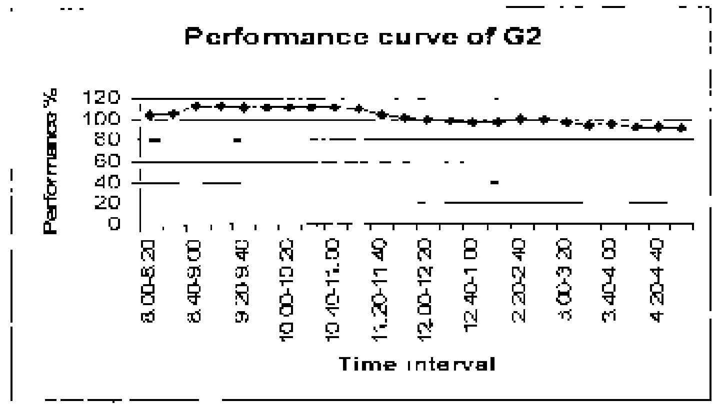


Figure 8: Performance curve of G_2

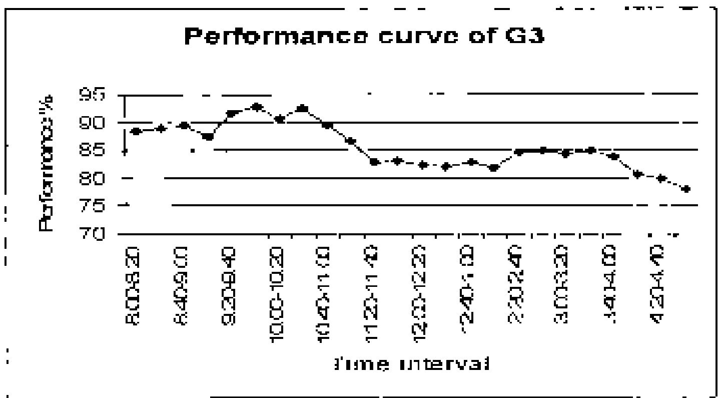


Figure 9: Performance curve of G_3

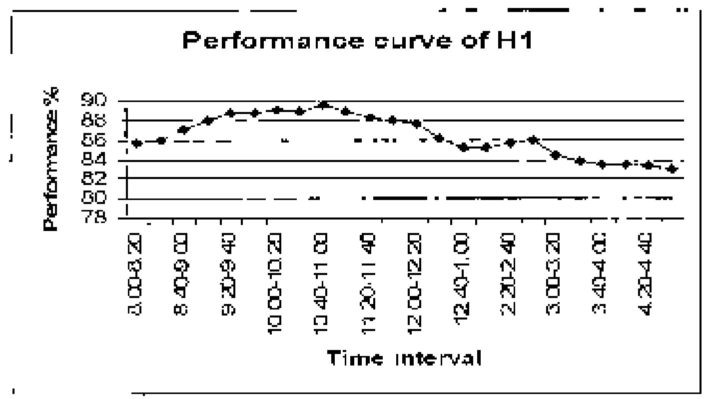


Figure 10: Performance curve of H_1

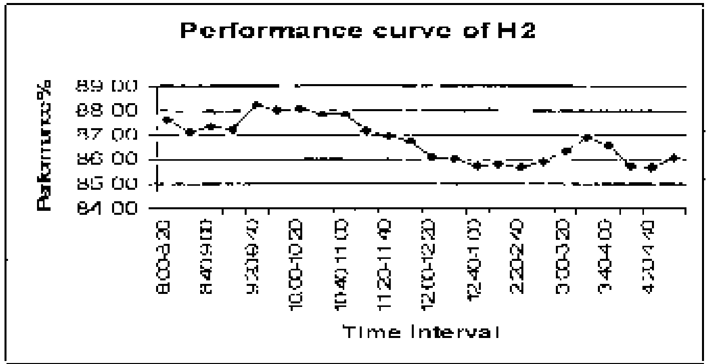


Figure 11: Performance curve of H_2

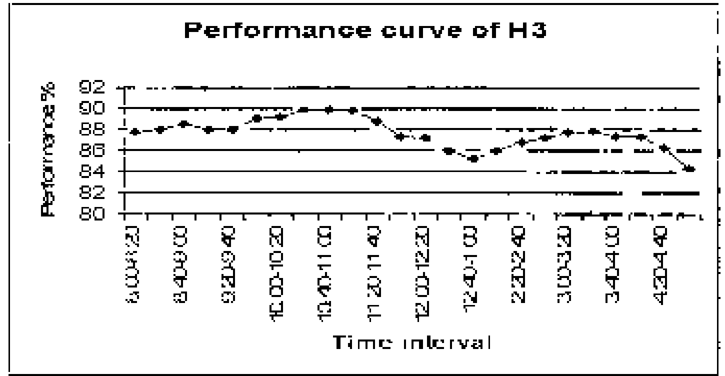


Figure 12. Performance curve of H_3

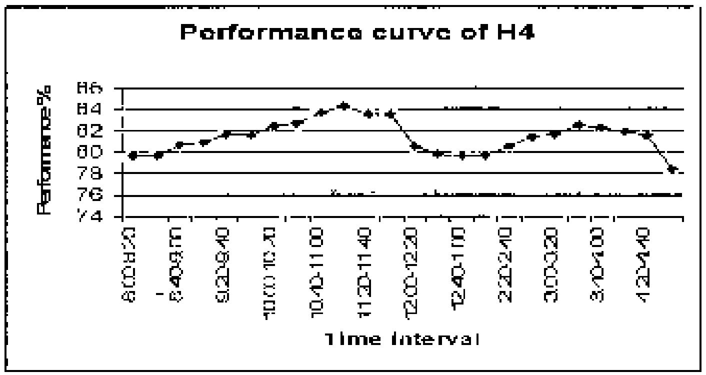


Figure 13: Performance curve of H_4

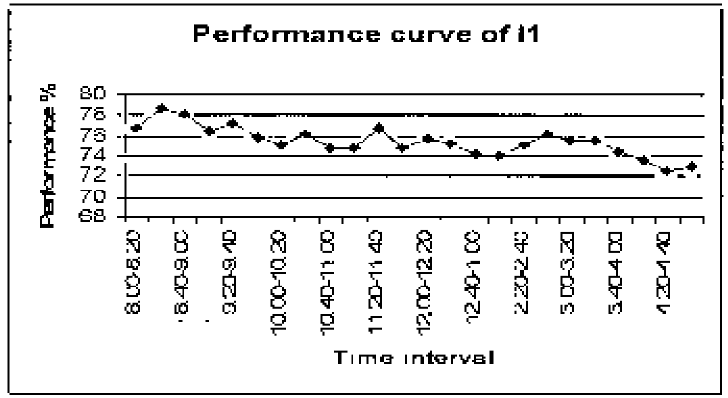


Figure 14. Performance curve of I_1

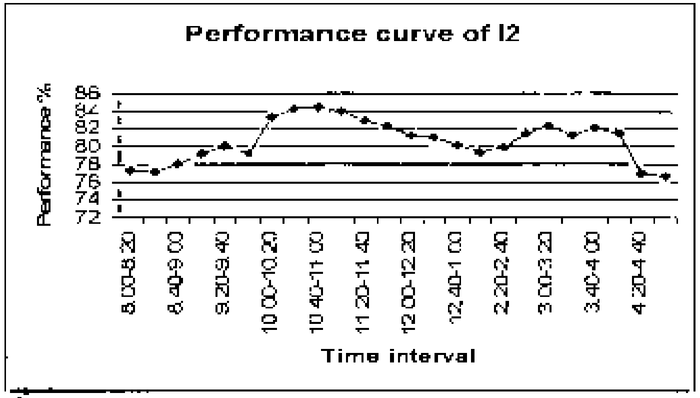


Figure 15 Performance curve of I_2

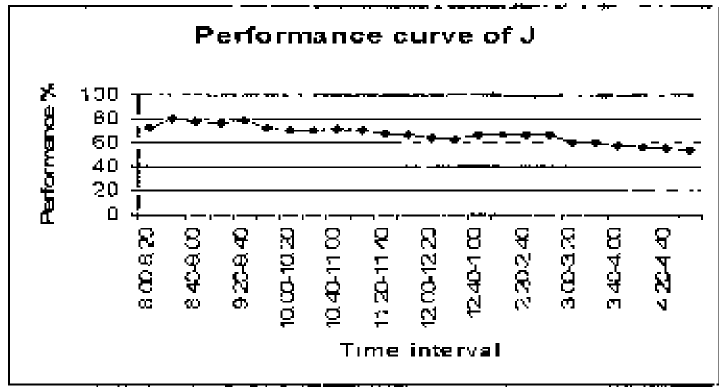


Figure 16: Performance curve of J

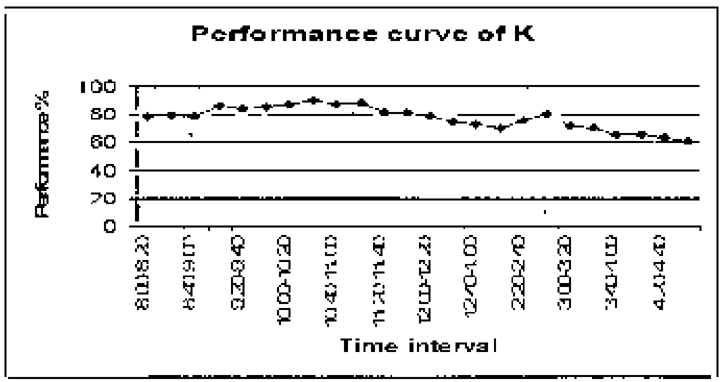


Figure 17: Performance curve of K

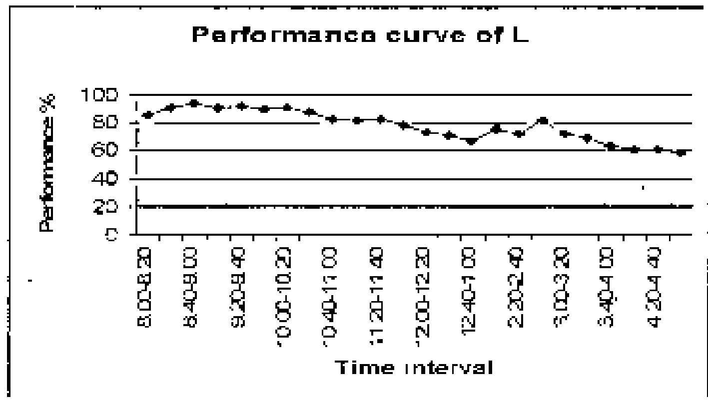
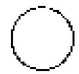
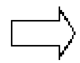
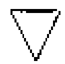
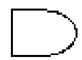
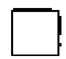
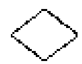


Figure 18: Performance curve of L

Annexure-VIII
LINE BALANCING OF PROPOSED LINE

Number of workstation	1	2	3	4	5	6	7	8	9	10	11	12	Activity	Productive time	Idle time	Total line capacity	Remarks
Worker name	H_1	C	L	K	E	I_1	$H_2H_3H_4$	A I_2 G_1 J	G_3 B	G2	F	D	Transfer B from 9 to 12	154.34	46.78	201.12	-
Average processing time, sec	9.72	15.17	11.95	11.69	10.34	15.92	11.98	12.42	6.84	16.44	15.03	18.78					
Worker name	H_1	C	L	K	E	C I_1	$H_2H_3H_4$	A I_2 G_1 J	G_3	C G2	F	BD	Assigning two workers at 6 and 10 whose efficiency is … of C	138.32	42.72	180.04	Improvement
Average processing time, sec	9.72	15.17	11.95	11.69	10.34	8.66	11.06	12.42	13.33	10.15	15.03	8.69					
Worker name	H_1	G2	L	K	E	C I_1	$H_2H_3H_4$	A I_2 G_1 J	G_3	C C	F	BD	Transfer G2 from 10 to 2 and C from 2 to 10	136.67	43.69	180.36	Improvement
Average processing time, sec	9.72	8.39	11.95	11.69	10.34	8.66	11.98	12.42	13.33	13.28	15.03	8.69					
Worker name	H_1	F	L	K	E	C I_1	$H_2H_3H_4$	A I_2 G_1 J	G_3	C C	G_2	BD	Transfer G2 from 2 to 11 and F from 11 to 2	136.22	23.84	160	Improvement
Average processing time, sec	9.72	12.03	11.95	11.69	10.34	8.66	11.98	12.42	13.33	13.28	11.74	8.69					
Worker name	H_1	F	L	K	E	C I_1	$H_2H_3H_4$	A I_2 G_1 J	G_2	C C	G_3	BD	Transfer G2 from 11 to 9 and G3 from 9 to 11	136.14	32.34	168.48	Increase in cycle time (Step)
Average processing time, sec	9.72	12.03	11.95	11.69	10.34	8.66	11.98	12.42	11.15	13.28	14.04	8.69					
Worker name	H_1	F	L	K	E	C I_1	$H_2H_3H_4$	A I_2 G_1 J	D	C C	G_2	G_3B	Transfer D from 12 to 9 and G3 from 9 to 12	136.68	23.68	159.36	Improvement & Stop
Average processing time, sec	9.72	12.33	11.95	11.69	10.34	8.66	11.98	12.42	12.74	13.28	11.74	9.14					

Annexure-IX
SYMBOLS USED FOR PROCESS FLOW CHART

No	Process	Name of symbol	Symbol	Significance
1	Operation	Operation		Represents processes which affect the shape and properties of raw materials, materials, parts of products
2	Transportation	Transportation		Represents processes which affects the location of raw material, materials, parts of products
3		Storage		Represents processes which store raw materials, materials, parts and product according to planning
4		Delay		Represents conditions where raw materials, materials, parts and products are accumulated according to planning
5		Quantity inspection		Represents processes where the volume or quantity of raw materials, materials, parts and products are measured and compared with the requirements for deviations
6		Quality inspection		Represents processes where the qualitative properties of raw materials, materials, parts and products are tested and compared with the requirements to determine acceptability of lots or products.