Efficiency Analysis and Performance Improvement of Bottling Production Line

(Case on: East Africa Bottling Share Company)

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I hereby declare that the work which is being presented in this thesis entitled **"Efficiency Analysis and Performance improvement of Bottling Production Line"** is original work of my own and has not been presented for a degree of any other university and all the resources of references used for the thesis have been duly acknowledged.

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Teklay Araya Date

This is to certify that the above declaration made by the author is correct to the best of my knowledge.

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Dr. Ermias Tesfaye

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ABSTRACT

In response to today's highly competitive business environment, companies are forced to analyze and improve their existing manufacturing system continuously to minimize production losses due to production disturbances that hinder the system efficiency, performance and reduce profitability. The major problems of the case production line are related with low throughput, high inefficiency losses, and higher raw material cost etc. As a result, over all equipment efficiency of the production line is blow target (management plan) and it was challenged to fulfilling the expected production plan (volume). Therefore, the purposes of this study are to evaluate line efficiency and improve performance of the bottling production line.

Researches in relation to production line, productivity, efficiency losses, OEE analysis, improvement, simulation modelling has been reviewed, primary and secondary data have been collected from the case company through direct observations, check sheets. Also, different tools such as OEE, Pareto chart, fish bone diagram, Arena simulation has been utilized, and root cause analysis, brainstorming sessions has been conducted in analysis and improvement process. Efficiency analysis of line is has been done using OEE, as a result the disturbances that results production losses are studied, major efficiency losses are identified, focus of improvement areas with associated challenges and their root causes has been investigated, then corrective actions, counter measures and action plans has been suggested as strategy for improvements. Also, model of the real production line has been developed Using Arena software, and validated. After analyzing the production line model, line behavior, disturbances, efficiency losses under varying set of circumstances were studied and performance measures quantified. Also, a number of problems including; short stops, starvation and blockage were identified as problems. Then a set of changes and modifications on the actual system simulation model has been suggested.

Finally, an improved model was proposed where line availability and performance can be enhanced by 11%, line OEE increased by 21.4% and raw material loss and cost reduced. Therefore, the achieved results in the proposed model can be easily adapted after similar studies and the company's targets can be achieved and profitability, competitiveness can be improved significantly.

Key words: Bottling, efficiency, performance, OEE, Arena, line simulation, production losses

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ABBREVIATIONS

OEE-overall equipment efficiency

OPE -overall production effectiveness

PET- Polyethylene terephthalate

PD-production disturbances

PL-performance losses

DES-Discrete event simulation

CI-continuous improvement

DTL-downtime losses

QL-Quality losses

AL-Availability losses

TUP-total units produced

TGUP-total good units produced

TTSV-total time starved

TTB-total time blocked

TTR-total time running

CHAPTER ONE

INTRODUCTION

Today's production systems are required to deliver high productivity, resource efficiency, and flexibility, and these requirements will continue to rise in line with continuous productivity improvement. Productivity improvement is one of the core strategies towards manufacturing excellence and it also is necessary to achieve good financial and operational performance. Improvement can be in the form of elimination, correction (repair) of ineffective processing, simplifying the process, optimizing the system, reducing variation, maximizing throughput, reducing cost, improving quality or responsiveness and reducing set-up time. Disturbance can occur in all system levels in manufacturing and the causes of disturbance in manufacturing systems may be related to many factors, such as: organizational, planning, operational and technical. The disturbance of production (PD) to perform the expected outcomes can result in substantial production losses, deteriorated quality, lowered safety, and can affect -performance of the organization. . The production disturbance loss can be classified into 6 losses of efficiency [1]. These are: equipment failures/breakdowns, setup/adjustments, idling and minor stoppages, reduced speed, reduced yield, and quality defects and also these can be classified in downtime, speed and quality losses. These losses are measured from the disturbance in terms of OEE [2], which is a function of the three components availability, performance, and quality. Effective handling of PDs is crucial; to achieve high reliability of production systems [3] to increase efficiency [4, 5], Increase output and increase profitability [6]. Therefore, identification and elimination of disturbances in manufacturing system is one of the ways to improve productivity [4, 5] and small improvement to system performance can realize tremendous gains [7]. It is important to design and operate this type of facilities at its most efficient condition through continuous improvement efforts and also to have the ability to carry out "what-if" scenario analyses to sufficient details to evaluate and identify constraints in the production line alternative decisions on improvement plans [8].Successful analysis of these systems requires effective modeling that considers the transport function of conveyors, variable machine production rates, buffer capacity, reliability issues, stochastic fluctuations and other factors. It is difficult to build accurate analytical models that include all these factors. However, the benefits of simulation modeling are well known in the high-speed processing industry, effective simulation models can be used to analyze such systems successfully and to support decision-making and to evaluate the impact of various opportunities for improvement.

In this paper, line OEE and simulation study has been conducted for investigation of the existing production system with the purpose of identifying production disturbance's, analyzing line efficiency in order to improve productivity. The model built has given a deep understanding of the system and to find best improvement strategies to be implemented on the actual system to increase efficiency and the performance of the production system.

1.1 Background of case company

The first Coca-Cola bottler in Ethiopia was established in 1959 as the Ethiopian Bottling Share Company in Addis Ababa. South Africa Bottling Share Company and Ethiopian Bottling Share Company signed a joint venture agreement on May19, 1999. Finally, it became East Africa Bottling Share Company (ESBS.C) in 2003 as member of Coca-Cola Sabco. Recently, ESBS.C becomes the member of Coca-Cola Beverages Africa.

This study is conducted in Addis Ababa plant on PET production line, which produces a variety of carbonated soft drink and water in different shape and sizes of Plastic bottles. The speed of production line is depending on the bottle sizes. It's installed and rated speed is 36000 bottles per hour or 3000 Pack per hour or 72,000 packs per day for 500mm PET bottle. Production continues almost seven days per week, 24 hours per day and each day consists of three shifts of 8 hours and every shift the line is run by a production team and the line works continuously even in the lunch, breaks, and shifts change time.

1.2 Problem Statement

In an increasingly competitive market place amongst the beverage industries, bottle filling industries in particular, show a clear and distinct need to improve their productivity operations [9]. Bottling plants are characterized by capital intensive, Bottling production systems are capital intensive, complex, mass production [10], and Continuous flow [11], Automated - high speed processes [7], that involves significant asset(consist of several machines and materials flow) both in investment and in the production phase. These investments alone are no guarantee for economic success. Optimal use could be achieved only to avoid losses in production through the permanent application of productivity tools.

The case production line is not achieving the targeted production plan because the line is producing below its capacity and at low overall performance (OEE) (as shown in Figure11), due to various disturbance of production system (i.e., frequent equipment failures, minor stops, speed losses, blocking, and starvation) which result in substantial production losses, and that affect the productivity and financial performance of the organization.

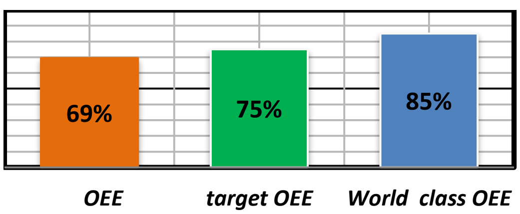


Figure 1.1. Comparison between the actual OEE for seven months period of operations, with targeted and world class OEE, the production target.
(*Source: company data, Oct, 2017)*

As a result, identification and elimination of constraints or disturbances in manufacturing system is one of the ways to increase efficiency [4, 5]. Improving the efficiency of production lines leads to lower packaging costs per unit by increased output or lower personnel costs and/or lower equipment and material costs.

1.3. Research Question

1) What are the potential production disturbances in bottling plants that that affects line productivity at the operating process?
2) How to evaluate current line efficiency and identify the focus improvement area?
3) What would be the suitable model to analyze, improve the current production line?
4) What would be the appropriate improvement opportunities or strategies recommended to be implemented on actual system to minimize efficiency losses and improve performance?

1.4 Objectives of the Study

1.4.1. General objective

The main objective of this study is to analyze efficiency and improve performance of Coca cola production line on the case of coca cola beverage Africa, East Africa Bottling Share Company.

1.4.2. Specific objectives

1) To study production disturbances in the case production system and bottling plant.
2) To evaluate current line efficiency and identify target area that needs improvement.
3) To develop simulation model to measure, analyses line efficiency and performance.
4) To find the relevant improvement opportunity or suggested strategies to be implemented in by the company to increase productivity of the production system.

1.5 Scope and limitation of the Study

Due to limitation of time, this research is limited to developing and analyzing three product types in only a size of 0.5 litters bottle size. These products sizes are produced in large quantity and the amount (78-88) % of the total production in the company in the time of data collection.

1.6 Significance of the Study

The study intended to develop simulation model that enables managers to measure ,identify and eliminate the hidden costs or losses and predict performance ,understand the impact of change and to test out different production scenarios respectively . Moreover, this could be used as a reference base for future improvements and researches within the industry as well as for academicians.

1.7 Organization of the thesis

This thesis is organized into **six** different chapters which include: In the chapter one, introduction part: the objectives, problem statement, significant of study etc. are discussed. In chapter two different literatures related to productivity, efficiency, performance OEE, improvement, and simulation analysis discussed related to the topic is organized. In the third chapter proposed methodology, in the fourth chapter overview of the company and line analysis and line simulation model development and simulation analysis, in final chapter, conclusion and recommendation has been made.

CHAPTER TWO

LETRATURE REVIEW

2.1 Concept of Production System and productivity

Production is defined as the step-by-step conversion of one form of material into another form through chemical or mechanical process to create or enhance the utility of the product to the user. Thus production is a value addition process. At each stage of processing, there will be value addition. The production system is ‘that part of an organization, which produces products of an organization. It is that activity whereby resources, flowing within a defined system, are combined and transformed in a controlled manner to add value in accordance with the policies communicated by management’[13].

Productivity is a major factor for operational management and plays a crucial role in boosting the growth of the organization and helps them to survive in a competitive world. Measuring the productivity enables the managers to know the current situation of their company [4]. Therefore, recognizing the idea, basic meaning of productivity and its relation to other similar terms is significant to properly Measure as well as improve productivity [2]. Productivity is also different confused with terms like efficiency and effectiveness [1], confirms that there is no agreement in industry of what the term productivity actually means. It is important to keep in mind that productivity is a relative concept, has an ambiguous nature and there is no universal definition of productivity.

However, emphasize on different views to the concept in slightly various ways and divide productivity definitions into three main categories: The technological concept: describes the relationship between ratios of outputs to the inputs used in its production, the engineering concept, the relationship between the actual and the potential output of a process, and the economist concept, the efficiency of resource allocation [14]. As result, the confusion surrounding the concept of productivity and its relation to other similar terms has been explored by using the Triple-P model (Figure 2.1). The model includes five terms; productivity, profitability, performance, effectiveness and efficiency, and explains how they are related to each other and the main differences between these terms can easily be captured.

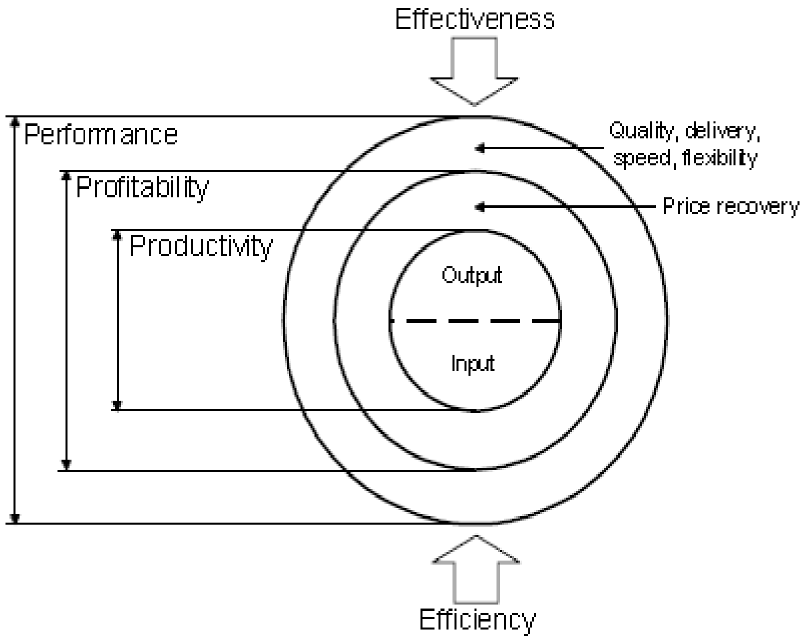


Figure 2.1 The Triple-P model [2].

Productivity is the central part of the Triple P-model and has a rather straightforward operational definition of productivity as a ratio of output quantity (i.e. number of correctly produced products which fulfils their specifications) divided by input quantity (i.e. all type of the resources that are consumed in the transformation process). Profitability is also seen as the relation between output and input, but includes influences from price-factors (i.e. price recovery). Performance is the umbrella term of manufacturing excellence and includes profitability as well as non-cost factors such as quality, speed, delivery and flexibility. Effectiveness is a term to be used when the output of the manufacturing transformation process is focused, while efficiency represents how well the input of the transformation process (i.e. resources) is utilized [13].

In improving the productivity of a company, the business will gain many benefits, which ultimately results in increased profitability of the organization. As a result of poor productivity, the company's production cost is so high that its viability is threatened. The company now needs to work on improving their manufacturing productivity so as to reduce the cost of production which would allow them to have an edge over their competitors based on price.

2.2 Production disturbances

Disturbances in production systems are defined by the several authors [11, 12].The different definitions of disturbances have many similarities but differ in important details (see Figure 2.2). Deviations from steady operating conditions are characterized by the incidence of disturbances originating from one of the different sources. [16] Defines Production Disturbance as: "Production Disturbances are discrete or decreasing, planned or unplanned disruptions or change during planned production time, which might affect availability, operational performance, Product quality, security, work conditions, environment, etc."

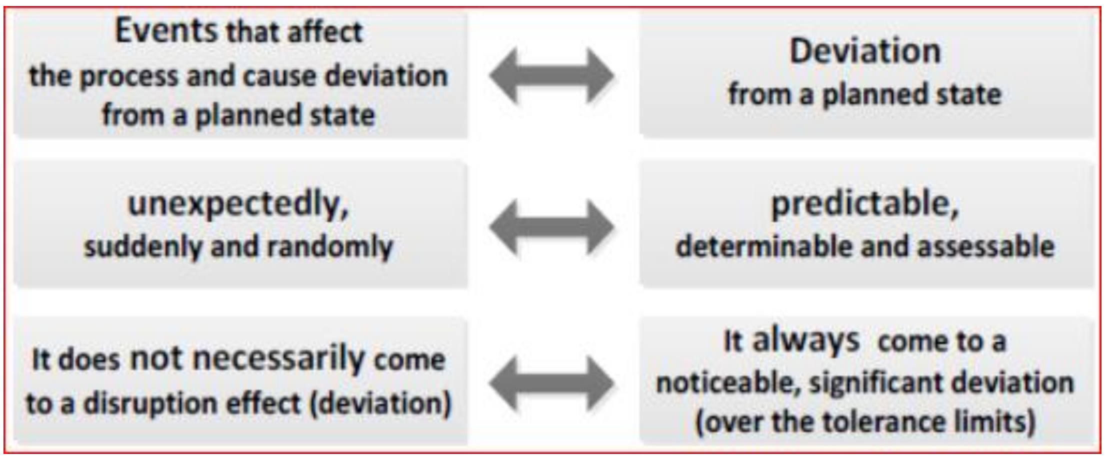


Figure 2.2 .The differences in understanding of production disturbances [13].

Disturbances, according to [25], roughly are divided into the two categories, chronic and sporadic, depending on how often they occur. Chronic disturbances: are small and hidden disturbances that are hard to detect since they are often seen as the normal state. They results low utilization of equipment and large costs because they occur repeatedly [10]. Chronic disturbances are more difficult to identify since they can be seen as the normal state. So, Identification of chronic disturbances is only possible through comparison of performance with the theoretical capacity of the equipment. Sporadic disturbances: are more obvious since they occur quickly irregularly and are easier to detect as large deviations from the normal state. They occur irregularly and their dramatic effects are often considered to lead to serious problems.

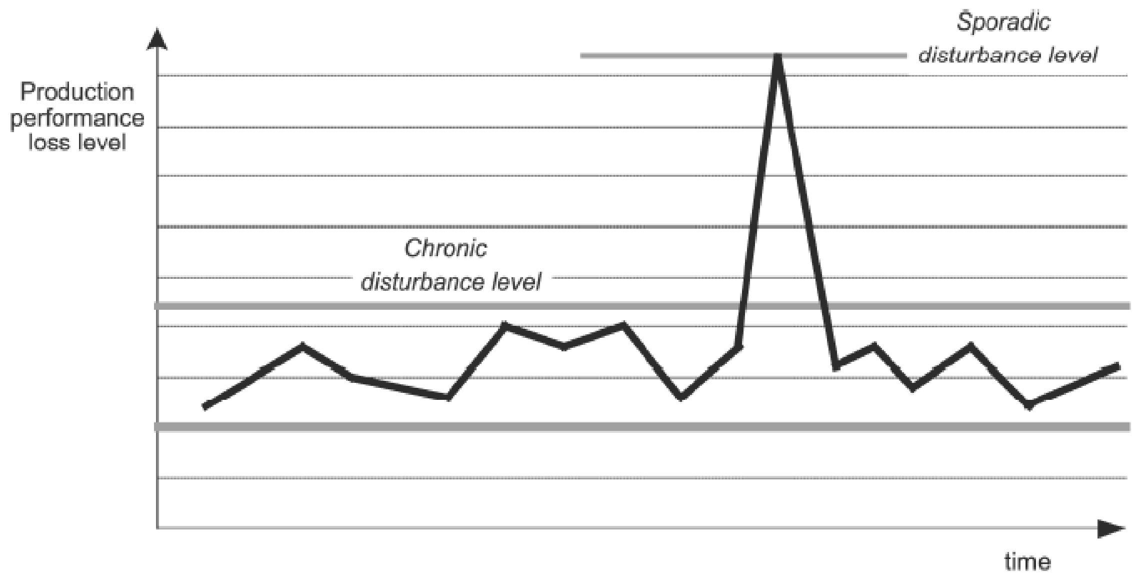


Figure 2.3: Production performance losses as a result of chronic and sporadic disturbances [27].

Disturbance can among other things be seen as losses, which can be classified into various types. To describe the efficiency of a manufacturing system, the production disturbance can be classified in downtime, speed and quality losses [14]. Reduction of downtime losses is seen as the most important in order to increase overall efficiency of a system (Figure 2.4).

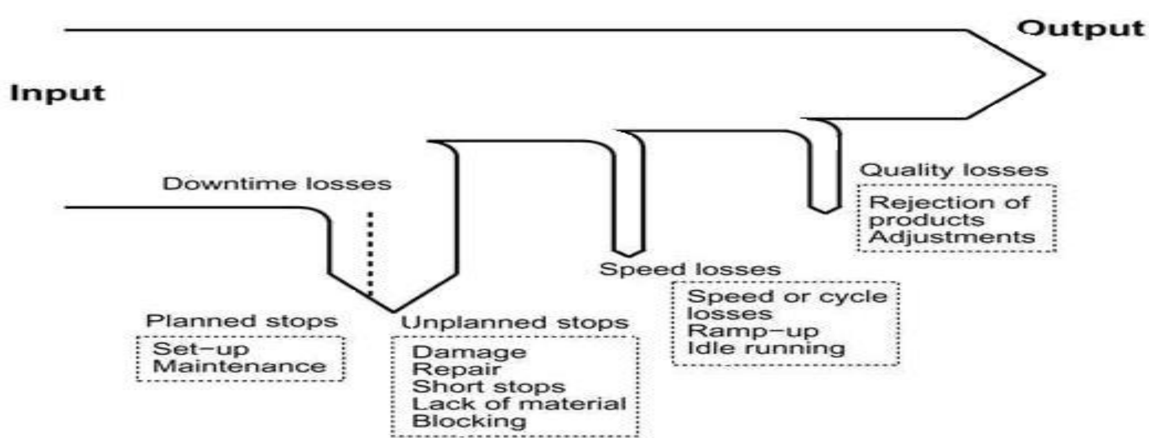


Figure 2.4.Different disturbances category [14].

Different types of problems (e.g. failures, breakdowns, material defects, lack of material) usually occur when a manufacturing system is operational, which in turn cause disturbances in the production flow and reduce the systems output.

Another common approach is to distinguish between the six major losses as demonstrated by the OEE-ratio: failures, set-up and adjustments, idling and minor stoppages, reduced speed, defects in process and reduced yield.

Production disturbance handling (PDH) is defined by [16] as: "All the activities that are carried out or should be carried out in connection with correction, prevention, and Elimination of production disturbances and potential production disturbances in both existing and future systems during their life--cycles." Handling of PDs is crucial to decrease productivity, increase product cost, and reduce profitability [15]. Moreover, PDs often result in direct safety risks for operators (Toulouse, 2002), and PDs may put entire organizations at financial risk. PDs directly hinder production performance [16], and decreasing the amount of PDs contributes to more reliable production systems [17]. In fact, PDs can threaten a company's competitiveness both in stable production phases and in changing conditions and handling of PDs is crucial in both high- and low-volume production [21]. The bottom line is that effective handling of PDs is essential to achieve high reliability of production systems ,but a consequence of classifying PDs differently is that they will be resolved differently [16].

2.3 Production Losses

In today's industrial scenario huge losses/wastage occur in the manufacturing shop floor. This waste is due to operators, maintenance personal, process, tooling problems and non-availability of components in time etc. Other forms of waste includes idle machines, idle manpower, break down machine, rejected parts etc. are all examples of waste. There are also other invisible wastes like operating the machines below the rated speed, start up loss, break down of the machines and bottle necks in process [22].

2.4 The six big losses

Chronic and sporadic disturbances in the manufacturing process result in different kinds of waste or losses. These can be defined as activities which absorb resources, but create no value and eliminating the six big losses is critical to achieve overall equipment effectiveness [23] [35].

Downtime losses

(1) Breakdown losses categorized as time losses when productivity is reduced, and quantity losses caused by defective products.

(2) Set-up and adjustment losses result from downtime and defective products that occur when production of one item ends and the equipment is adjusted to meet the requirements of another item.

Speed losses

(3) Idling and minor stoppage losses occur when production is interrupted by a temporary malfunction or when a machine is idling.

(4) Reduced speed losses refer to the difference between equipment design speed and actual operating speed.

Quality losses

(5) Quality defects and rework are losses in quality caused by malfunctioning production equipment.

(6) Start-up losses are yield losses that occur during the early stages of production, from machine start-up to stabilization.

The six big losses are measured in terms of overall equipment effectiveness (OEE), which is a function of availability (A), performance rate (P) and quality rate (Q) [35].

2.5 Performance Measurements

In the industry, performance measures are most often denoted as KPIs (Key Performance Indicators). Widely used KPI metrics are, cycle time, Mean Time between Failure (MTBF) and utilization**.** Other common methods are MWT (Mean Waiting Time), MTTR (Mean Time to Repair) and MTBF (Mean Time between Failures). However, these parameters, and many other common parameters, do not give a comprehensive view of units and equipment if displayed alone. Included in TPM, there is a metric called OEE (Overall Equipment Effectiveness), which gives a more inclusive view of the value added by the unit, compared to other metrics [25].

The real values of OEE is most commonly used for development and follow up of KPIs in production, to identify critical equipment such as bottlenecks, to identify and direct Improvement work as well as a way of monitoring and controlling processes and equipment.

2.5.1 OEE measurement

The OEE can be used to help focus on improving the performance of machinery and associated processes by identifying those performance opportunities that will have the greatest impact to the bottom line. Improvements in changeovers, quality, machine reliability, working through breaks and more, can be measured and improved utilizing the OEE metric. It is the ratio of actual equipment output to its theoretical maximum output. OEE can be viewed as the percent of time that equipment would need to run at its maximum speed in order to attain the actual output of that tool or machine. It is calculated using the following formula [22].

Due to the fact that OEE measurement can be implemented within different levels in an industrial environment, it value can be used as a "benchmark" for further measurements of any manufacturing plant [26].

2.5.3 The Purpose of OEE

OEE value from one manufacturing line can be used to compare different performance lines across an industry. In an individual level, OEE measure can identify which machine performance is ineffective and required special attention [23].OEE provides more KPI's, framework for improving a process, pinpoint rank for improvement, Identifying any losses that restrict equipment from achieving it maximum effectiveness and wasting resources with no value creation. The main purpose of OEE is to become the most efficient, most effective manufacturer within a market, minimizing the main losses.

2.5.4 OEE economics and financial benefits

The strength of OEE is to improve competitiveness in any manufacturing industry by creating better return on investment (ROI) and producing increased productivity [30]. It is often hard to measure the financial benefits of proposed improvement projects and it is easy to oversee important projects and instead priorities average projects. Bottlenecks are what prevent a process throughput and limits a plant from becoming effective; therefore, bottlenecks should be the first place where OEE is applied. In order to priorities the OEE improvement projects relative to the average ones, it is important to be able to show the financial gains [28]. OEE brings immediate financial benefits to manufacturing operations. A few major benefits are Reduced Downtime Costs, Repair Costs, Quality Costs and Increased Labor Efficiencies, Personnel Productivity, Production Capability [29].

The benefits of OEE would enhance;

- ❖ Accuracy of information through automatic data collection.
- ❖ Efficiency and effective usage of their existing equipment and facilities.

- ❖ Visible and clear reporting to inform decision making.
- ❖ Energy efficiency and quality monitoring facilities [26].

2.6. Production line

In recent years increasing competition in global markets has pushed industries to adopt innovative production systems, targeting improved production quality at reduced cost. In particular high volume production, demands a highly automation and organization in production lines [33].

A production line is a type of manufacturing system in which products visit a number of workstations in a fixed sequential order. A workstation consists of one or more machines, at which products or material are being processed, assembled or inspected. The term “production” in this thesis is used in a broad perspective: it can be the manufacturing of products, but also assembly, inspection, processing of fluid, etcetera [35]. A production line is a set of sequential process established on an industrial shop floor. A production process or a manufacturing process is the transformation of raw materials or components into finished products.

2.6.1 Categories of production line

The nature of a production line depends on the complexity of the manufacturing parts, the production volume, the sensitivity of the product and cost. The production or manufacturing lines in industries can be categories into three type’s i.e. automated production lines, semi-automated production lines and manual production lines. Industries have installed machineries to assist workers. This is known as semi- automated process lines. Automated process lines are designed to operate with fewer workers. This can cut cost in the long run. A fully automated process line is designed to fulfill mass production output and is ideally suited to serve large. Machineries for automated production process such as robots are capable of working for long duration at a consistent rate of production output. Thus, such process lines demand expert and professional people in designing and maintaining the system [35].

2.6. 2 Production line efficiency

Factors contributing to production line efficiency are manpower utilization and machine efficiency. Measuring the machine efficiency and man power utilization should be on-line, accurate and truthful. The major factors affecting production lines are machine efficiency and man power utilization.[25].

Machine efficiency is one of the factors that are frequently overlooked by the management and this can lead towards losses which reduces the yield [35]. Efficiency analysis of a packaging line (new or installed) is the activity of gathering the appropriate data, representing these data in a comprehensible manner, calculating the relevant performance indicators and interpreting these figures. The main goal is to understand or explain the (loss of) production. Improving the efficiency of packaging lines leads to lower packaging costs per unit by increased output or lower personnel costs and/or lower equipment and material costs. It also improves the delivery reliability. Knowing the effect of the line parameters on the efficiency can help in making cost/benefit analysis of packaging lines. Finally, an awareness of the effect of the line parameters on the efficiency might influence the production practice [36].

2.6.3 Production line performance

To control the production line and to make tactical decisions, manufacturers are interested in the performance of their production line. The most common performance measure is the throughput, quality and delivery etc. which is the number of products processed per unit of time. By conducting a sensitivity analysis, the bottleneck of the line can be identified and the effect of changes in the production line can be estimated without the need of expensive and time consuming practical experiments [39]. The manufacturing system must also be stable to produce efficiently. DES is a useful tool in the improvement work. Stability is achieved by a process with as little production disturbances as possible.

Overall equipment effectiveness (OEE) is a well-accepted measure of performance in industry.

And is a quantitative metric that has been increasingly used in manufactory systems for controlling and monitoring the productivity of production equipment, and also as an indicator and driver of process and performance improvements. The OEE is a key performance measure in mass-production environments that consists of three important components which are availability, productivity and quality [40].

Performance measurement systems measure the inputs and outputs to an operation in order to determine how well (or poorly) the operation is using them. Continuous improvements of manufacturing systems are necessary for a competitive industry. There are different ways to achieve increased performance [38].

2.7 Continuous performance improvement

Many organizations have adopted continuous improvement, especially for processes, where continuous process improvement is used to improve products and services through improving the inputs and Processes used to produce them. Many tools have been developed to help work teams and quality improvement teams take a structured approach to improvement. The PDCA (planning, doing, checking and analyzing) cycle describes an overall approach to continuous improvement, whilst the five-why process, the fishbone diagram and Pareto analysis are associated with process improvement.

2.8 Production System Model

2.8.1 General Properties of Transfer /production lines

Synchronous and Asynchronous Lines: in synchronous production lines cycle times of different machines are identical and deterministic; therefore operations start and stop contemporarily for each machine. In asynchronous production lines cycle times may differ among machines and operations do not start and stop contemporarily for each machine [18].

Discrete and Continuous lines: in discrete production each operation requires a fixed time to process a part and the number of products present in buffers, at each time instant, is an integer number. Typical applications of discrete systems can be found in automotive lines, white goods production lines and mechanical components production lines. In *continuous production systems* machines perform operations on continuously owing incoming parts. In this case, the quantity of products stored in buffers is a real number. Typical applications of this type of systems can be found in food industry, textile production lines, chemical lines and pharmaceutical lines. This are commonly analyzed through the use of continuous models, which treat the flow of material as a continuous fluid. These continuous models can also approximate the behavior of discrete systems in the case in which cycle times are consistently shorter than failure and repair times and buffers are small in size [22].

Starvation and Blocking phenomena: a machine is said to be starved if no part is available for processing. The machine is said to be blocked if there is no available place to store the processed part. Blocking and starvation phenomena are usually caused by interruptions of flow which propagates through the line. If no buffers are present, a failure of a machine immediately propagates to all the other machines composing the line. In this case, maximal coupling of machines in the line is verified. Buffers are commonly adopted in real production systems to decouple the behavior of machine and prevent blocking and starvation phenomena from propagating along the line. Once one machine fails, starvation propagates to the downstream machines while blocking propagates to the upstream machines.

Capturing the correct dynamic of propagation of blocking and starvation in the system is fundamental for the development of accurate models and methods for the performance analysis of systems.

Two models are generally adopted to describe the blocking and starvation dynamics [23]: they are known as Blocking before Service (BBS), also named production blocking, and Blocking After Service (BAS) also named communication blocking. The first mechanism considers the Following dynamics: the machine starts processing a product only if place to store it is available in the downstream buffer. The second mechanism models the case in which the machine starts processing the part (taking it from the upstream buffer) and, once finished the operation, the Availability for place to store the part in the downstream buffer is checked. Analytical methods generally adopt the BBS assumption.

2.8.3 Buffer Characteristics

Buffers are present in real production systems with the role of transporting material from one machine to another one, decoupling the behavior of the machines and reduce the effect of the propagation of blocking and starvation in the line. They can be automatic conveyors, floor space, etc. This work considers buffers to be reliable and not subject to failure [18].

2.8.4 Simulation and Analytical Methods

Two types of models are typically used to estimate performance measures are: simulation models and analytical models.

Simulation method involves the representation of the real manufacturing system in a computer-based model via the use of an appropriate simulation package. Simulation models are capable of handling complex model structures; however they need validation to be representative of the true manufacturing system. On the hand analytical methods involve formal mathematical solution to the problems. Due to the complexity involved two approaches are used namely, exact and approximate methods. Exact analytical solutions are feasible for simplified models, and usually small scale problems. Approximate methods derive approximate solutions often by means of appropriate and efficient algorithms to actual mathematical problem [25].

2.8.5 Comparison of production models

Comparison of these performance measures models helps for better understands is necessary as follow in table 2.1

Table 2.1: Comparison of analytical and simulation models [30],[39].

	Advantages	Disadvantages
Analytical models	• Low effort in application • Fast in executing phase • Relatively easy to validate	• Only applicable for relatively simple systems • Hard to deal with dynamic situations
Simulation models	• User friendly • Useful in convincing people due to visualization • Possible to experiment without risks •Cheap compared to experimenting in reality	• Takes a lot of time in both development and execution phase • Hard to validate • Lot of data needed

2.8.6 Choose of Simulation type

Discrete-event simulation models mimic the real system by constructing a list of events that occur in the real system. At each event occurrence, such as a processing completion or a breakdown, new events are scheduled and added to the event list. The randomness in times between two events is captured by drawing random numbers from pre specified distributions. These distributions can be derived from data of the production system; both empirical and fitted distributions can be used. In order to obtain accurate estimates for the performance of the production line, the simulation should run for a sufficient amount of time [39].

In this study simulation model, the stochastic variables indicate that the system evolves over time and the state of the system changes, which means that we should use random input components. Our model is a discrete event simulation, because the state of the system only changes when an event occurs. Furthermore, the processing times of the bottles are stochastic, because breakdowns on machines can occur. Taken the different dimensions into account and the reason that this project deal with a complex system, the conclusion is that we use a discrete-event simulation [32].

2.9 Simulation modeling

2.9.1 An Introduction to Simulation

Simulation in general, can be said, that every complex system or phenomenon, i.e. processes that contain stochastic, nonlinear or time variable, often cannot be describe by a set of deterministic mathematical expressions or equations, and they are usually analyzed by modelling and simulating. The term simulation stems from the Latin word "simulate" that means "imitation", which is essentially the main goal of the simulation execution[31].

Simulation is an imitation of performance of the real process or system over the time. it relates to the fictitious creation of history of the system and its revision for the purpose of reaching some conclusions about the features of real system function.it can be used to investigate various questions about the real system such as “What will happen if?” In order to predict the effects of possible changes on performance, those changed can initially be simulated. Simulation for the purpose of studying the systems under designing is also applicable prior to their creations.

The availability of languages that are specific to simulation, extensive computational capabilities together with decreasing costs of any computation, and advances in simulation techniques, have caused this topic to be considered as one of the most common and most widely accepted in research tools in systems’ operations and analysis [30].

2.9.2 Purposes of Simulation

The simulation modeling and analysis of different types of systems are conducted for the purposes of [33]:

- ❖ Gaining insight into the operation of a system
- ❖ Developing operating or resource policies to improve system performance
- ❖ Testing new concepts and/or systems before implementation
- ❖ Gaining information without disturbing the actual system

2.9.3. Goals of simulation modeling

Simulations are expected to provide numeric measures of performance, such as throughput under a given set of conditions, but the major benefit of simulation comes from the insight and understanding gained regarding system operations. Visualization through animation and graphics provides major assistance in the communication of model assumptions, system operations, and model results. Often, visualization is the major contributor to a model's credibility, which in tum leads to acceptance of the model's numeric outputs [30],[36].

Of course, a proper experimental design that includes the right range of experimental conditions plus a rigorous analysis and, for stochastic simulation models, a proper statistical analysis is of utmost importance for the simulation analyst to draw correct conclusions from simulation outputs. The major goals of manufacturing-simulation models are to identify problem areas and quantify system performance [41].

2.9.4 Issues Addressed by Simulation

The following are some of the specific issues that simulation is used to address in manufacturing: The need for and the quantity of equipment and personnel [33]:

- ❖ Number and type of machines for a particular objective
- ❖ Number, type, and physical arrangement of transporters, conveyors
- ❖ Location and size of inventory buffers
- ❖ Evaluation of a change in product volume or mix
- ❖ Evaluation of the effect of a new piece of equipment on an existing manufacturing system
- ❖ Evaluation of capital investments
- ❖ Labor-requirements planning

Performance evaluation

- ❖ Throughput analysis
- ❖ Time-in-system analysis
- ❖ Bottleneck analysis

Evaluation of operational procedures

- ❖ Production scheduling
- ❖ Inventory policies
- ❖ Control strategies [e.g., for an automated guide vehicle system (AGVS)]

- ❖ Reliability analysis (e.g., effect of preventive maintenance)
- ❖ Quality-control policies

Following are some of the performance measures commonly estimated

- ❖ Throughput
- ❖ Time in system for parts
- ❖ Times parts spend in queues
- ❖ Queue sizes
- ❖ Timeliness of deliveries
- ❖ Utilization of equipment or personnel

2.9.4 Measures of System Performance

The following are some of the performance measures commonly estimated by simulation [30]:

- ❖ Throughput
- ❖ System cycle time (how long it takes to produce one part)
- ❖ Utilization of resources, labor, and machines
- ❖ Bottlenecks and choke points
- ❖ queuing at work locations
- ❖ Queuing and delays caused by material-handling devices and systems
- ❖ WIP storage needs
- ❖ staffing requirements
- ❖ Effectiveness of scheduling systems
- ❖ Effectiveness of control systems.

2.9.5 Types of simulation models

The different types of simulation models can be classified using three dimensions [32]:

- ❖ Static vs. Dynamic: when a model is static it only concerns the system at a fixed time; when a model is dynamic it shows how the system evolves over time.
- ❖ Deterministic vs. Stochastic: when a model is deterministic no randomness is induced; when a model is stochastic one or several sources of randomness are modeled.

- ❖ Continuous vs. Discrete: when a model is continuous the change of the system state is calculated continuously; when a model is discrete the system state changes at certain intervals.

Also, Several types of simulation models can be used:

- ❖ Discrete-Event Simulation
- ❖ Continuous Simulation
- ❖ Combination of Discrete and Continuous Simulation
- ❖ Monte Carlo Simulation
- ❖ Spreadsheet simulation (for small simple problems)

2.9.6 Advantages of Simulation

The advantages of simulation are here summarized as follow Based on [25]:

- ❖ Cost: Enables cost reductions and/or avoids costs.
- ❖ Time: Reduces ramp-up time of production and possibly development lead-time.
- ❖ Complexity: Enhances understanding of relationships, interactions, dependencies, etc.
- ❖ Dynamics: Captures time-dependent behavior.
- ❖ Replicability: Experiments can be repeated at any time.
- ❖ Visualization: Provides visual analysis capabilities.

2.9.7 Disadvantages of Simulation

The disadvantages of simulation according to [30] are:

- ❖ Need for special training: Building a simulation model is an art that is learned over time and through experience.
- ❖ Difficulties of interpreting the results, a significant amount of knowledge of statistical theory and methods is required.
- ❖ Time and cost: Modeling and analysis can take a lot of time and may be expensive.
- ❖ Inappropriate use: Simulation is sometimes used when an analytical solution would have been possible or even preferable, or in any of the other cases described previously.
- ❖ Non-optimized results: Simulation is *not* optimization, and even when near optimal results are achieved there is a risk for sub-optimization

2.9.8 Use of Simulation in Packaging line

Simulation is a valuable tool for efficiency analysis of packaging lines and can be used to answer the following questions about packaging lines [36]:

- Which buffer capacities should be increased to improve the line efficiency?
- Should the conveyor speed of a buffer be changed?
- What is the expected optimal order sequence to produce a certain set of orders?
- Do the benefits of stopping a certain machine every two hours for cleaning and inspection cover the loss of production time during the stops?
- How do two or more design alternatives compare?
- What is the influence of the value of certain line parameters on the line efficiency?"
- What is the maximum or expected productivity of a certain packaging line?
- What is the effect of lunch breaks on efficiency?

Today, there are hundreds of commercially available DES software packages; some of the packages are classified as shown in below table 2.2.

Table 2.2, classification of simulation languages and environments [31], [33],[36].

Simulation Languages	General-purpose programming languages ALGOL, C, C++
FORTRAN, Pascal	Simulation programming languages GASP, GPSS, GPSS/H
SIMAN, SLAM	General languages designed for simulation SIMULA, SIMSCRIPT
Simulation Environments	2-D animation Arena, Extend, Witness
3-D animation AutoMod, Quest, Taylor ED	
Simulation Languages	General-purpose programming languages ALGOL, C, C++

Simulation is a powerful tool to analyze complex models, when analytical models cannot supply the solution. Although process data analysis of packaging lines is indispensable for process control and often leads to improvements of the line efficiency, many questions can only be answered using simulation. Simulation of packaging lines to analyze the line efficiency involves discrete event simulation of the production units of the packaging line.

2.10. Reviewed Related Works

The following reviews literature that has already been conducted within the field of productivity or performance improvement based on Simulation modelling and OEE tool applied for high speed, mass production and complex processes particularly bottling industries.

A stochastic model has been made [37] on an automatic assembly line of a manufacturing factory to calculate the optimal processing rates of both the machines and the conveyors to increase the throughput of the system and minimizing the time the bottleneck is blocked, he uses fixed operational speeds. [38] Propose an analytical model that calculates the needed safety stock between different stages to reach a pre-set efficiency level. Within this model they take down-time of the machine into account either due to a defective item being produced, breakdown of the machine, or blockage or starvation of the machine. In this model it is assumed, however, that the line starts production with safety stock already present at the line at start up and that safety stocks are replenished at the end of production. Also, [39], Conducts research on Finnish paint and varnish manufacturing company. The studied Paint Filling and Packing Production line was lower production efficiency and higher setup work due to production loss specifically downtime loss is a serious problem. By dealing with production improvement tool OEE's, and setup time reduction tool SMED's, 15 % of Setup time reduced as well as standardization of changeovers is done to achieve the targeted improvement.

The OEE tool is designed to identify losses that reduce the equipment effectiveness. These losses are activities that absorb resources but create no value. According to [40] the losses are due to manufacturing disturbances that are either chronic or sporadic. Chronic disturbances are small, hidden and are as a result of several concurrent causes. Sporadic disturbances on the other hand, are more obvious since they occur quickly and have large deviations from the normal state.

Due to the chronic nature of the operational causes of production losses, pertinent rates like availability, performance rate, quality rate, scheduled downtime rate, etc needs to be highlighted to enable specialized attention to the particular losses. The OEE measurement tool has its strength in the way it integrates different important aspects of manufacturing into a single measurement tool. The perspectives integrated in the OEE tool are the maintenance effectiveness, production efficiency and quality efficiency.

As indicated by [41] the OEE concept is becoming increasingly popular and has been widely used as a quantitative tool, which is essential for productivity measurement but, still in the early stages of development and is limited to productivity behavior of individual pieces of equipment.

[42] Indicated that the gains in OEE, while important and ongoing, are insufficient because no machine is isolated. They determined that the manufacturing process is a complex web of interactions between process tools, materials, machines, people, departments, companies, and processes.

[43] OEE is beneficial in high-volume process-based manufacture where capacity utilization is a high priority, and stoppages or disruptions are expensive in terms of lost capacity. For production processes with buffers in between, OEE would need to be redefined, since downtime on one process stage does not have a direct consequence for the next stage. The breakdown is not always a loss as we could still create customer value with downstream center. Due to the nature of these processes, deployment of OEE in such a case is not very beneficial.

As discussed before, there is debate as to whether machine breakdowns always represent a loss. For [44], further research should be done to explore the dynamics of translating OEE in terms of cost, making it more significant for management. The process of searching for this answer could be a journey to discover some limitations of OEE towards flexible adaptation and wide-range application. Without a clear answer to that question, it is difficult to persuade people to pursue this form of performance measurement.

According to [44], the validity and usefulness of the OEE measure are highly dependent on the data collection and accuracy. As reported by [45], accurate equipment performance data are essential to the success and long-term effectiveness of TPM activities. Without reliable data, the different losses cannot be measured and identified, and thus TPM actions cannot solve the core problem or improve the performance.

As mentioned in the previous section equipment operates in a linked and complex environment. So it is necessary to pay attention beyond the performance of individual tools towards the performance of the whole factory. The ultimate objective is to have a highly efficient integrated system and not brilliant individual equipment's [46]. This insufficiency of OEE tool has led to modification and enlargement of original OEE tool to fit a broader perspective as deemed important in the manufacturing systems. There many methodologies and approaches, with different level of complexity, different information coming from and different lacks. According to [42], the answer to this requirement is the OFE metric , The problem is that a specific and unique method to calculate OFE does not exist. Muthiah et al.[24], developed the approach to derive OTE metrics for these subsystems based on a “system constraint” approach that automatically takes into account equipment idle time.

Other methods are based on modeling the manufacturing systems. Some of these notable approaches are queuing analysis methods, Markovian methods; Petri net based methods, integrated computer-aided manufacturing definition method, and structured analysis and design technique. In addition to them there are several commercial tools that have been reviewed and categorized by [30].

Although the above mentioned models present possible ways to analyze and improve the performance, they rely on analytical models that are not suitable in complex system [47], [49])present simulation models within a beer factory which correspond to this research. [48] Tries to improve performance by changing the moment of changing operating speed of both the conveyors and the machines. The idea behind the control of different kinds of speed is to have a better continuous flow of your products and with that all machines will have less start and stop situations. This improves the reliability of every machine which will consequently improve throughput [48]. Performance of the line can be improved by changing the theoretical speeds and buffer quantities [44]. This study also uses a simulation program to simulate different “what if” scenarios to see if this improves current performance.

The last similar study is done by [49] in this study, the author tries to change both the location of sensors for changing speeds as well as the speed levels themselves. Different locations and speed levels were tested by means of a simulation model and the author found that these changes would positively influence both the production balance as well as the output.

2.11. Summary of Literature Review

On all the previous studies the improvements focused on the single machines or some part of production process. However, the conveyors and buffers also play an important role in the line performance. This research, will consider every flow line between two consecutive machines or whole production line. So that, multiple improvement steps can be made. From the discussions in the literatures, it is concluded that OEE analysis is a valuable measure that gives information on the sources of lost time, lost production and helps to optimize the performance of the existing capacity. However, as mentioned in the previous section equipment operates in a linked and complex environment. So it is necessary to pay attention beyond the performance of individual tools towards the performance of the whole factory. The ultimate objective is to have a highly efficient integrated system and not brilliant individual equipment's. The performance elements measured by OEE tool, though important, are not sufficient to describe the effectiveness of a production system. Some important measures (e.g. cost and flexibility) are not measured in the OEE and also, further research should explore the dynamics of translating equipment effectiveness or loss of effectiveness in terms of cost.

Generally, simulation model analysis is considered the most reliable method to date in studying the dynamic performance of a manufacturing system. In this study, to analyze efficiency and improve bottling production line combining OEE and simulation model are considered in discovering some limitations of OEE and considered method to study the dynamic performance of a manufacturing system.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Research Design

Research designs are plans and procedures for research that span the decisions from broad assumption to detailed methods of data collection and analysis [12]. The overall decision involves which design should be used to study a topic and the selection of research design is also based on the nature of the research problem or issue being addressed, the researcher personal experience, and the audience for the study. To achieve the objective of this study the researcher expected to explore in depth, program, event, activity, process or one or more individuals and collect detailed information using a variety of procedures over sustained period of time and limited activity. Therefore, this proposed study intends to use case study as a research design to study how to improve production line performance

3.2 Methodology

The researcher expected to flow defined procedures, understand and explore in depth, activity, process flows or one or more individuals and collect detailed information using a variety of procedures over sustained period of time on the actual selected production line. Generally a methodology is proposed to be followed to achieve the objective of this study as shown in Figure3.2.

3.3 Production line

To achieve the objective of this study the researcher expected to understand and explore in depth, activity, process flows or one or more individuals and collect detailed information using a variety of procedures over sustained period of time on the actual selected production line. In addition, different research works and documents like journal articles, literature reviews, books in relation to this production system are important to understand the general characteristic and current seniors in the field.

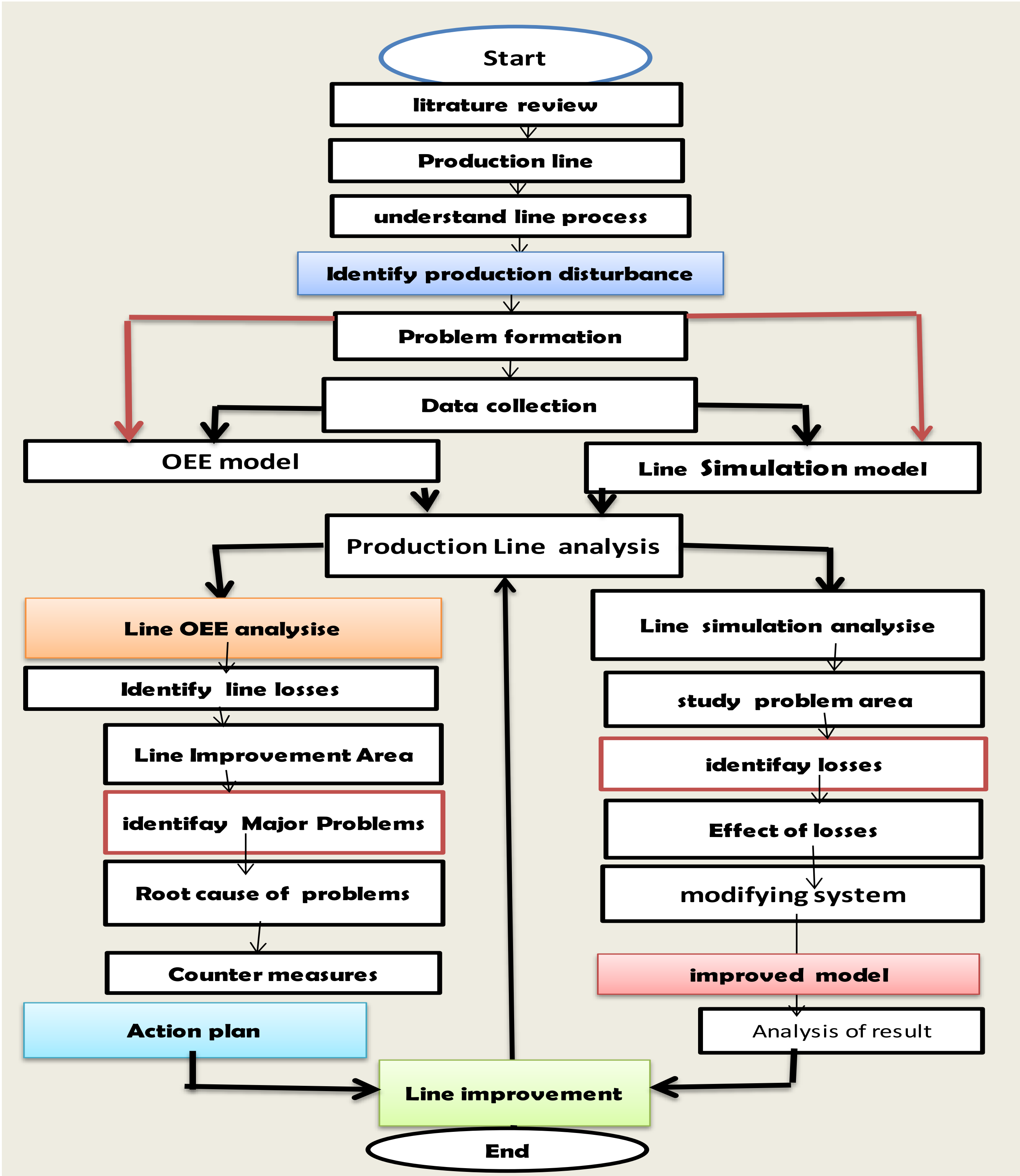


Figure 3.2: Detail of Proposed line improvement methodology

3.4 Data collection, analysis and presentation

The primary and secondary data from the real production system, literature for performance analysis, improvement modeling and simulation has been collected in study. All collected are analyzed and evaluated by using different tools and software to obtain the probability distributions and their parameters of the raw data. Finally, Tables, Equations and graphs will be used to present the results on various variables in the study.

3.5 Line analysis

Line analysis is the activity of isolating the appropriate data, representing these data in a comprehensible manner, calculating the relevant performance indicators and interpreting these figures. This stage is characterized by a follow up and identification of Efficiency Losses, identifying major concerning areas, corrective actions and by providing respective suggestions and finding optimal improvement opportunities using OEE and simulation model analysis.

3.6 Simulation model analysis

Building a simulation model for a complex production system that mimics the behavior of the real system requires a good understanding of the system, collecting enough data, building the model using computer software in addition to the process of verification and validation. After the line OEE analysis major efficiency losses, major concerning areas and their root cause is expected be identified. Then some counter measures are suggested as corrective action towards the end so that production losses of line can be reduced to enhance productivity. The computer simulation enables the reduction of disturbance and constraint in existing capacity suggested improvement in productivity than existing production operation.

The proposed simulation methodology is done in three phases.

Phase 1: Problem definition (from step 1-step 2)

- ❖ The simulation study starts with conducting extensive literature survey, problem definition and formulation and a plan is made for the study.
- ❖ Introduce the problem, and determine goals, restrictions and timing, visualization and run times, Expected contribution and results
- ❖ Concise model description: scope and detail, assumptions, experimental factors and reports.
- ❖ Data requirements and collection and Time planning and Cost estimate

Phase 2: Model building (from step 3-step 7)

Data needs to be collected and the model is defined and programmed. The model will be verified and validated. Is it the right model? It investigates if the created model compatible with real process. In contrast, verification is interested if we build the model in the right way.

Phase 3: Experimental design (from step 8-step 11)

Determines the experimental design, executes the experiments and analyses the output of the experiments. Also determines the factors, their levels, and the combination of levels that will be used.

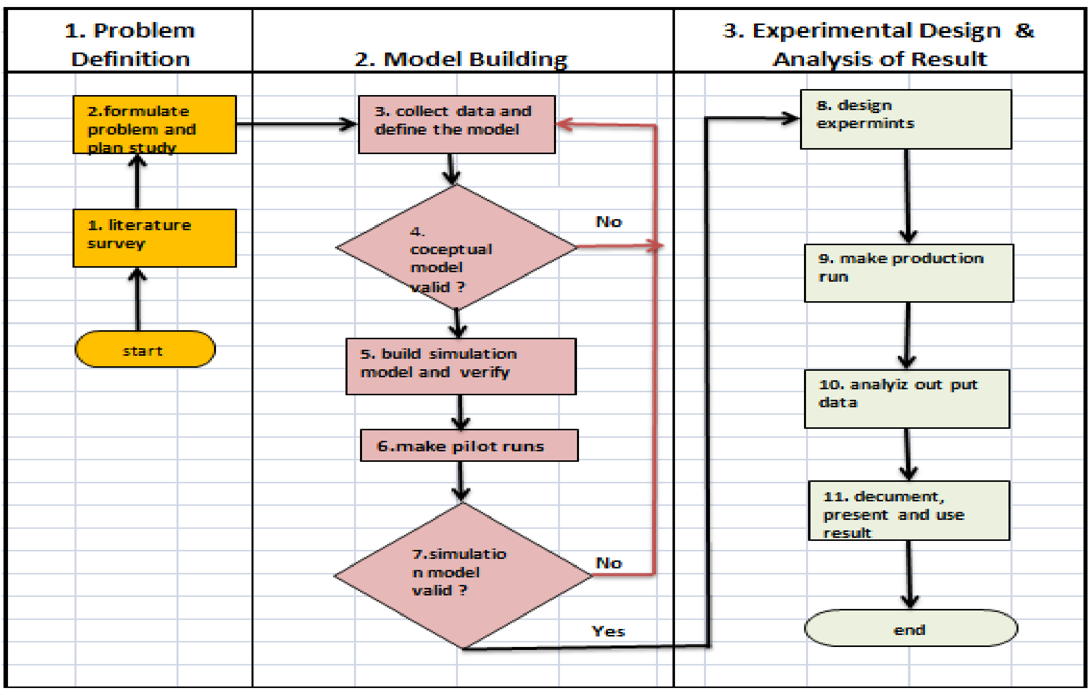


Figure 3.3: proposed simulation methodology

3.7 Change implementation and improvement

From the line analysis, the major production line losses, their root cause and action plan presented and the effect of major line parameters on loss propagation on the whole production system is studied. Then at this is final stage, change on the existing situation is introduced on line parameters and other aspects of the process is made depending on the improvement scenarios and their assessment to improve the efficiency performance and productivity of the line in general.

CHAPTER FOUR

OVERVIEW OF CASE COMPANY AND LINE ANALYSIS

4.1 Introduction

In this chapter, overview about line process, work flow, simplified lay out, data collection and line analysis and operation of real bottling line at has been discussed.

4.1.1 Line Process Overview

In the beginning of the production process as shown in Figure 3.4 , performs are loaded to perform silo (C1] from row material store and flows through elevator (C2), unscramble (C3), Rail guide (C4), to block stations that includes Heating module(M1),blow molding (M2), Base cooling (M3) and filling machine(M4). The quality specification of preform is checked at discharge of M1 and if preform passes quality requirements, performs moves to M2 to become a bottle .if performs quality is not confirmed the preform rejected to rejection bine 1 (B1). Then, the empty bottle from M2 is checked for quality, if bottle quality is not confirmed, the bottle is rejected to rejection bine 2(B2) and, if quality is passed the bottle moves to base cooling (M3), M4 for filling process. Simultaneously, Cap feeds to filling station from cap silo (C5) in row material store through different Cap feedings (C6, C7, and C8), to capping station (M5) to seal the filled bottle in filling station. Then, the filled bottle moves to full bottle inspection (M6) if the bottles pass all the inspection requirements it move to manual palletizing station(PLC) through labeling(M6),shrink wrapping(M7) with the help different conveyers(SC, AC, PC, and SC) .
Finally, Fork lift moves the full bottle pallets from palletization to Pallet wrapping processes (M) and the wrapped pallets moves to Warehouse with the help of Fork lift for storage.

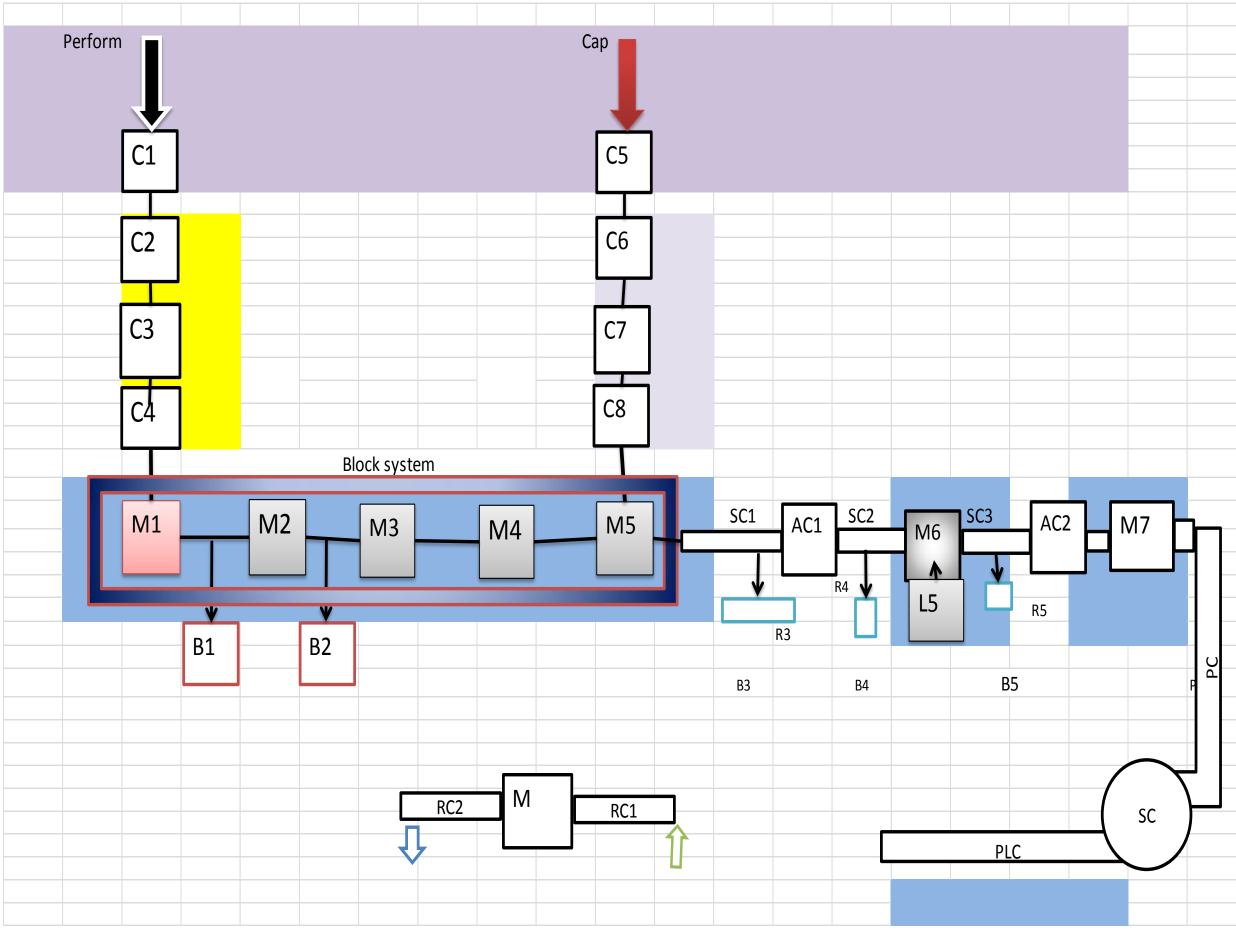


Figure 3.4: existing lay out of the production system

4.1.2 Line control systems

The bottling line under study is a fully automatic and PLC controlled, that consists of different stations and different types of conveyors. The Control System is designed to fully integrate the conveying system with the stations. It maximizes the output by controlling the speed of the machines. The conveying line controller provides the logic and instructions to each of the conveyor drives based on data received from line sensors, together with the data collected from the individual machines. Each machine has its own control system which is interfaced with the line control system. . Photocells on the conveyor system control the speed and state of their respective machine. All machines work initially at low speed and when a machine receives a signal from a specific photocell, its state changes accordingly to Low speed, medium speed and high speed or stoppage depending on the corresponding photocell.

The system calculates the movement of bottles relative to the filler taking into account the line accumulation and adjusts the speed of the individual machine to suit. This allows the filler to run at the highest speed it is capable of for the particular bottle and product. For instance, Ifthe shrink wrapper stops then the container infeed will build back towards the labeler. When a sensor notes that the bottles are backing up at a certain point, this slows the labeler down whilst a sensor further upstream will stop the labeler. They allow ramp up and ramp down of conveyors and machines to suit circumstances, all these being pre-programmed into the PLC.

A. Speed Regulation

The filler machine and blow molding machine runs at 100% of their rated speed and the other upstream and downstream processes have higher rated speeds than the filler and blow molder with three different values: low, medium and high. Photocells on the conveyor system control the speed and state of their respective machine.

The blow molding machine has only two basic states: stoppage and maximum speed operation and it only need one photocell for stoppage (after the machine).The status of Blow Molder and filler depends on the number of accumulated entities on accumulation Conveyor 1 before Labeling. The number of accumulated bottles on accumulation Conveyor 1 before Labeling depends on Blow Molder, filler and Labeler speeds and failures. For example, if the Labeling machine is down, the Blow Molder and filler will continue processing with the bottles accumulating on accumulation conveyor 1 until the bottles queue length reaches the location of photocell "Blow Molder Stoppage". In that case, the Blow Molder will stop until the Labeling machine is up and running again which reduces the queue length of accumulated bottles from the maximum set by the location of the Blow Molder stoppage photocell which in turn, restarts the Blow Molder machine. The Labeling machine has three states: stoppage (depending on the number of accumulated entities on accumulation Conveyor 2), operation at the low speed, operation at the medium speed and operation at the high speed (depending on the number of accumulated entities on accumulation Conveyor 1). The variopack machine has three states: stoppage (depending on the number of accumulated entities on pack Conveyor), operation at the low speed, operation at the medium speed and operation at the high speed (depending on the number of accumulated entities on accumulation Conveyor 2). Stretch wrapper machines which always operate at constant speeds.

B. *Deferent states of a machine and conveyer*

Since a machine is not producing all the time, there are several states that indicate the condition of the machine. A machine and conveyer can be in different states, which are formulated below:

- Producing: The machine is producing products. This could be with different speed levels.
- Planned production stop: The machine is not producing due to planned maintenance.
- Starvation: The machine is not producing due to a lack at the infeed. Mostly caused by failures of preceding machines.
- Blockage: The machine is not producing due to a backup at discharge. Mostly caused by failures of succeeding machines.
- Failure: the failure duration can be for short or long time .Short failure:

The machine has an internal or external failure and also the machine or conveyor can only be in one of these states at any given time. The planned production stop is necessary and is known beforehand, this aspect will not influence the performance of the production line. The external failures are not taken into account. These failures are caused by other departments but do have an influence on the performance of line.

4.1.3 Production line Design and Process flow

First of all it is important to identify: equipment, layout, production process, space and workers of production lines, which produce different brands in different formats and especially in smaller series charging there are frequent changes of formats and flavors of filling which requires following operations:

- Shut Down – preparing for production stop
- . Clean In Place - external/internal cleaning
- Change Over – change of format parts
- Start Up – preparing for start of new production

Bottleneck Machine

A bottleneck is a phenomenon, where the performance or capacity of an entire system is limited by a single or limited number of components or resources. In engineering, a bottleneck is a phenomenon by which the performance or capacity of an entire system is severely limited by a single component. Formally, a bottleneck lies on a system's critical path and provides the lowest throughput. A bottleneck in project management is one process in a chain of processes, such that its limited capacity reduces the capacity of the whole chain. The bottle neck machine is due to which productivity is going down most of the time and this plant was selected as equipment for OEE calculation.

4.1.4 Data Collection

Data Collection is an important aspect of any type of research study. Inaccurate data collection can impact the results of a study and ultimately lead to invalid results. Data is essential for investigating the Root Cause of the problem. Data also provides the foundation for:

- Defining the current performance
- Identification of root cause
- Measuring progress
- Verifying effectiveness of solutions
- Building simulation model

Generally, the following Data are collected both from historical database and directly from the production system. A systematic approach is used to collect data of all the manufacturing machines within the different types of processes and product. Data collected is collected manually by the respective process engineers, automatically recorded by the machine and studied while measurements, observations and interviews were employed on hourly, daily and weekly basis. Generally, the following Data are collected both from historical database and directly from the production system following specific procedures.

- Time loss for machines downtime,
- Time loss for set ups and product change over
- Time loss for component stoppage law material lack; micro downtimes;
- Time loss for preventive maintenance (Planned downtime)
- Time loss for resources lack
- Planned and final output
- production volume

Also the following facilities and equipment related data are collected

- sensor position
- conveyer length and accumulation
- conveyer velocity and capacity

- machine cycle time
- machine speeds
- production rate

The data should be analyzed over different production shift teams, different time periods, different product types, and different production parameters of line. By using OEE model and Simulation model that are standard and generally applicable methods, the analysis packaging lines is made easier, more familiar and comparable.

The use of such data fed into simulation programmers will highlight where small improvements can be made. This will lead to an improved OEE.

Figure 1senser position

Figure 2 conveyer length and accumulation

Figure3 conveyer velocity and capacity

Figure4 machine cycle time

Figure 5 machine speeds

Figure 6 production rate

Table 4.1: Actual Production and planed production lose

	Actual	planed	losses
	net production	production quantity	variance
1	89208	94292.856	5084.856
2	164124	173479.068	9355.068
3	174420	184361.94	9941.94
1	194112	205176.384	11064.384
2	191096	202558.472	11462.472
3	192372	203337.204	10965.204
1	172740	182586.18	9846.18
2	72144	76256.208	4112.208
3	196680	207890.76	11210.76
1	112872	119305.704	6433.704
2	168264	177855.048	9591.048
3	216856	230356.792	13500.792
1	0	0	0
2	7920	8371.44	451.44
3	192888	203882.616	10994.616
1	159336	168418.152	9082.152
2	162648	171918.936	9270.936
3	234816	248200.512	13384.512
1	23304	24632.328	1328.328
1	60000	63420	3420
2	173496	183385.272	9889.272
3	228540	241566.78	13026.78
	3187836	**3371252.652**	**183416.652**

Table 4.2: classification of time lost due to planned downtime and unplanned downtime for 21 production shift

		UNPLANNED DOWNTIME															PLAND DOWNTIME							
Factors		1	2	3	5	6	7	8	9	10	11	12	13	14	#	16	17	18	19	20	121	22	23	24
Shift	1	120	0	0	40	10	5	28	0	0	0	0	30	0	0	0	0	0	92	0	0	0	0	0
Shift	2	0	0	0	0	0	8	0	10	5	28	0	44	0	0	0	34	0	59	0	0	0	0	17
Shift	3	0	20	0	30	0	0	39	0	0	9	0	41	0	0	0	30	0	0	20	0	0	0	0
Shift	4	0	0	0	0	0	30	73	0	5	0	0	0	0	0	0	36	0	0	0	0	0	10	0
Shift	5	0	0	0	0	0	0	40	28	0	9	0	0	0	0	0	35	0	0	0	32	0	0	0
Shift	6	0	0	0	0	0	12	21	56	6	40	0	0	0	0	0	15	0	0	0	9	0	0	0
Shift	7	0	0	0	0	0	0	26	10	0	0	81	0	0	0	0	20	0	0	0	55	0	0	0
Shift	8	120	0	0	28	0	10	0	28	0	0	0	40	0	0	0	20	0	0	0	114	0	0	0
Shift	9	0	0	0	0	0	9	21	0	0	0	0	26	0	0	0	48	0	0	0	45	0	0	0
Shift	10	0	0	0	0	0	0	28	13	7	0	0	7	0	0	0	30	0	0	0	199	0	7	0
Shift	11	0	0	0	0	0	0	25	13	7	0	0	0	0	25	0	26	14	0	0	89	0	0	0
Shift	12	0	0	0	0	0	4	51	0	0	0	0	0	0	0	0	31	0	0	0	0	0	0	0
Shift	13	0	0	0	0	0	0	105	0	0	0	0	0	0	0	0	480	0	0	0	0	0	0	0
Shift	14	0	0	120	40	0	0	0	0	0	0	0	0	0	0	0	307	0	0	0	0	0	0	0
Shift	15	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	30	0	0	0	0	0	0	0
Shift	16	0	0	0	0	0	12	25	0	10	50	0	0	0	0	0	30	20	0	0	30	37	0	0
Shift	17	0	0	0	0	0	0	104	0	0	0	0	9	0	0	0	20	0	0	0	25	0	0	0
Shift	18	0	0	0	0	0	0	59	0	0	50	0	0	0	0	0	25	0	0	0	0	0	0	
Shift	19	0	0	120	42	0	0	35	0	0	0	0	33	65	0	0	0	0	0	0	20	17	0	0
Shift	20	0	0	0	0	0	15	20	25	0	7	0	0	0	0	75	23	0	0	0	0	0	0	0
shitt	21	0	0	0	0	0	8	30	17	10	8	0	7	0	0	0	16	0	0	0	0	0	0	0

Table 4.3: Time losses due to unplanned downtime

L1	L2	L3	L4		
CO-SU	OT	EF	SDL	DTL	TL
160	43	30	92	233	325
0	23	72	110	95	205
50	39	50	50	139	189
0	108	0	46	108	154
0	68	9	67	77	144
0	95	40	24	135	159
0	36	81	75	117	192
148	38	40	134	226	360
0	30	26	93	56	149
0	48	7	236	55	291
0	45	25	129	70	199
0	55	0	31	55	86
0	106	0	480	105.6	585.6
160	0	0	307	160	467
0	0	20	30	20	50
0	47	50	117	97	214
0	104	9	45	113	158
0	59	50	25	109	134
0	0	0	0	0	0
162	35	98	37	295	332
0	60	82	23	142	165
0	65	15	16	80	96

Table 4.4. Frequency and duration component stoppage (unplanned downtime component

s/ n.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
fcs1	3	4	0	10	0	6	0	4	5	0	0	3	0	0	0	8	0		0	7	5
CS1	5	8	0	30	0	12	0	10	9	0	0	4	0	0	0	12	0	0	0	15	8
fcs2	13		20	28	9	10	15	0	14	16	11	28	19	0		8	31	26	17	12	9
CS2	28	0	39	73	40	21	26	0	21	28	25	51	105	0	0	25	104	59	35	20	30
fcs3	0	4	0	0	8	19	7	11	0	6	7	0	0	0		0	0	0	0	5	7
CS3	0	10	0	0	28	56	10	28	0	13	13	0	0	0	0	0	0	0	0	25	17
fcs4	0	3	0	1	0	3	0	0	0	5	4	0	0	0	0	3	0	0	0	0	6
CS4	0	5	0	5	0	6	0	0	0	7	7	0	0	0	0	10	0	0	0	0	10

Table 4.5: collected equipment failure

		Equipment failure			
BM	BL	FL	FBC	LB	SR
0	0	30	0	0	0
28	0	44	0	0	0
9		41			0
0	0	0	0	0	0
	0	0	0	0	0
9	0	0	0	0	
40	0	0	0	0	0
0	0	0	0	0	0
0	81	0	0	0	0
0	0	40	0	0	0
0	0	26	0		0
0	0	0	0	0	
0	0	7	0	0	0
0	0	0	0	25	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
20	0	0	0	0	0
0	0	0	0	0	0
50	0	0	0	0	0
	0	9	0	0	0
50	0	0	0	0	0
0	0	0	0	0	0
0	0	33	65	0	0
0	0	0	0	0	0
7	0	0	0	0	75
8	0	7	0	0	0
221	81	237	65	25	75
9	1	9	2	1	1
24.55	81	26.33	65	25	75

Table 4.6: collected equipment failure time and frequency of failure

					Equipment failure						
	BM		BL		FL		FBC			LB	
0	**0**	0	0	5	**30**		0			0	
6	**28**	0	0	8	**44**		0			0	
2	**9**	0		6	**41**						
0	**0**	0	0		**0**		0			0	
0	**0**	0	0		**0**		0			0	
4	**9**	0	0		**0**		0			0	
8	**40**	0	0		**0**		0			0	
0	**0**	0	0		**0**		0			0	
0	**0**	3	81		**0**		0			0	
0	**0**	0	0	9	**40**		0			0	
0	**0**	0	0	5	**26**		0		0	0	
0	**0**	0	0		**0**		0			0	
0	**0**		0	2	**7**		0			0	
0	**0**		0		**0**		0		9	25	
0	**0**		0		**0**		0			0	
0	**0**		0		**0**		0			0	
0	**0**		0		**0**		0			0	
0	**0**		0		**0**		0			0	
5	**20**		0		**0**		0			0	
0	**0**		0		**0**		0			0	
9	**50**		0		**0**		0			0	
0			0		**9**					0	
11	**50**		0		**0**		0			0	
0	**0**		0		**0**		0			0	
0	**0**		0	8	**33**	10	65			0	
0	**0**		0		**0**		0			0	
1	**7**		0		**0**		0			0	3
2	**8**		0	1	**7**		0			0	
48	**221**	3	81	44	**237**	10	65		9	25	3

Table 4.7: Sensor location and relative accumulation of belt 1

sensor	Location (m)	Width (m)	Area (m2)	Accumulation
P1	10.2	0.54	5.508	1283.838
P2	10.8	0.54	5.832	1359.358
P3	11.56	0.54	6.2424	1455.016
P4	13.12	0.54	7.0848	1651.368
P5	15.07	0.54	8.1378	1896.807
P6	16.33	0.54	8.8182	2055.399
P7	18.13	0.54	9.7902	2281.959
P8	21.33	0.54	11.5182	2684.731
P9	22.43	0.54	12.1122	2823.184
P10	24.03	0.54	12.9762	3024.571
P11	25.63	0.54	13.8402	3225.957
P12	34.83	0.54	18.8082	4383.928

Table 4.8. Sensor location and relative accumulation of belt 2

position	location	area	unit density	accumulation
P15	4.3	0.45	1.935	451.02141
P10	3.95	0.54	8.046	1875.409956
P9	2.2	0.54	9.234	2152.316124
P8	1.95	0.54	10.287	2397.755682
P7	2.1	0.54	11.421	2662.075206
P6	1.75	0.54	12.366	2882.341476
P5	3.5	0.54	14.256	3322.874016
P4	2	0.54	15.336	3574.606896
P3	7.5	0.54	19.386	4518.605
P2	7.9	0.54	23.652	5512.950072
P1	6	0.54	26.892	6268.148712

Table 4.9.Conveyer's velocity and accumulation capacity

	Conveyor Name	Length (m)	Width (m)	Area [m2]	U/Density (units/m2)	Average accumulation
1	SC1	21.2	0.07		11	233
2	AC1	62	0.54	33.48	233	7800.84
3	SC2	28	0.07		15.26	427
	SC3	16.5	0.07		11	181.5
4	AC2	24	0.54	12.96	233	3,019.68

Table 4.10: Station parameters

	Machine	head	Cycles/Minute	Units/Cycle	Speed(Bpm)
1	PF	-	-	-	-
2	HM	258	-	-	-
3	BM	18	33.3	18	600
4	FL	120	5	120	600
5	LB	18	38.3	18	690
6	SW	11	62	12	744

Table 5.0: Collected equipment failure /down time per month in one year duration.

	Jan-	Feb-	Mar-	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	
PF	1.2	0.99	4.67	0.17	0.25	0	0.83	0.55	1.58	1.3	1.25	7.33	20.12	4%
BM	6.26	6.08	12.34	26.01	7.28	21.34	10.21	6.66	8.58	31.88	10.03	27.7	174.37	35%
HM	1.17	3.33	2.66	0.33	0.33	0.42	0.47	0.53	2.5	3.99	1.58	0.4	17.71	4%
BL	0	0	0	0	0	0.95	5.3	0.83	0	0	0	0	7.08	1%
FL	4.19	2.54	7.58	14.75	3.6	1.53	2.26	5.09	4.49	6.96	1.96	12.98	67.93	14%
CAP F	0	0	0	0	0	0	0	0	0	0.42	0	0.17	0.59	0%
CAPPER	0.25	0	0	0.8	0.58	3.16	2.09	0.23	1.33	0	4.21		12.65	3%
D C	0	0.76	0	0	0	1.8	0.9		0	0	0	0	3.46	1%
FBI	1.99	0	0.33	0	0	0	0	0	0	0	0.32	0	2.64	1%
FBC	0.33	1	0.96	10.47	2.99	1.3	1.42	0.67	1.42	0.27	1.58	0.67	23.08	5%
LB	0.84	12.59	8.94	3.13	3.95	3.87	4.05	3.06	1.74	6.24	1.22	5.24	54.87	11%
SLEEVA	0	0	0.00	0	0	0.25	0	0	0	0	0	0	0.25	0%
FCC	0.47	3.83	4.41	0.33	0	1.66	12.29	10.47	14.46	8.88	1.5	4.9	63.2	13%
S/ W	1.15	2.5	0.92	3.91	4	2.11	1.17	6	3.07	2.08	8.97	1.58	37.46	8%
FPC	1.83	0	0	0	0.55	0	0	0	0	0	0	0	2.38	0%
STR/W	2.92	0	0.00	0	0.58	0	3	0	0.58	0	0	0	7.08	1%
SUM	22.6	33.62	42.81	59.9	24.11	38.39	43.99	34.09	39.75	62.02	32.62	60.97	494.87	

4.2 Production Line analysis

Initially, the efficiency of the production equipment of all the production line should be studied in terms of OEE to measure the efficiency of the production line .The OEE analysis of the specific line aims to understand which are the principal factors and causes that more affected production efficiency. Also, this aids in defining methodologies to investigate losses and elaborating solutions that aim to improve the efficiency of the productive equipment's using simulation. Before starting analysis, understanding the loss analysis structure (as shown in bellow Figure 5.1), the definitions of terms and calculation formulas utilized in this study vital to limit the scope and to come into common thoughtful.

4.2.1 Definition's

a) Calendar Time (Ct)-is the total time that the machine is available to manufacture in the year based on the calendar, which includes weekends, public holidays, etc.
b) Working Time (Wt)-The actual number of hours that the plant is expected to operate in a year or month, excluding public holidays and shifts not planned.
c) Loading Time (Lt)-is the time the line is planned to run. The total shift time minus shutdown losses.
d) Operating Time (Ot)-The actual time used for production, the actual time that the plant / production line actually operates minus downtime losses.
e) Net Operating Time (Nt)-The time during which the plant is manufacturing at the Standard Production Rate (Base Quantity), including minor stoppages.
f) Value Adding Operating Time (Vt)-Nett time used to produce saleable (good quality) product in the total shift time.
g) Quality Lost Time This is all the cases (Accumulation Table Rejects and Scrapped Quantity) lost on the line due to quality defects divided by the manufacturers Rated Speed (Base Quantity).
h) Shutdown Losses-These are losses which are caused by planned activities related to equipment or activities which are not directly falling within the control of a production line.
i) Downtime Losses (DTL)- These are losses which are caused by unplanned activities by equipment or activities which are directly related to the production line.

j) Performance Losses-These are losses which are caused by short stops and speed losses only, which affects the gross output of the filler.

k) Short Stop / Minor Stop-This is a stoppage on any equipment on the production line that directly causes a filler stoppage for less than 5 minutes at a time.

l) Speed Losses-This is when the filler, due to its own inability or any up or down stream equipment influences, runs consistently slower than Line Rated Speed.

4.2.2 OEE model Calculations

i. Loading Time=Total shift time – Shutdown Losses ---(1)

ii. Operating Time=Loading Time – Downtime Losses---(2)

iii. Net Operating Time=Gross Production / Base Quantity -----------------------------------(3)

iv. Value Adding Operating Time=Nett Operating Time – Quality Lost Time---------------(4)

v. Availability= Net Operating time / Loading Time ---(5)

vi. Performance= Net Operating Time / Operating time --------------------------------------(6)

vii. Quality= Value added Operating Time / Net Operating Time-------------------------------(7)

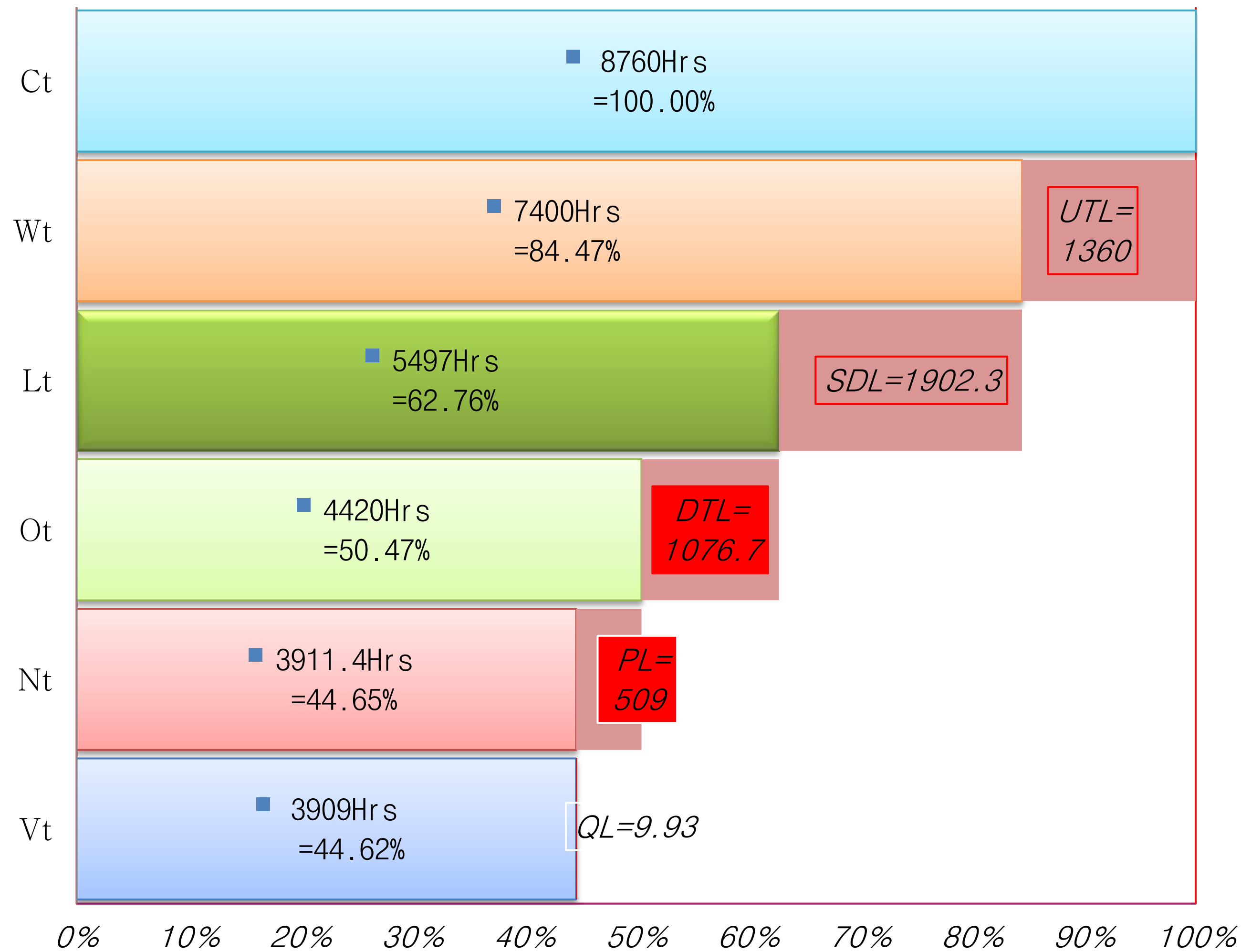
viii. Capacity Utilization = Loading Time / Calendar Time --------------------------------------(8)

ix. Asset Utilization= (Value Added Operating Time / Calendar Time -----------------------(9

4.2.3 LINE LOSSES ANALYSIS STRUCTURE

The losses analysis structure helps to provide the necessary structure for tackling the problems, improving efficiency and capacity, driving down costs and improving profitability. Also this framework can also help unlock additional capacity while reducing manufacturing costs and improving profitability. By having a structured framework (as shown in figure 5.1) to isolate the big Losses, to track principal issues and some of the Events that contribute to these losses with their root causes and, focus on ways to monitor and correct them will be necessary next step .Categorizing data makes loss analysis much easier, and a key goal should be fast and efficient data collection, with data put it to use throughout the day and in real-time.

Figure 5.1: production line losses analysis structure



From the Figure 5.1, the one year production process about 1902 hours was shutdown losses (SDL), 1076 hours in down time losses (DTL), 509 hours performance loss (PL). The quality of product satisfies all standards and specification of the company which has quality losses around 10 hours which is negligible.

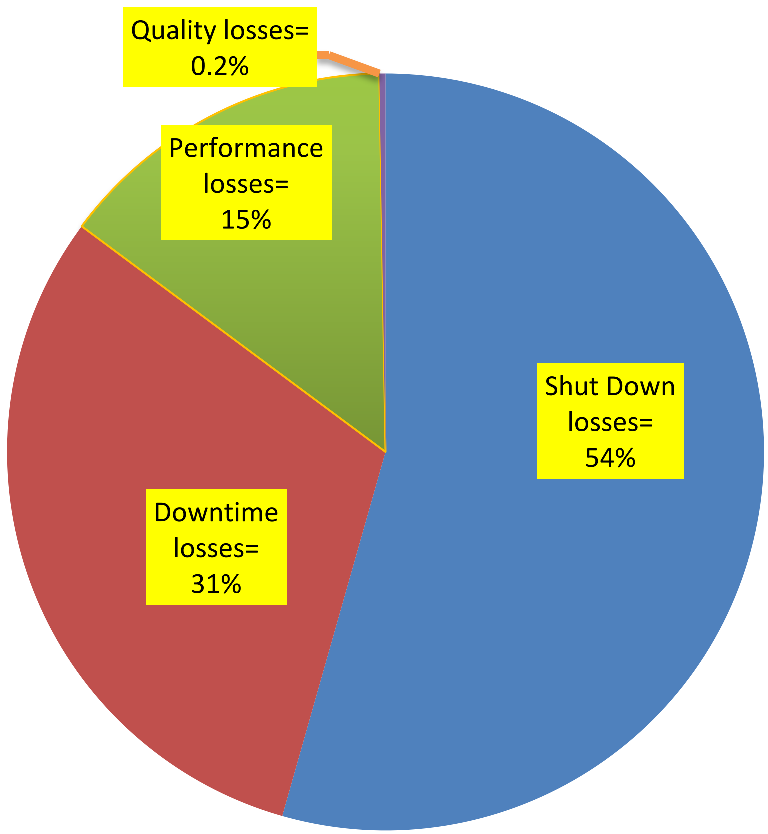
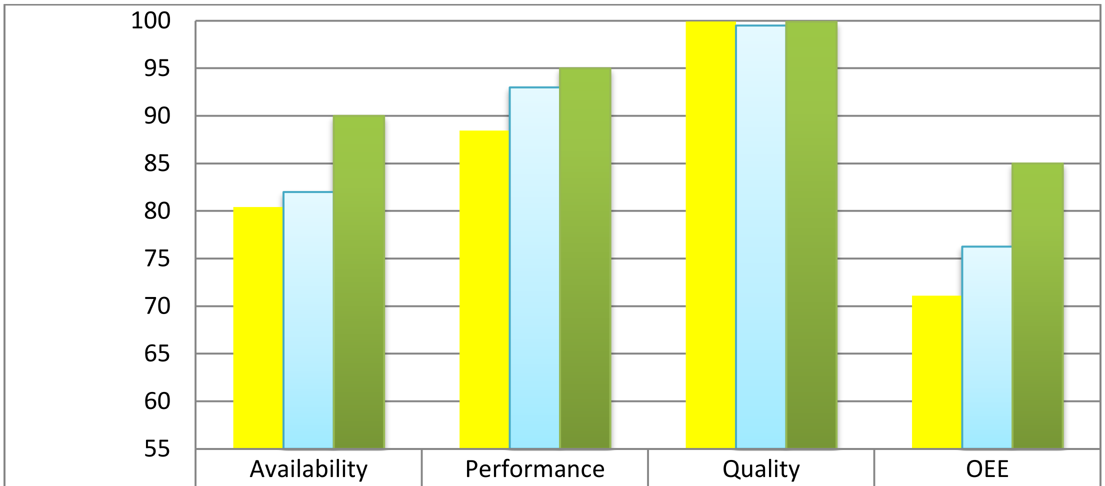


Figure: 5.2 contribution of shutdown, down time, performance losses total time lost distribution.

Unplanned down time, planed down time, and performance losses contributes 54%, 31% and 15% respectively as shown in the pie chart (Figure 5.2). The actual down time is so far and beyond the planned target, this shows there is an excessive downtime loss that kills the line performance so that there is huge room for improvement. Planed down time is not part of OEE calculation and the quality rate losses is within target and world class level therefore the focus of this study is on availability and performance factors.

Figure 5.3: Comparing the actual , target, and world class OEE and its factors.



	Availability	Performance	Quality	OEE
Actual	80.41	88.47	99.94	71.1
desired	82	93	99.5	76.26
world-class	90	95	99.9	85

From the Figure 5.3, the one year availability , performance and OEE of the production line is blow target (management plan) by about 5% and about 14% below the world class. Improving toward the target and a world class OEE rating would mean a huge improvement in productivity.

The line analysis was done to identify the production loses and their sources: as result (from down time Loss factors table), the main reasons for lower availability is higher down time due to excess machine breakdown ,longer set up and adjustment and frequent component stoppage .

4.2.4 Identification of production disturbances (the big losses)

A manufacturing system involves a complex mix of people, processes, equipment, configuration, and coordination. Dealing with a disturbance, in fact, requires identification of certain parameters that turn a disturbance into a risk situation. If an organization identifies causes and consequences of its day to day operational disturbances, it can improve its productivity easily. This study identifies 21 typical production disturbances and associated contribution in general lost time. It then will discover the most detrimental disturbances, and their root causes and consequential effects on business performance. It also highlights the major consequential effects of the operational disturbances.

Table 5.1: general identified productivity losses factors, associated hours lost and their contribution to total time losses.

	General production losses	hours lost	Cumulative %
1	*planned maintenance*	*834.59*	*23.86%*
2	*machine breakdowns*	*486.36*	*13.91%*
3	*warehousing*	*340.99*	*9.75%*
4	*CIP requirement*	*330.57*	*9.45%*
5	*short stops*	*211*	*6.03%*
6	*speed losses*	*203*	*5.80%*
7	*external services*	*201.08*	*5.75%*
8	*set up & adjustments*	*198.28*	*5.67%*
9	*component stoppages*	*191.74*	*5.48%*
10	complexity (flavor changes, start	164.03	4.69%
11	services equipment down	131.15	3.75%
12	unaccounted losses	95.55	2.73%
13	planned stoppages	21.55	0.62%
14	services stoppages	18.49	0.53%
15	housekeeping	16.95	0.48%
16	planning	15.68	0.45%
17	labor	9.42	0.27%
19	quality loss	9.093	0.26%
20	size changes	8.52	0.24%
21	trials	7.67	0.22%
22	planned meetings	2.2	0.06%
	total time lost	3497.613	100%

Table 5.2 : Identified major production losses (The big losses) and their deviation from standard

	Major production losses identified	Actual	Desired	devotions
1	Planned maintenance	834.59	740	-94.59
2	Short stops, speed loss, uncounted losses	509.52	365.29	-144.23
3	Machine breakdowns	486.36	318.2	-168.16
4	CIP requirement	330.57	185	-145.57
5	Set up & adjustments	198.28	159.1	-39.18
6	Services equipment's down	131.15	111	-20.15

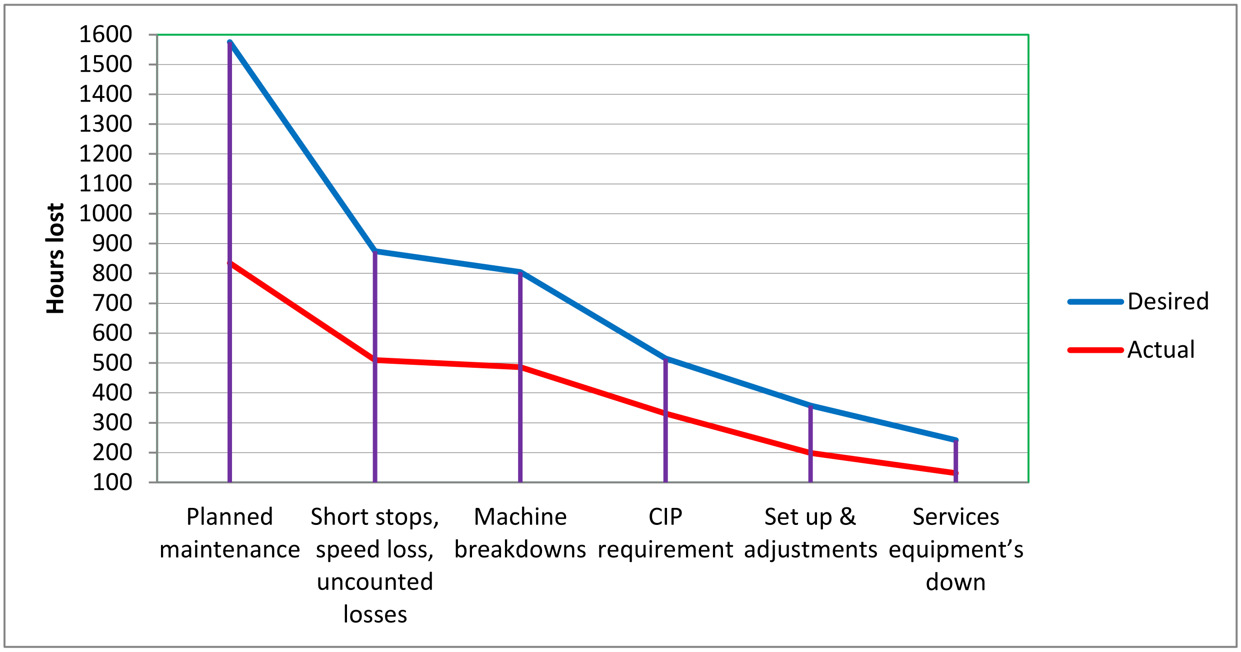


Figure 5.4: identified major production losses (The big losses) and their lost hours.

Planned Shut Down, which includes all events that should be excluded from efficiency analysis because there was no intention of running production (e.g. breaks, lunch, scheduled maintenance, or periods where there is nothing to produce). In this study general 10 factors are identified out of the 10, three major determinant contributors are isolated, normally they are not part of the OEE calculation. *Higher planned maintenance*, *CIP requirement* and *warehousing* are the identified major planned production Disturbance, are considered to be the most important to reduce.

Table 5.3: productivity losses factors classified as planned Shutdown losses.

	Shut down Loss factors	shut down loss	comu.%
1	*planned maintenance*	*834.59*	*43.87%*
2	*CIP requirement*	*330.57*	*17.38%*
3	*warehousing*	*340.99*	*17.93%*
4	trials	7.67	0.40%
5	services equipment down	131.15	6.89%
6	planned stoppages	21.55	1.13%
7	planning	15.68	0.82%
8	planned meetings	2.2	0.12%
9	housekeeping	16.95	0.89%
10	external services	201.08	10.57%
	total shut down losses	1902.3	100%

4.2.5 Line OEE analysis

Items or factors classified as planned shutdown (as shown in table 5.3), that is planned downtime is the time used by the packaging line without producing, according to the standards used in the production plan. Which do not count against the OEE; typically include not scheduled to run, weekend and holiday. Additionally, External unplanned downtime is excluded because this downtime is not caused by the operation of the packaging line itself; taking these into account would result in an indicator for the efficiency of the organization instead of just the packaging line·. Also extremal unplanned downtime is hard to measure if you don't measure it, you probably won't be focused on improving it.

Besides measuring the product coming out of a machine, the Six Big Losses framework helps to calculate performance investigate into the essential categories affecting performance and determining where effectiveness is suffering. The framework categorizes the reasons why 100 percent efficiency is not being attained into three major areas—downtime (availability), speed losses (performance) and defect losses (yield)—which are then broken down further into six distinct categories.

Below in Table 5.4 and Table 5.5 is a list of the Major Loss Events that responsible for decrease the productivity and efficiency of a line and the Loss Category associated.

Table 5.4 : productivity losses factors classified as down time losses

	down time Loss factors	Down time losses (hours)	Comu.%
1	*machine breakdowns*	*486.36*	*45.20%*
2	*set up & adjustments*	*198.28*	*18.43%*
3	*complexity (flavor changes, start*	*164.03*	*15.24%*
4	component stoppages	191.74	17.82%
5	services stoppages	18.49	1.72%
6	size changes	8.52	0.79%
7	Losses due to Labor	9.42	0.88%
	total down time loss	1076	

As shown in Table 5.4 ,It is found that the identified down time losses factors and more than 80% of down time losses is due to *machine breakdowns*, *set up & adjustments*, *complexity (flavor changes, start up) which are* major disturbances at different magnitude.

Then the speed losses, and short stops (as shown in Table 5.5), are responsible for more than 80% of total performance losses. Finally the focuses of this study will be on the downtime losses and performance loss , because the quality level is within the target and world class level.

Table 5.5: productivity losses factors classified as Performance losses

	Performance Loss factors	performance losses(hours)	comu.%
1	*short stops*	*211*	*41.41%*
2	*speed losses*	*203*	*39.84%*
3	unaccounted losses	95.55	18.75%
Total Losses		509.55	

4.2.6 Addressing the Big Losses

Now that what are the major big losses are identified and some of the Events that contribute to these losses, focus on ways to monitor and correct them will be necessary next step. Generally, by breaking down the reasons for productivity losses into three main factors the major big losses are identified. Also based on the from the data analysis done the big losses are caused by Availability and Performance losses factors. So the focus of the study is on these two critical factors. Therefore detailed analysis will be done separately as 1) Line Availability analysis and 2) Line performance analysis in the next section.

4.3 Line Availability analysis

Availability of machines can be increased by reducing the downtime or breakdowns of the machines. Main objective is to improve the machine performance by finding out the major breakdowns causing production losses to the company and arriving & executing the counter measures by which these problems can be reduced.

Availability factor measures productivity losses resulting from downtime. Downtime is any event that stops planned production for a period of time. Determining plant's availability is a huge part of calculating your OEE, and the biggest factor that affects availability is downtime. There are two types of downtime that affect OEE: planned downtime, and unplanned downtime. Unplanned downtime occurrences are the only events that affect your OEE in a negative way, so from here on out all references to unplanned downtime will simply be referred as "downtime". Supplying downtime reason codes will help you monitor and specify a particular source for later evaluation using Root Cause Analysis.

Downtime is the most critical factor to improving OEE because when the process is not running you cannot address other metrics. It is also one of the factors that is the hardest to fix, because there can be so many things that could be affecting it. Generally, for this analysis purpose one year data is collected and used to understand, investigate the nature of the downtime, to find the root cause and to find the ways to monitor as well as correct them.

4.3.1 Equipment breakdown

Eliminating unplanned downtime is critical to improving productivity. Other OEE factors cannot be addressed if the process is down. It is not only important to know how much and when down time equipment is but also to be able to link the lost time to the specific source or reason for the loss. With down time data tabulated, the most common approach is the Root Cause Analysis. It is applied starting with the most severe loss categories.

For down time / availability analysis purpose one year down time of line stations is collected and also its part losses analysis structure as shown in figure 5.1. For this study unplanned down time or equipment breakdown is considered for analysis because planned down time is not a part of OEE calculation.

Initially , one year equipment break down /failure is collected first and presented as down time per month as shown, in Table 4.10 which is found in the data collection section. Second, the cumulative time of equipment failure is done in Table 5.6, to identify the commutative effect in the given year. Third, Major problem areas of the line in terms of break down factor are identified as in Figure 5.7. Finally, major causes of problem of the three vital stations (S1, S2, and S4) are separately listed out.

Table 5.6: Collected Cumulative yearly down time

Stations	Breakdown (hours)	cumulative down time (%)
S1	**174.82**	35
S2	**67.93**	49
S3	**63.2**	62
S4	**55.29**	73
S5	**37.46**	80
S6	**23.08**	85
S7	**20.37**	89
S8	**17.68**	93
S9	**12.65**	95
S10	**7.08**	97
S11	**7.08**	98
S12	**3.46**	99
S13	**2.64**	99
S14	**2.38**	100
S15	**0.59**	100
S16	**0.25**	100
Total	**495.96**	

Where: (S1, S2, S3, S4, S5…., S16) are Machines and conveyers in line stations.

4.3.2 Downtime Analysis with Pareto Chart

A Pareto chart is basically a bar graph in which the bars are arranged in descending order of height, starting at the left. This “picture” quickly highlights the “vital few” problems that should be worked on first. Thus, it aids in identifying and prioritizing what needs to be done. It also provides a common knowledge base founded on facts, instead of hunches, which results in gaining the cooperation of all involved. According to Pareto analysis, around 20% of the downtime factors causes 80% of total downtime. A Pareto chart was drawn to identify the predominant downtimes that caused around 80% of total downtime.

As shown in Figure 5.7, blowing, filling, case conveying, labeling and packing are the “vital few” or the major problem areas of the line in terms of breakdown factor and Around 175 hours production time was lost in blowing station, this indicates 35% of the production line failure has been occurred in this area. Flowing the blowing station, the filling station, case conveying labeling station and packing station has been down for about 68, 63, 55 and 37 hours respectively. These areas / station are source of 80% of the equipment down time that kills the availability of line.

Also, Pareto chart has been used in downtime analysis as shown (Figure 5.7, Figure 5.8 and Figure 5.9), in identifying and prioritizing what needs to be done in Major problem areas of the problematic stations separately .

From Figure 5.8 : the major causes of problem of blowing station are located on blowing module , bottle discharge module , transfer/turntable module that caused around 80% of total downtime in this station .

From Figure 5.8 : the major causes of problem of filling station are located on Infeed Star module , Bottle Handling Equipment module, Bowl/ Product Supply module that caused around 83% of total downtime in this station.

Figure 5.10 : the major causes of problem of labeling station are located on component Vacuum module, bottle Infeed module, supply Electrical module and station Discharge module that caused around 86% of total downtime in this station.

As a result of the downtime analysis one year data, out of the three highly affected stations totally 24 locations are recognized. Based on the collected data and deeper analysis the worst areas of the three problematic stations are isolated as key problem areas of the line for further investigation to know what is happening in these areas.

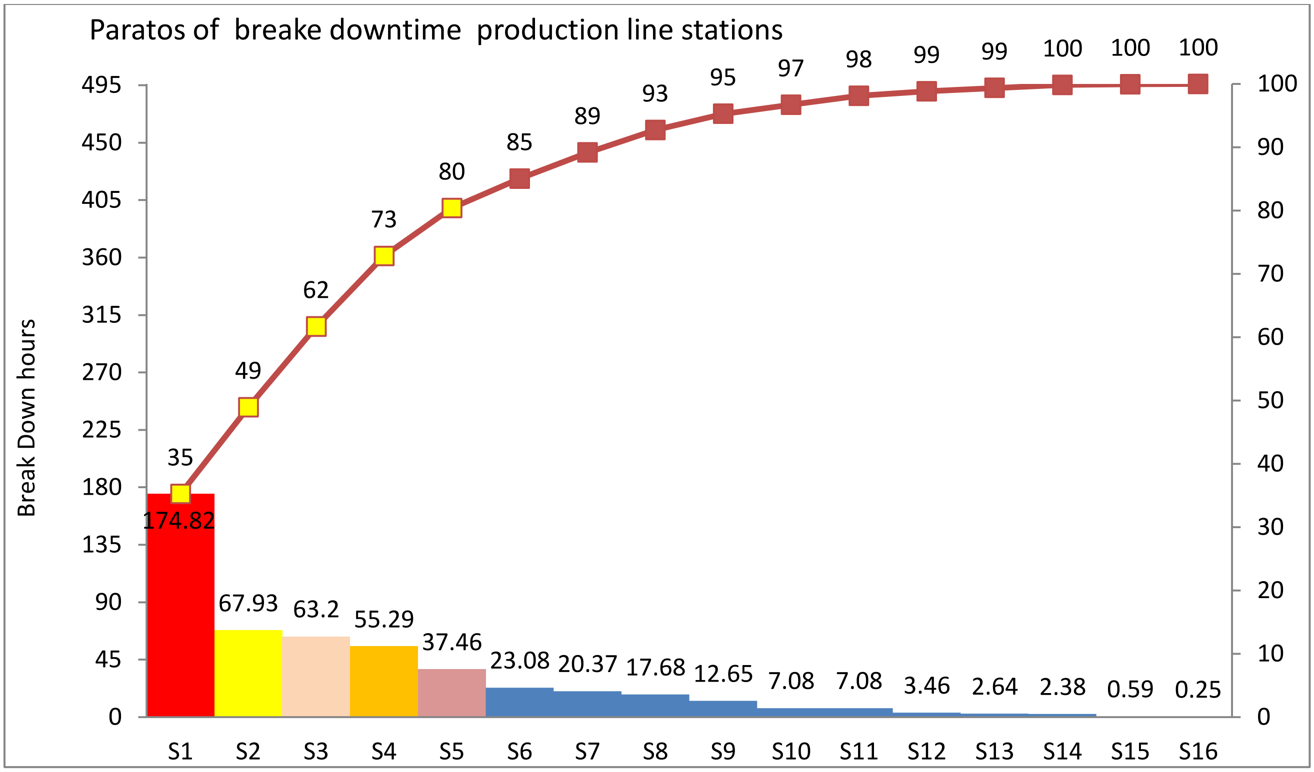


Figure 5.5 : Major problem areas of the line in terms of break down factor

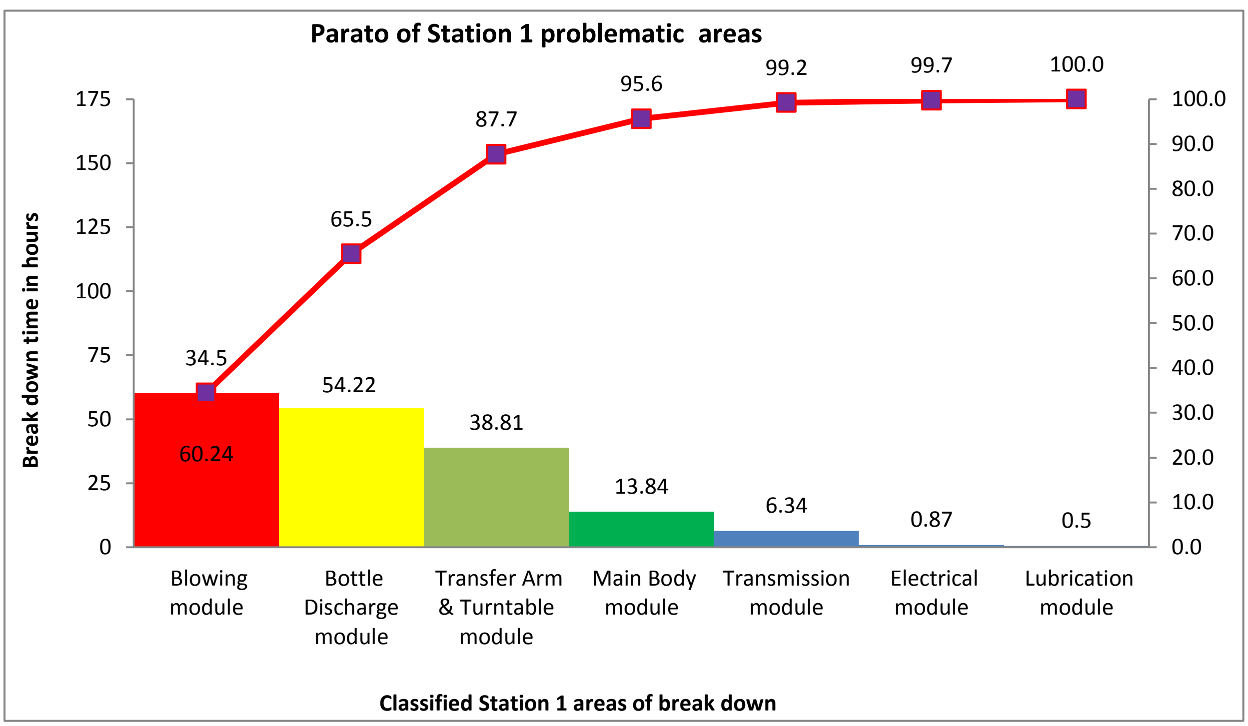


Figure 5.6 : major causes of problem of S1

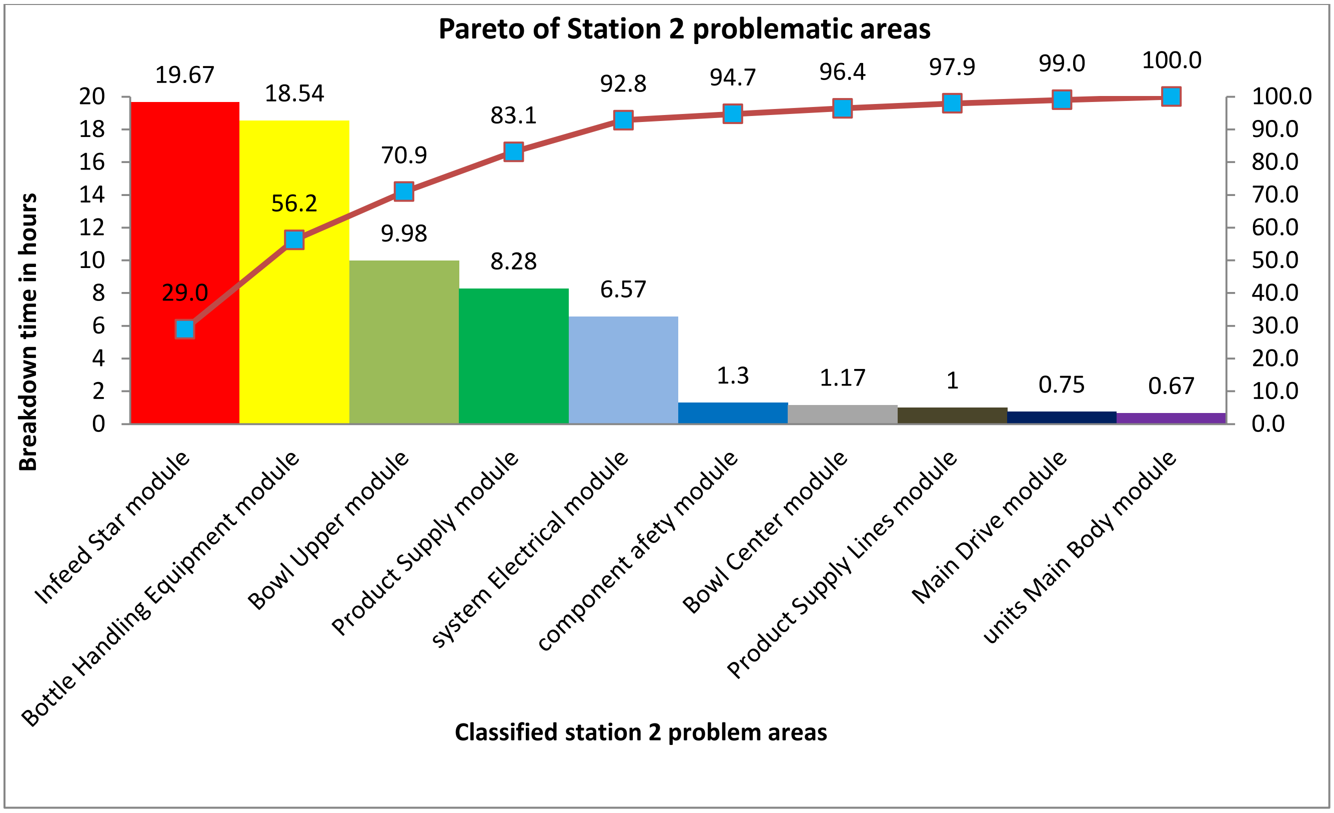


Figure 5.7: Major problem areas filler S2

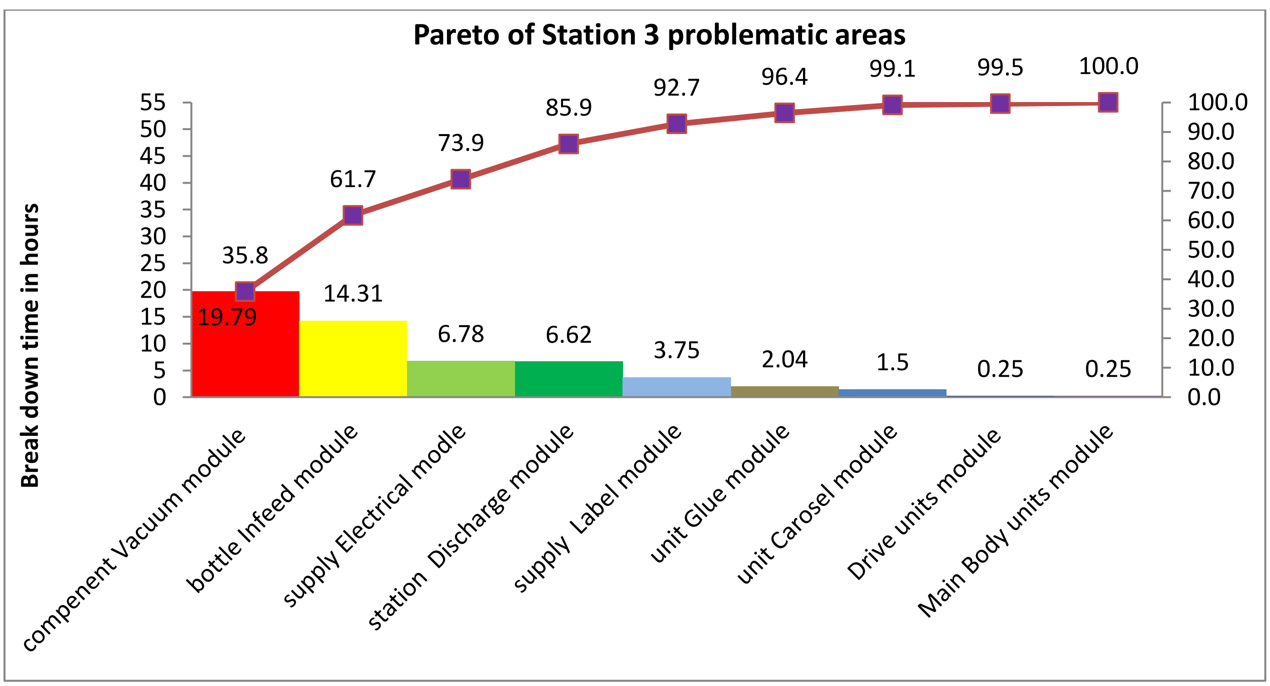


Figure 5.8 : major problematic areas that causes of problem of S3

4.3.3 Major Break down Problems identified in stations

From observation and data analysis major problems highly affect the three key areas of stations are categorized into 4 sections according to nature and location of existence summarized as blow Table 5.7.

Table 5.7, Identified general problems of the critical stations

Blowing station key problems	Combined problems	Filling station	Labeling station key problems
✓ Blowing station Unlocking ✓ Base mould broken ✓ High vibration at Machine/ base mould ✓ Unusual/high noise in machine ✓ Base mold cooling leakage ✓ Bottle jamming at blowing station ✓ Fault blowing processes ✓ Stretch rod damage /bent/ problem ✓ Preform jamming	✓ Gripper timing problem ✓ Gripper clamp broken ✓ Bottle transfer problem ✓ Base cooling timing problem ✓ Timing problem b/n blow molder and filler ✓ Drive block at filler ✓ Bottle falling at base cooling discharge ✓ Too large position Deviation ✓ Bottle transfer/ timing problem at base cooling ✓ Base cooling pressure drop/filter ✓ Servo drive initializations	✓ Drive block at filler star wheel ✓ Frequent bottle falling at filler – Discharge ✓ Frequent bottle falling at filler infeed ✓ Servo drive initializations ✓ Filler griper problem / timing ✓ Bottle falling from filling station ✓ Under filling ✓ Over filling ✓ Excess Empty bottle rejection at filler inside ✓ Too large position deviation ✓ Capper – incorrect capping /problem	✓ Back up at discharge conveyer ✓ Safety clutch tripped at worm 1/infeed ✓ infeed star wheel timing problem ✓ Label transfer problem ✓ Frequent V/cylinder contamination/dirty ✓ Vacuum pump malfunction/failure ✓ Vacuum pump bearing failure ✓ Vacuum cylinder timing / calibration problem ✓ Discharge conveyer broken/disconnected ✓ Bottle falling at discharge ✓ Back up at discharge conveyer ✓ Safety clutch tripped at worm 2/discharge ✓ Discharge star wheel timing ✓ Glue contamination

Once a major problem areas, the problems in the area of the line has been selected (as shown in the downtime analysis section) form the Pareto chart, it needs to be analysed for possible causes**.** The next step is to find out the root causes for the major concerning areas. For this, Brainstorming session has been flowed by Cause and Effect Diagram or Fishbone Diagram was used in this part of the process.

4.4 Line Performance Analysis

Performance is a factor that measures a loss in productivity due Short /minor stoppages and reduced speed or slow cycles. Slow cycles occur when the manufacturing process is running at less than optimum speed. When you divide the current production rate by the ideal production rate, the result is the performance ratio. Minimizing machine stops such as product misdeeds and component jams will help improve performance. These stops are typically under ten to five minutes and don't require maintenance to be called to the process. Minor stoppages and reduced speed are the most difficult of the Big Losses to monitor and record. It is important to analyze Minor stoppages and reduced speed separately because the root causes are typically very different.

From the previous analysis done (as shown in Table 5.5), the speed losses, and short stops are responsible for more than 80% of total performance losses.

For analyzing the performance, initially by following losses analysis structure the rough analysis is done OEE and availability, the collected data of short stops and components failure is analyzed and presented for further simulation analysis.

Table 5.8, identified performance losses problems of the critical stations

	Performance Losses Problems
1	Electrical Power and air supply interruption
2	Bottle jamming
3	Cap and Preform jamming
4	Material quality(cap, preform, label and glue)
5	Upstream or downstream failure
6	Set up and adjustments
7	Communication problem
8	Incorrect process parameters

Once a major problem area, the problems for performance losses in the area of the line has been selected form the Pareto chart, it needs to be analyzed for possible causes. For this, Brainstorming session has been flowed by Cause and Effect Diagram or Fishbone Diagram as shown in Figure 5.9 to find out the root causes and remedies have been identified.

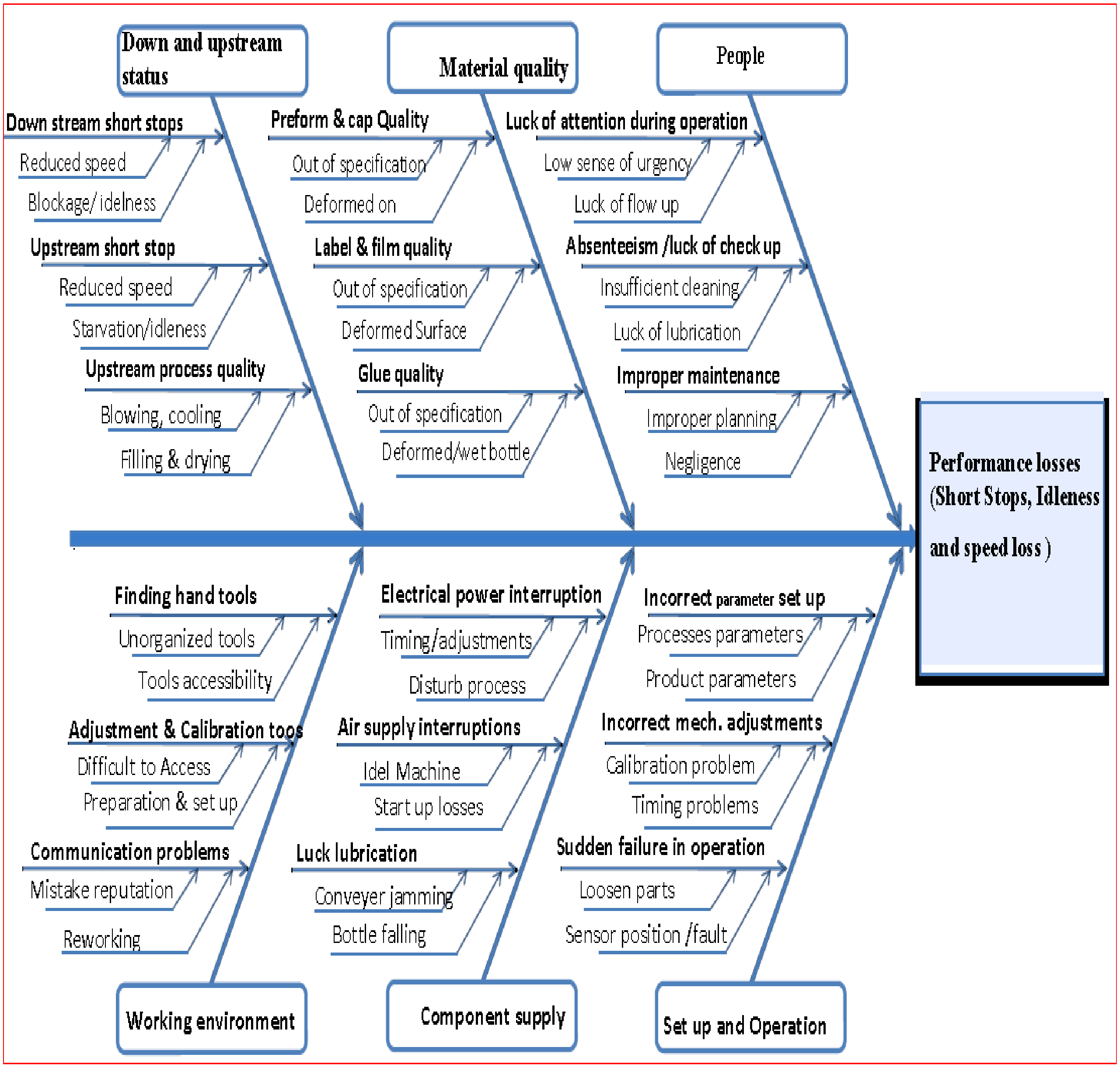


Figure 5.9 Cause and effect diagram of high line performance losses

The fishbone chart, as shown above in Figure 5.9, organizes and displays the relationships between different causes for the effect (performance losses) that has been examined. The major categories of causes are put on major branches connecting to the backbone, and various sub-causes are attached to the branches, tree-like structure showing that the many facets of the problems.

4.5 Root cause analysis

After searching the general problems occurred in each station as shown in table 11 & 12 above. In order to came up in to common understanding the terms , nature of problems their relation to each stations , risk and effect on other areas of the nearest station is studied before finding the root causes of the problems. This helps to clearly state what each problem is especially for the team to agree that the statement describes the problem.

Following the completion of the relevant portions of data collection/analysis activities as described on the above ,the next a key first step in the RCA process has been done to summaries ,state, categories to make clear problem statements by all team members. This was supposed to make helps to accumulate all of the potential causes and contributing factors.

Following the above step, the general problems of three stations was summarized in to 18 problems and agreed by the team as shown in (Table 5.13) .Thus, 6 basic problems per station recognized for 'brainstorming' processes. Brain storming the problem was not only identifying the most obvious root cause, but also to identify any possible underlying issues.

Table 5.9 , The general summarized problems of three stations.

Blowing station area	Intermediate area(base cooling area)	Filling station area
Base mould unlocking and breakage	*Drive block at base Cooling, blow molder and filler (infeed, discharge, star wheel).*	*Back up at discharge conveyer*
High vibration at Machine/ base mould	*Frequent bottle falling at filler –Discharge*	*Safety clutch tripping at worms*
Unusual/high noise in machine	*problem transfer /grippers at base cooling*	*infeed / discharge star wheel timing problem*
Preform/Bottle jamming at blowing station	*Base cooling pressure drop/filter*	
Fault blowing processes	*Frequent bottle transfer /falling at base cooling, filler infeed*	*Glue Supply /glue unit problem*
Stretch rod damage /bent/ problem	*Servo drive initializations at (base cooling ,filler and capper) grippers, star wheels drives*	*Label supply problem and*
Gripper timing problem	*Under filling*	*Label transfer problem*
Bottle transfer problem *Gripper clamp broken* *Base cooling timing problem*	*Over filling*	*Glue Supply /glue unit problem*

4.5.1 Brainstorming Contributing Factors

Brainstorming has been taken place in a structured session for three production shift teams involving six team members every shift. All participants of the three shifts have minimum three years' experience and out of the six members, the two are specialist's engineers (mechanical and electrical), one line technician, one quality and three processes engineers. This makes diverse brainstorming team and has experience in the problem area

All participants were encouraged to identify any possible causes or contributors, and careful consideration of all ideas from team members taken. Once all of the potential root causes are categorized and sub-branches identified graphically, supporting data has been associated with each item as the investigation proceeds.

Generally, the Brainstorming session has been carried out to find root causes and remedies have been identified. The fishbone chart organizes and displays the relationships between different causes for the effect that is being examined. The major categories of causes are put on major branches connecting to the backbone, and various sub-causes are attached to the branches, tree-like structure showing that the many facets of the problems. In the Figure 5.13, Figure 5.14 Figure 5.15, Cause and Effect Diagram for blowing station, filing station concerning problems and labeling problem are shown. Based on these remedies identified, improvement action plan suggestion has been made (Table 5.10 to Table 5.13).

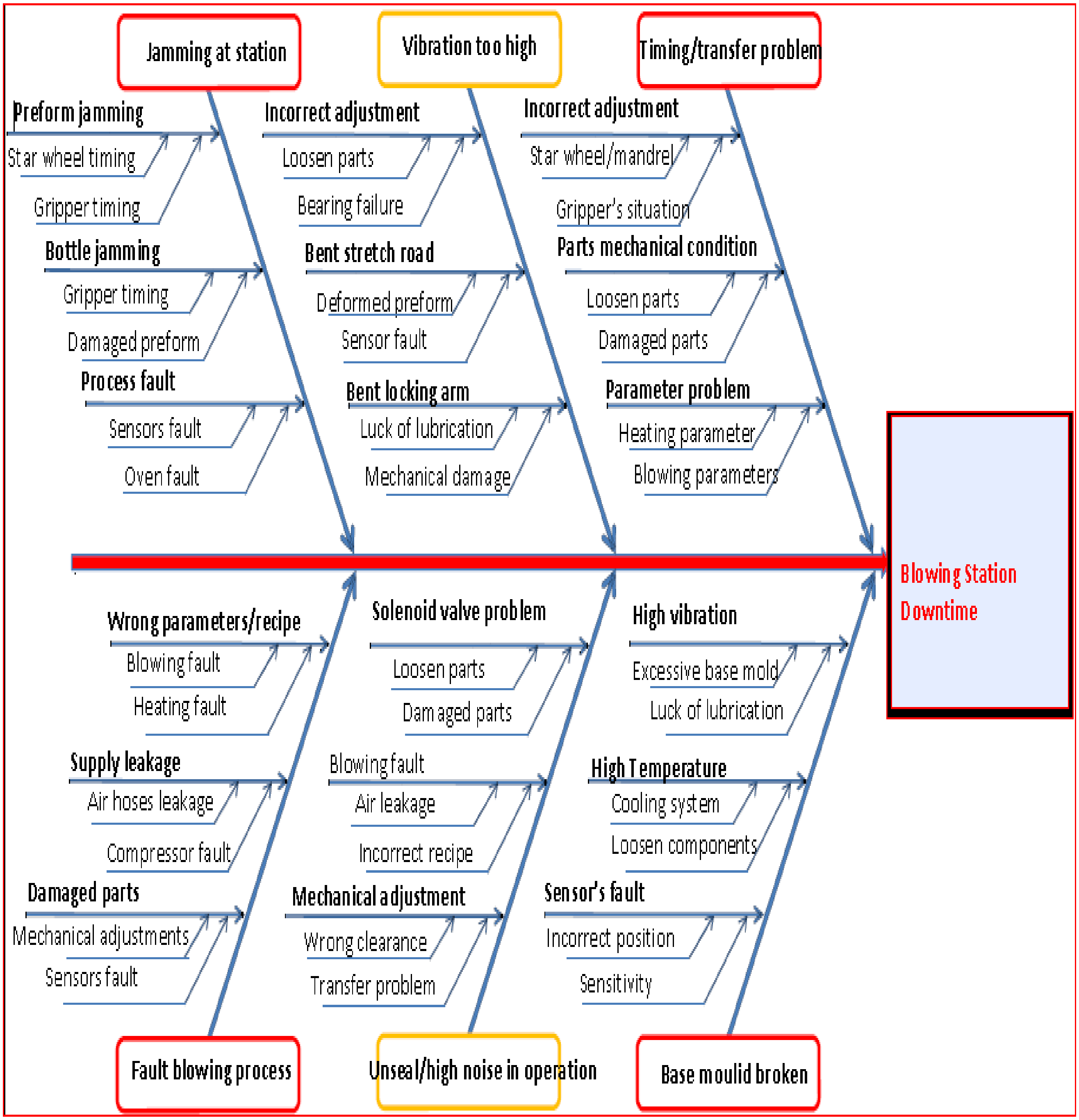


Figure 5.10 Cause and Effect Diagram for major blowing station problems

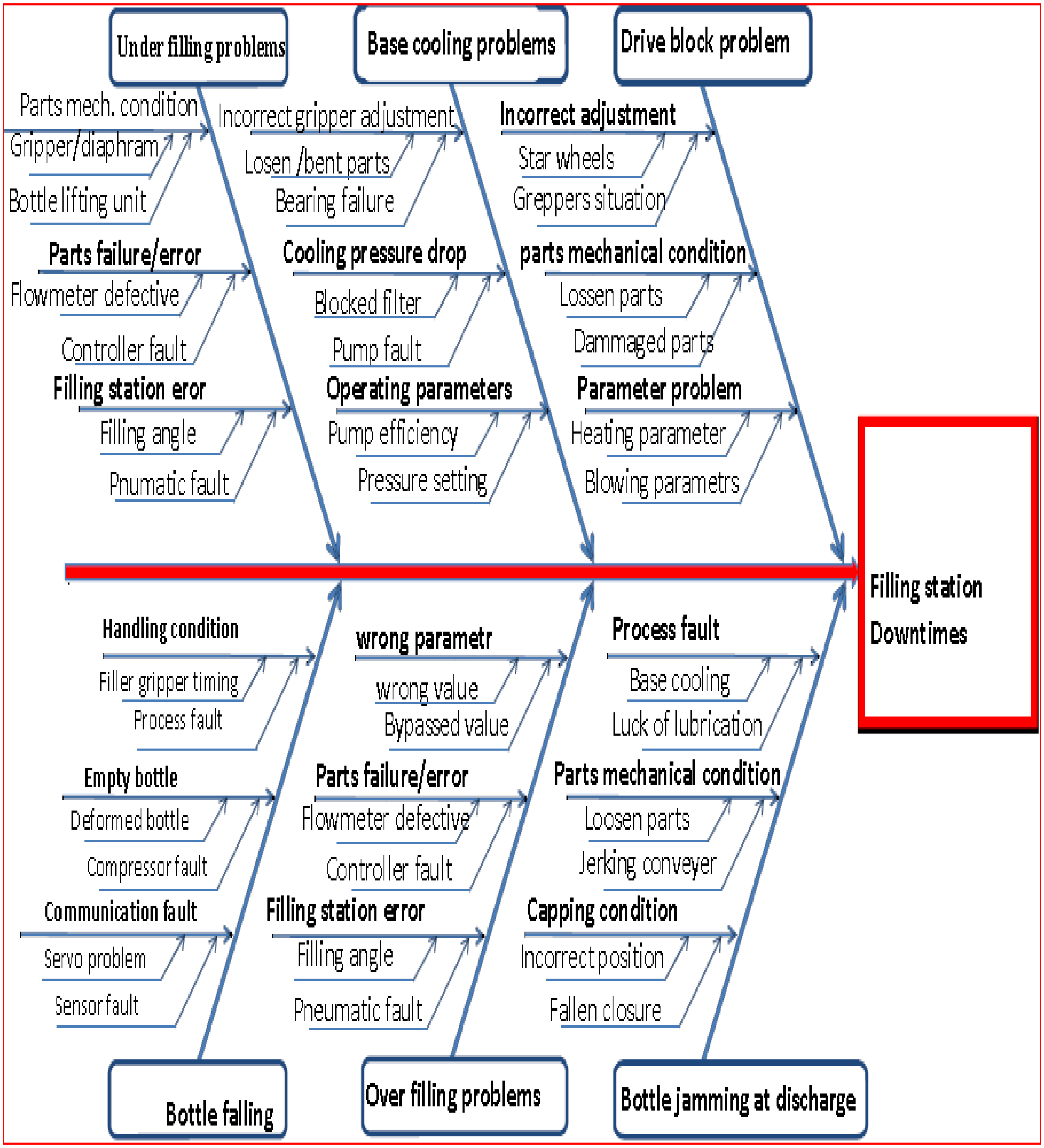


Figure 5.11 Cause and Effect Diagram for major filling station problems

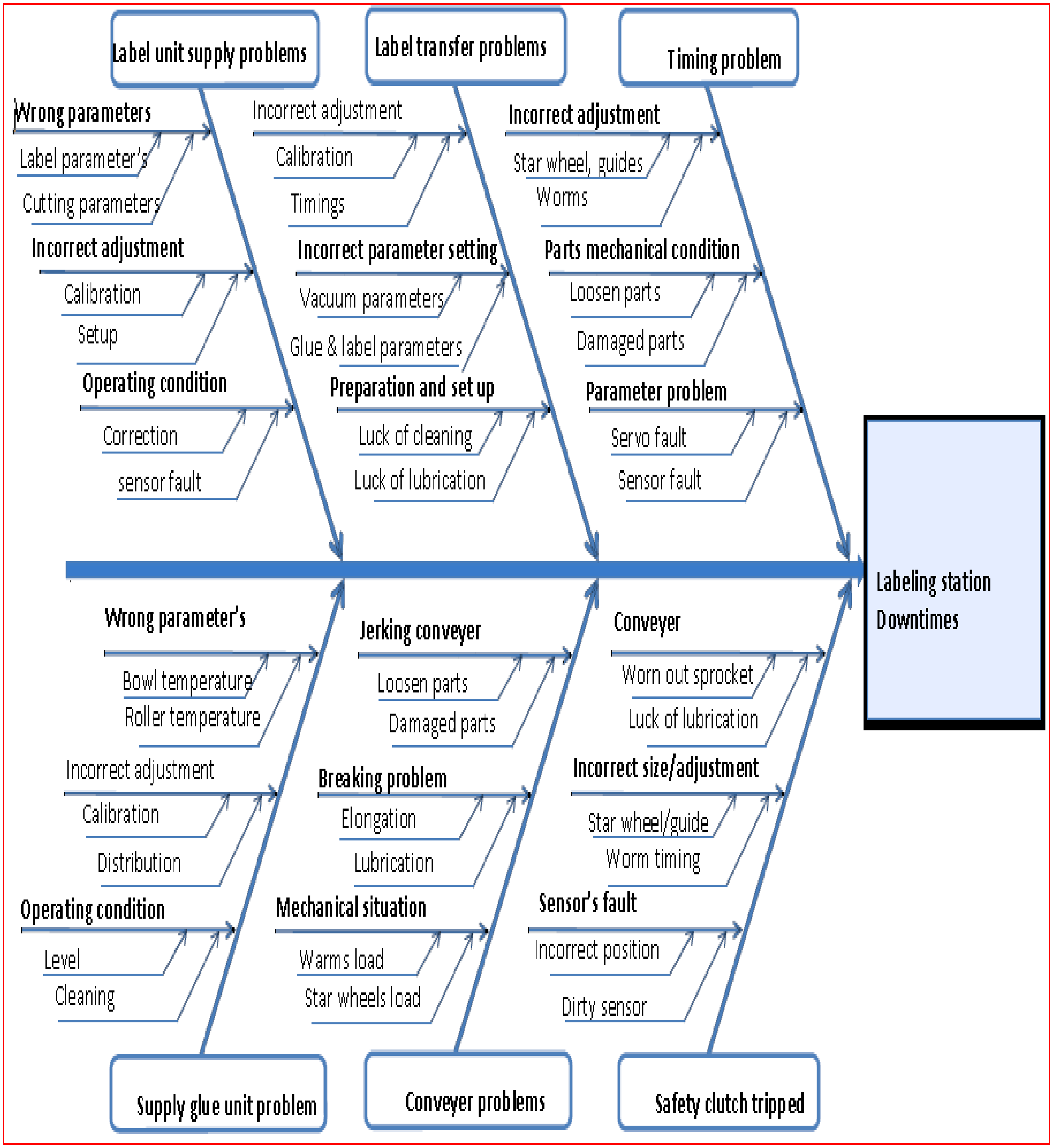


Figure 5.12 Cause and Effect Diagram for major labeling station problems

4.5.2 Suggestions as counter measures

The brainstorming team should be diverse and have experience in the problem area. A lot of good information can be discovered and displayed using this tool. Observation and Brainstorming session has been carried out to find root causes and remedies have been identified. Based on these remedies identified, improvement action plan suggestion has been made to reduce the factors of the loss due to Equipment breakdown are suggested and are shown in Table 5.10, Table 5.11, Table 5.12, and Table 5.13.

Table5.10. Suggested solutions for blowing station problems.

	Major Problems	Possible root cause	Possible solution/ counter measures
1	Base mould broken	✓ *Battle fragments in blowing station.* ✓ *A preform has not been correctly transferred to the blowing mold.* ✓ *The preform supply contains not matching or damaged performs* ✓ *A blowing station is mechanically damaged or not adjusted correctly.* ✓ *The used preform does not match the used blowing mold.* ✓ *incorrect proximity sensor position,*	✓ *Make sure there are no bottle fragments in the blowing stations.* ✓ *Check the preform supply for deformations, orality and dimensional accuracy.* ✓ *Check whether the mechanical components of all blowing stations are ok and correctly adjusted.* ✓ *Check, in particular after a type change over , whether the corrected blow mouldes have been fitted into all blowing stations.* ✓ *Check, in particular after a type change over , whether the correct preforms are used.* ✓ *check and adjust the correct position of sensor.*
2	High vibration at Machine/ base mold	*gap b/n roller and cam, bearing failure/broken, insufficient lubrication, adjustment problem, bearing / and shock/ mechanical failure absorber failure, bent stretch rod .bent locking cam,*	*Do lubrication on time,* *do adjustment correctly,* *change the failed parts,* *fix the locking arm by o.33mm,* *change the adjustments periodically, check lubrication.*
3	Unusual/high noise in machine	*solenoid valve problem,* *damaged leap seal, damaged shock absorber ,mechanical parts loosen/ damaged* *leakage, vibration, and temperature, blowing process fault,* *bearing failure,* *incorrect adjustment* *gap between roller and cam, leakage of air, failure of electromagnetic components*	*Select/use/ do correct recipe ,* *correct the temperature distribution,* *check/ change the bearing,* *check loosen parts,* *check clearance and* *do proper adjustment, lubrication.*
4	Preform/B	*Gripper adjustment problem,*	*Check sensors, timing, process / parameter and*

	ottle jamming at blowing station	*timing problem,* *gripper damaged,* *preform / bottle damaged ,* *Sensor fault or mechanically misadjusted.*	*preform quality as flow:* *1. Check whether a bottle is present in the specified blowing station and remove it .* *2. Clean the PE sensor at the discharge star wheel.* *3. Check the Mechanical orientation of PE sensor. at the discharge star wheel.* *4. Check the mechanical orientation of the PE sensor at the discharge star wheel, and of the reflector.*
5	Fault blowing processes	*Air leakage , leakage on nozzle's, poor quality preform, improper process setting, mechanical damage Preform heating problem, blowing and heating parameters*	*Check timing and temperature values,.* *Use good preform quality, set correct process setting, Mechanical Adjustments, change blowing nozzles/seals if damaged/necessary.*
	Stretch rod damage /bent/ problem	*Cold preform, air leakage on pneumatic cylinder, misalignment, and preform stuck inside station, stretching rod solenoid problem, damaged preform, station misalignment, mechanical problem in stretching cylinder .poor preform quality, in correct heating recipe, wrong adjustment.*	*Check air leakage and for proper blowing'* *Check Heating temperature and for using the right recipe if not develop.*
	Gripper timing problem	*Bad quality preform, incorrect preform heat, Power interruption, Improper setting /timing & adjustment, damaged gripper, damaged preform, loosen gripper ,servo drive synchronization*	*Check incoming preform quality, check preform storage condition,* *Avoid/ minimize power interruption by communicating with utility department.* *Periodic checkup of timing(develop a plan for chck up)* *Use proper tightening / torque wrench.*
6	Bottle transfer problem Gripper clamp broken B.cooling timing problem	*Timing problem, preform quality, power interruption, loosen gripper, wrong height adjustment., damaged roller bearing, ,bottle fragment, Incorrect blowing process, defective drive/servo/ motor, defective sensor, power fluctuation, vibration*	*Check mechanical conditions of griper befor/after operation,* *check preform quality,* *Develop periodic check sheet,* *Check gripper, clamp*

Table5.11: Suggested solutions for filling station problems

Problems	Possible causes	Possible solution/ counter measures
1. Drive block at basic Cooling, blow molder and filler (infeed, discharge, star wheel).	*High torque on transfer gripers and star wheel, timing problem b/n star wheels / grippers , transfer bottle bended ,damaged gripper and clamp, Poor bottle quality, servo motors fault, power interruption, preform and bottle jamming, faulty locking assembly, foreign object on the drive, worn out axle, pressure piece*	*Check timing frequently (develop check list), Develop common recipe, Check mechanical condition, Check bottle/preform quality, Check whether a foreign object has caused a jam: remove foreign object. Prior to turning ON the machine, manually rotate the drive until the bottle can be properly transferred. If there is no jam, check the drive for smooth operation by rotating it mechanically. If it is easy to turn the drive by hand, there is electrical problem.*
2.Frequent bottle falling at filler – Discharge	*Lack of lubrication on conveyer, conveyer guide adjustment, bottle swelling, damaged or jerking /worn-out conveyer/worn out sprocket, insufficient bottle cooling, base cooling water pressure low, blowing process problem, irregular bottle shape(bottle base), bottle quality, filing valve problem, damaged lift plate, damaged pressure pieces, damaged grippers.*	*Check conveyer has sufficient lubrication. Check whether foreign objects (bottle,closure) is stacked in the star wheels and conveyer guides. Check the guide is adjusted correctly. Check the bottle quality especially the bottle base shape is normal. If the shape is irregular check the pressure of base cooling. If the bottle quality is not normal check the heat profile , and check the correct type of recipe is used for the particular preform.*
3.Base cooling pressure drop/filter	*Blocked piping, blocked filter, blocked heat exchanger lower pump efficiency, water pump fault, foreign object in filter/ heat exchanger, sensor fault, Incorrect parameter setting.*	*Check and clean, Develop check sheet for cleaning interval for filters, piping's , heat exchanger, Protect circulating water from dusts & foreign objects, Check pump/pressure parameters and filling level of water in base.*
4.Frequent bottle transfer /falling at BC, filler infeed	*Opening and closing unit failed, damaged grippers, bottle quality, transfer gripper failed,timing problem.*	
Servo drive initializations at (B.cooling ,filler and capper) grippers, star wheels drives	*Communication fault, servomotors problem, drive block problem, overload, faulty signal on servo drive, timing problem, power interruption, machine synchronization.*	*Check operating/ general conditions of all servo drives(motors),and their parameter's, Adjust timing b/n SW*
5.Under filling	*Pressure loss on product bowl, Damaged gripper, Controller fault, Flow meter defective Wrong parameter setting*	*Check gripper mechanical conditions before start up Check the condition of filling valves , Check the parameter values for product type, Check the right controller operation,*

6.Over filling	*Incorrect correction value,* *Pneumatic components fault,* *Controller faulty,* *Incorrect Pressure and pressure(gas) parameters*	*Check the gas and pressure of product before start up.* *Check the condition of filling valves ,* *Check the parameter values for product type,* *Check the right controller operation,*

Table5.12: Suggested solutions for labeling station problems

S.N	Problems	Possible root causes	Possible solutions /counter measures
1	Back up at discharge conveyer	*Luck of conveyer lubrication, elongated conveyer, worn out conveyer belt, worn out sprockets, problem on conveyer guide, damaged drive bearing/ sprocket, improper label and or glue application, incorrect worms adjustment/ timing, incorrect worm type, loosen worm carries/ holders, vibration on warms, jerking conveyer, loosen bolts and fixtures, bottle quality (irregular bottle size and shape),*	*Check lubrication system for correct timing and amount of spired,* *Do correct preventive maintenance regularly,* *Adjustments of bottle guide,* *Check is applied in the correct position and do this especially before start up,* *Check and do before start up,* *Check condition of sprocket and conveyer belt regularly.*
2	Safety clutch tripped at worm 1/infeed	*Battle jamming, battle quality, power interruption, sensor fault, bearing failed, damaged/ loosen universal joint, dirty PE sensor/reflector, timing problem, guid adjustment, over load due to incorrect gap, damaged/ faulty clutch, faulty safety clutch sensor,*	*Check for proper mechanical condition of the infeed assembly ,* *Do timing and adjustment before start up,* *Check the components are right size and type.* *Check the bottle is sealed correctly,* *Check the conveyer mechanical conditions ,* *Check the sensor on the clutch is in correct position*
3	infeed / discharge star wheel timing problem	*Incorrect adjustment, loosen parts,/locking bolt, bearing failure, infeed conveyer elongated , luck of lubrication/ system failure, power interruption,* *In correct type/size handling component used, centering ball and base problem, belt tension loosen, incorrect gap between vacuum grip cylinder and carrousel assembly.*	*Do timing of the star wheel relative to infeed assembly components, tight the loosen components,* *Reduce the length of conveyer up to the recommended length,*
4 & 5	Label supply problem and transfer problem	*Timing problem and lebble quality.* *Vacuum cylinder adjustment Glue roller, cutting drum adjustment problem,* *incorrect label cutting point,* *in correct blowing air setting, mechanical*	*Check the transfer timing is done correctly especially before any start up,* *Do preventive maintenance* *Use the same batch and FIFO,* *Check lable quality for dimension and physical*
	Glue Supply /glue unit problem	*The glue temperature is bellow operating temperature, the glue unit is turned off,* *Glue bowl is empty or low level,* *Incorrect or mixed glue is type/ batch ,* *The glue pump is blocked with label,* *The glue pump drive motor is tripped*	*Check the if the unit is turned off,* *Check the level of glue bowl,* *Check whether the glue is correct type/ batch as previously used by the machine ,* *Check the actual temperature.* *Check the set parameter temperature,*

4.5.3 Productivity improvement strategy

Generally from the discussed on the line OEE analysis key production losses in the bottling line and their root cases are identified ,categorized and the area for line improvement can be made is determined thus counter measures and action plans to minimize are suggested as line improvement strategy in Table 5.13.

Table5.13: Suggested solutions as line improvement strategy

Strategy		**Action**		**Result**
Challenge & related losses	***Objective***		*Result measures*	*expected effect*
Utility failure **Shut down losses**	*Minimize power supply interruptions.*	1. *improve communication supporting departments of line* 2. *Readymade UPS all time for machines to prevent sudden stoppage.* 3. *Improve preventive facilities maintenance strategy.*	*Communication first*	*Reduce effect of sudden power interruption*
Quality failure **Quality losses**	*Improve the quality of input materials (challenges with in coming preform, cap quality and higher rejection in heating as well as blowing station).*	1. *Create strong partnership, relationship, and communication with the suppliers. For example , involvement of input materials consumers(bottling line experts) in production process of supplier as well as input material producer (suppliers experts) involvement in bottling line processes to prevent quality and other issues at the source in the first time.* 2. *Improve storage condition of raw material.* 3. *Use FIFO (First in first out principle).* 4. *Do right the first time* 5. *Make sure the Implementation of standards and if necessary revise or update the company incoming inspection producers/ standards continuously.* *Develop common definition of is what are the acceptable quality problems in row materials beside of production, quality and suppliers team.*	*FIFO* *weakly raw material Quality audit* *Weakly production line quality* *Quality in quality out*	*Reducing short stop , reduced speed and idealness by 50%* *And minimizing process rejections preform reject loss*
Machine failure **Availability losses**	*Reduce cause frequent un wanted break downs and unplanned maintenance stoppages*	1. *Update and revise preventive maintenance procedures, standards and strategy continuously based on the operating conditions of machineries.* 2. *Identify critical components which demands higher priority to fail and keep their spare parts in stock.* 3. *Develop standard procedures for gripper timing adjustment based on the current*	*Machine available* *Weekly Line machine audit*	*Reduce unplanned maintenance ,and stoppage by 40%*

		situation.		
	Reduce frequent timing and adjustments needed during line operation.	*1. Use standard tools and procedure for timing and adjustment. Especially, Use torque ranch for timing adjustments.* *2. Place a log book for line technicians and line process engineers to right down the challenges, corrective action and operating condition of their machine at the real time. This helps to know the history of machine events for measuring conditions, developing or improving procedures' ,and as in put for maintenance planning* 3. *Place communication board in visible and common place in order to right down what kinds of maintenance activities problem and solutions has been done by the previous shifts team in every station .the communication board should be visible for every team of line .*	*Weekly Line machine audit*	*Reduced mechanical and operational adjustments by 45 %*
Operation failure **Performance lossesses**	*Minimize short stoppage's, idealness's and reduced speeds*	*1. Keep optimal operating condition of machines* *2. Keep machine neat and clean all time.* *3. Do necessary set ups and adjustments before any start up ,* *4. Do all preventive maintenance activities at the right time and interval.* *5. Approve the quality of material to be consumed before operation.* 6. *Develop, identify, standardize and document best process recipes for each types of product*	*Run non stop* *Line cycle time analysis audit*	*Performance losses by 50%*
Human failure **Combined losses** (Factors of availability ,performance and quality losses)	*develop the habit to follow the standard operating procedures of company , supplier and machinery manufacturer for quality, operational as maintenance tasks.*	*1. Put all necessary standards or (maintenance, operating and quality manuals) for cleaning, lubricating, and adjustments at the working station.* *2. Develop awareness the habit to follow the standard operating procedures and manufacturer operational as well as maintenance manuals.* *3. Documentation of results and Learn from past challenges* 4. *Introduce team based continuous improvement activities or projects , for instance , TPM activities is one of the famous and commonly practiced in world class companies especially for packaging line productivity improvements..*	*Team work* *Form CI team.* *Provide Training on continuous improvements*	*Culture of continuous improvement ,attractive working condition ,higher employ motivation and engagement Human error's Better line result and image.*

CHAPTER FIVE

LINE MODEL DEVELOPMENT AND SIMULATION ANALYSIS

5.1 Simulation software

5.1.1 Selection of simulation software

There are different simulation software packages are available in the market. An extensive review about simulation software and their reputation ranking could be found [29]. Based on comparative analysis of strengths and weaknesses of each simulation tools, Arena, Simul8 and Witness are selected as the three most popular simulation packages (tools).

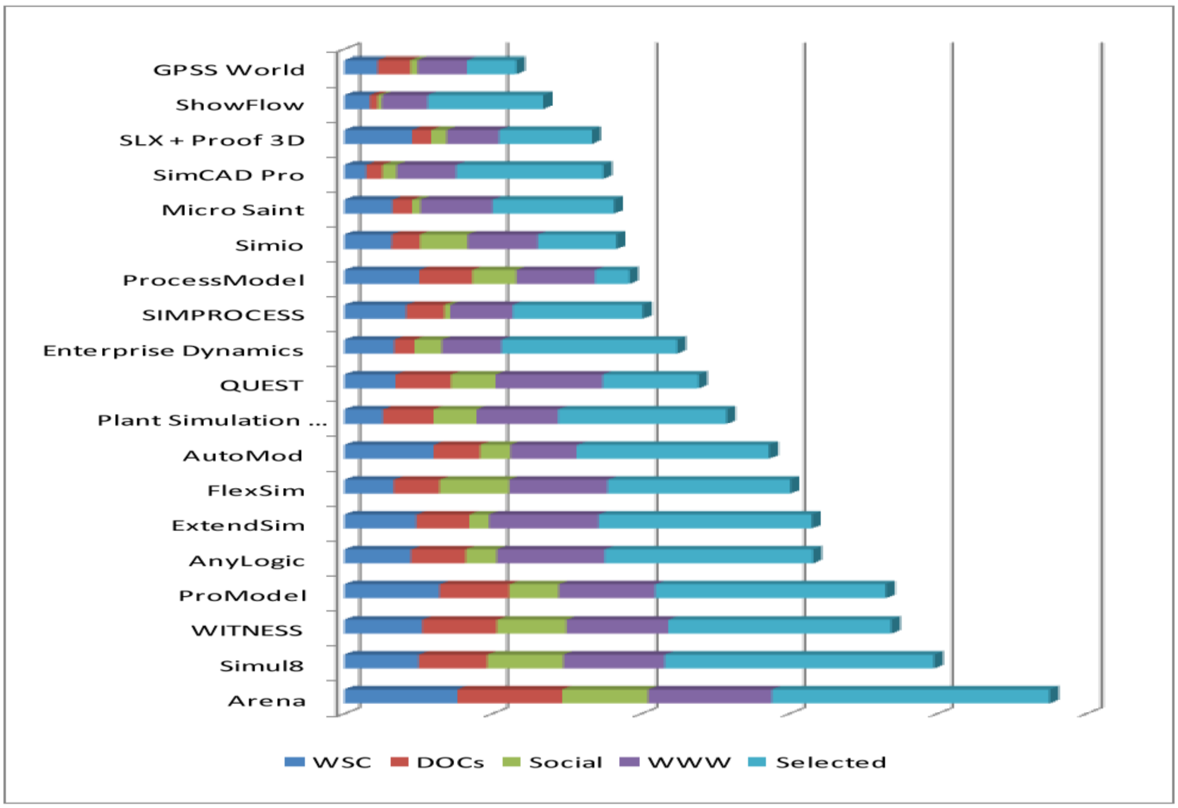


Figure 6.1: simulation tools Popularity ranking presented by [29].

In this study, based on the popularity ranking above (figure 6.1) Arena Software from Rockwell Automation, Inc. is selected to construct a model to this real production line. This software is used to build line simulation model and conduct simulation experiments to achieve the objectives of the study.

5.1.2 The Arena Software

In many projects there is no need to invest in equipment for the results to appear. Sometimes just Changing the logic of production allows having various benefits [30].

The Arena Simulation Software performs the simulation of processes allowing to do analysis without interfering with the system. All and any modification in processes performed by the tool will only be modeled computationally and not with the real system. This is possible because all the defining characteristics of the real system are attributed to the software.

5.2 Development of simulation model

In the next stage is simulation model which design similar to the real process and the input data can be combined to visualize the real background of the problems and the disturbance or constraint may be further studied. DES is powerful tool to analyses disturbances, their effects and propagation in a manufacturing system due to the easiness of alterations in a model, and improvement in the system can easily be shown.

5.2.1 Input, output data, performance indicators and assumptions

The input data used for the model are:

- ❖ Machine cycle / processing times
- ❖ Machine set up time
- ❖ Production plan (types of product, quantity of product to be produced)
- ❖ Machine and conveyer speed
- ❖ Conveyer length
- ❖ Width of conveyer
- ❖ Position of sensor on conveyers
- ❖ Machine /component failures
- ❖ Production loss
- ❖ Cost

Output data/ performance indicators

- ❖ To measure output data we use the following performance indicators are:
- ❖ Production/ Output quantity

- ❖ Overall efficiency (OEE)
- ❖ overall production effectiveness (OPE)
- ❖ Amount of production lost
- ❖ Cost of Production losses

Assumptions

The goal of a simulation model is to mimic the real world system being delivered, including real world conditions and assumptions. It is well known that the starting point for creating a simulation model is the establishment of assumptions to approximate the simulation model with a real life line situation. Building a reliable and valid simulation model requires specific steps to be followed. The line simulation model was built after creating the following list of some key assumptions:

- ❖ Required amount of line input materials are always available at the row material Sore
- ❖ The Model is flexible and new elements can be easily add or remove
- ❖ No maintenance activities have to be done
- ❖ No production plan change have to be done
- ❖ No lack of label ,shrink film and stretch film during production
- ❖ No Shortage of supply of beverage, Co_2, raw water in to the processing stations
- ❖ For parts, First-In-First-Out (FIFO) rule is applied
- ❖ Line operators are always available in the line
- ❖ There is enough storage place for the final manufactured products
- ❖ The human factors, management system are not considered.

5.2.2 Line simulation model

After completing the data collection and analysis, a line simulation model has been built to represent the real production line using ARENA software. As the simulation model built is not to represent the real line processes only, to understand, to analyze the behavior of individual production facilities as well as the part of line as a system, and the effect of change of line parameters under different operating conditions could be investigated for improved productivity.

The simulation model of existing production system with associated line improvement area are presented as shown in Figure no.6.2 below.

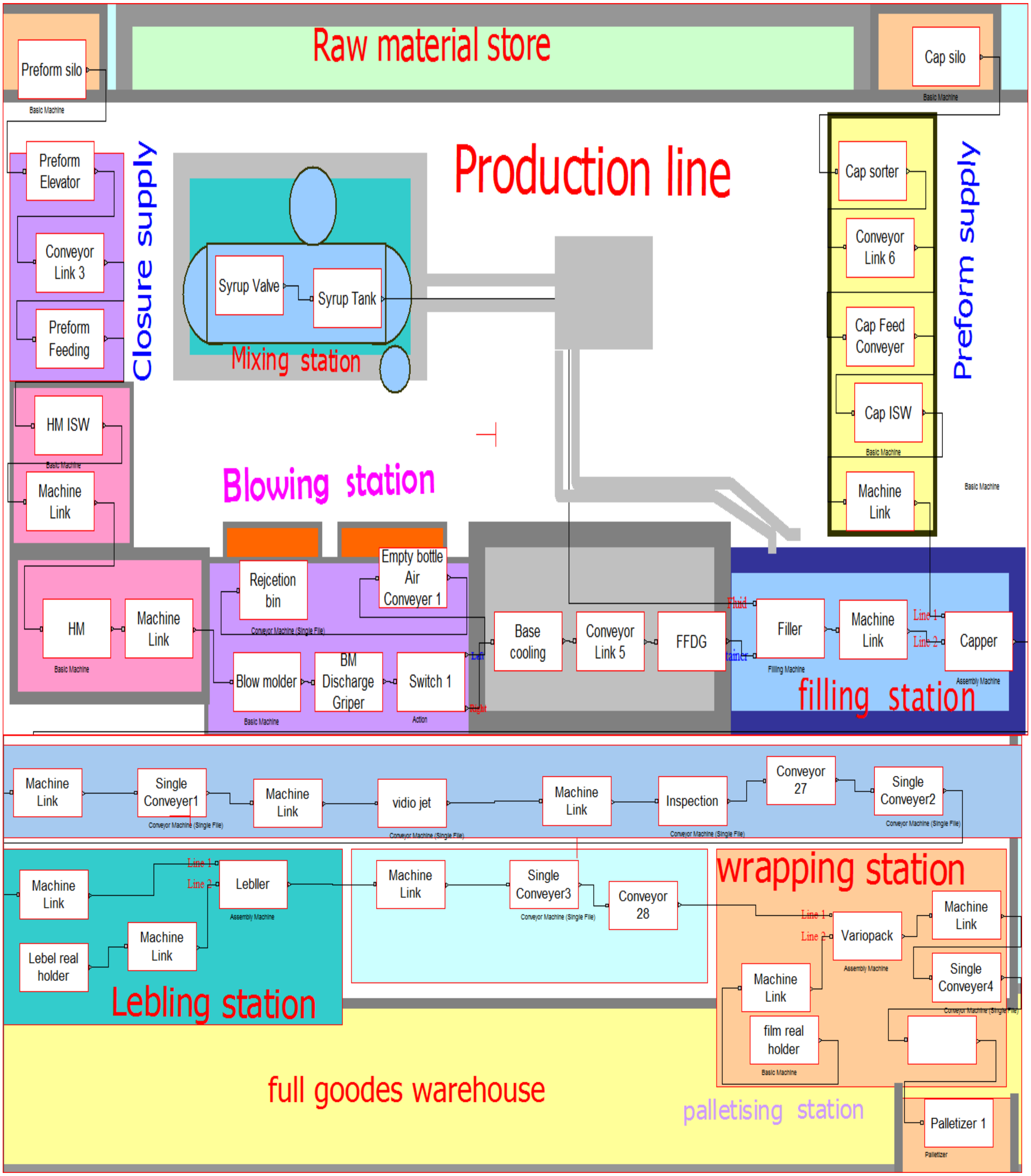


Figure 6.2: line Simulation Model of the existing system

Figure 6.3, bellow, helps to measure and analysis effect of production time losses at the focus improvement area in the form of availability losses (breakdown), performance losses (shortstops, idleness's), and quality losses (in put material rejection) as a result of failure in individual machine (station).

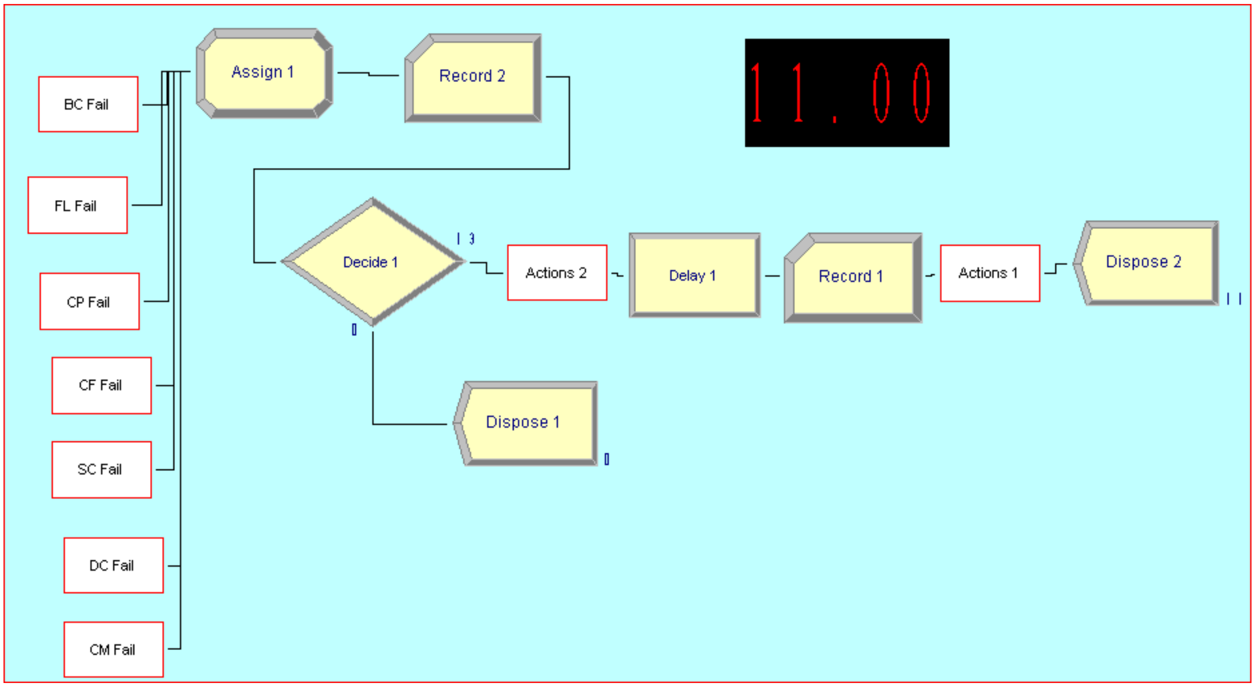


Figure 6.3: Production time losses as function of individual machine station failure.

5.2.3 Number of Replication

According to Kelton et al. (2007), higher number of replications of the system run will lead to more precise results for the simulation model and hence is preferred in practice. In this simulation run, after analyzing all the data in required format and specifying the appropriate replication number of 15 and each replication length of 7889 minutes which is a duration of 21 production shifts.

5.2.4 Simulation Model Verification

In the case production line, model verification and validation steps were implemented.

For verification, the animation method was used to show the entities movement inside the model and to ensure that the movement is similar to what it should be and it is in accordance with the flow of the raw material and bottles in the real production line; and this verifies the model.

5.2.5 Pilot run of developed model, Results and summary

After the line simulation model has been developed, considered assumptions are made and all required input parameters are provided a pilot run is done. A simulation runs of 7889 minutes or for duration of 21 production shifts for 15 replications were conducted. Finally based on the results obtained from simulation were used for calculating, measuring the line Productivity (OEE) factors and associated losses.

Simulation model analysis has been done from the output values of the developed line model by collecting the data around the bottleneck stations (blowing and filling). Particularly, total time out put rate greater than zero, Simulation run length, total unit produced times, total unit produced, total good units produced and production time, down time data's are important outputs of line simulation for this analysis.

The following data's are collected from developed line simulation model of filling station (filler) and has been used for OEE analysis on the developed model.

- ✓ Total units processed (TUP) =3181668 bottles
- ✓ Total units good processed (TGUP) =3181597 bottles
- ✓ Total units lost (TUL) = 96 bottles
- ✓ Total units planned to produce (PU) = 4733436 bottles without failure.
- ✓ Total time out put rate greater than zero (TTORGZ) =5302.77 minutes
- ✓ Simulation run length (SRL) =7889.06 minutes
- ✓ Total time failed (TTF) =212.10 minutes
- ✓ Total time blocked (TTB) =508.45 minutes
- ✓ Total time starved (TTSV) =1865.62 minutes

Before conducting OEE analysis on simulation result some terms from simulation result and OEE model terms are related as follow:

- ✓ The value of working time is equivalent to value of Simulation run length plus shut down losses,
- ✓ The value of loading time is equivalent to value of Simulation run length,
- ✓ The value of operating time is equivalent to value of total time out put rate greater than zero,
- ✓ The net operating time is equivalent total unit produced times station cycle time (600).

- ✓ The value added time is equivalent to total good units produced.

Finally, the OEE analysis conducted on simulation model results and the real production OEE analysis result are summarized, presented in tabular form (as shown in Table 6.1) to facilitate easy comparison with the actual line values. The same procedure is followed for value of blowing station as shown in left side of the Table 6.1.

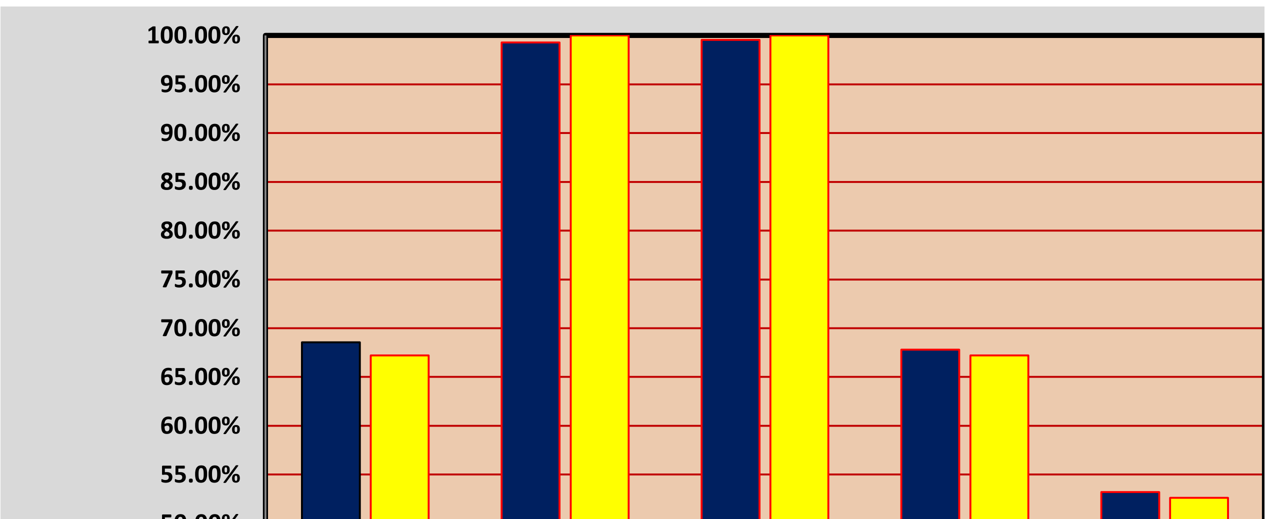
Table 6.1 , Comparison of OEE analysis result of simulation model and actual production line.

	Parameters	**Real system**	**Simulation Model**	
	Time (minute)	production line	Filler	Blow molder
A	working time	10080	10080	10080
B	load time	7912.8	7889.06	7889.06
C	operating time	5425.8	5303.06	5491.22
D	net operating time	5388	**5302.77**	5491.17
E	value added time	5364	5302.77	5302.79
	productivity factors			
C/B	Availability	68.57%	67.22%	69.61%
D/C	Performance	99.30%	99.99%	100.00%
E/D	Quality	99.55%	100.00%	96.57%
	OEE	**67.79%**	**67.22%**	**67.22%**
E/A	**OPE (%)**	**53.21%**	**52.61%**	**52.61%**
	Productivity losses			
A-B	shut down loss	2167.2	2190.94	2190.94
B-C	downtime loss	2487	2586.00	2397.84
C-D	performance loss	37.8	0.29	0.05
D-E	Quality loss	24	0.00	188.38

5.2.6 Validation of the simulation model

In the validation process of production line simulation model, the OEE and overall production effectiveness (OPE) performances indicators were used. OEE only measures the efficiency during the time the equipment is planned to be operating. Finally, the overall production effectiveness (OPE), measures how well the supply chain is effectively utilizing the manufacturing assets. Thus, the OPE measure considers planned downtime and unscheduled time as a supply chain losses.

Validation of the Arena model was done by comparing the results of OEE and OPE from model output with the real system output as revealed in the Figure 6.4below.



	Aviliablity	Performance	Quality	OEE	OPE
Actual system	68.57%	99.30%	99.55%	67.79%	53.21%
Simulation model	67.22%	99.99%	100.00%	67.21%	52.61%

Figure 6.4: Comparison of actual and results from simulations for OEE and OPE indicators. Source: own work

To check the validity of the model, the average value of OEE factors (availability, performance and quality) and OPE per 21 production shifts from the model is compared with average the actual values of the real system. As shown in the Figure 6.4, that there is no significant difference in between actual data and model output data which is considered to be valid.

5.3 Line /Productivity analysis using Simulation

Thus, based line OEE analysis, that the bottleneck stations (block of filler-base cooling-blow molder) have been responsible for line productivity loss and pointed out as area for improvement. Simulation model of real production line is developed, verified using animation, validated using OEE and OPE analysis values from model against the real line values as shown in Figure 6.4.

Therefore, focus of the simulation analysis is done in this targeted area especially between filling and blowing stations. To study losses propagation to or from individual stations as well as throughout the whole system , and to show how these dynamics affect line OEE or productivity in a complex real manufacturing system through a line simulation analysis process.

Form the line process simulation model developed as shown in Figure 6.4, the different four events of machines from are summarized from the simulation result as shown in the table 6.2 below. The four basic events of machines are selected to understand behavior of the stations and how much time has been productive and how much time has been not productive. Any station is said to be productive because station is producing if state is running, otherwise the rest three states are non-productive states which is no production in station. The question here is which nonproductive state should be analyzed and reduced to minimize unused time. For this reason, the data in Table 6.2 is considered as starting information's for analysis. In addition to this a pie chart is drown for more understanding and analysis too.

Table 6.2 collected data from simulation model result (report)

Station	Failed	Blocked	Starved	Running
Filler	*212.10*	***508.45***	***1865.62***	***5302.77***
	Failed	***Blocked***	***Starved***	***Running***
Blow molder	*232.04*	*719.55*	*1446.24*	*5491.22*

From the Table 6.2, it's clearly shown that the starvation, blockage and failure are reasons for nonproductive time. Minimizing one of the three events can increase the running time (productive time). But the behavior, inter action between machines or stations with the whole system should be investigated to understand their background.

As shown in Figure 6.6, in the pie chart of the two stations (machines) that the only 67% and 70% of time of filler and blow molder has been used for total amount production in every station respectively. Here the production time of blow molder is greater than the filler production time because the total units produced is combination of total unit lost and total good units produced . So that blow molding station was producing rejects or scraps due to every failure of other downstream machines (base cooling, filler, capper, and date coder, conveyer and inspection station). The rest 3% has been both stations in failure or stopped.

As shown in Figure 6.6, about 24% and 18% of production time filling and blowing stations was starved due to lack of supply from their upstream components normally due to cap feeding and preform feeding respectively. Filler and blow molding is said to be starved if no part (cap, preform, bottle) is available for processing.

Also, 6% and 9% of time was blocked due to lack of space or stoppage in downstream components capper, date code, conveyer and inspection). In reality, this happens, if supply of preform but capper is waiting for cap luck of cap supply interrupted or cap feeding stoppage. These stations said to be blocked if there is no available place to processes or store or the processed part.

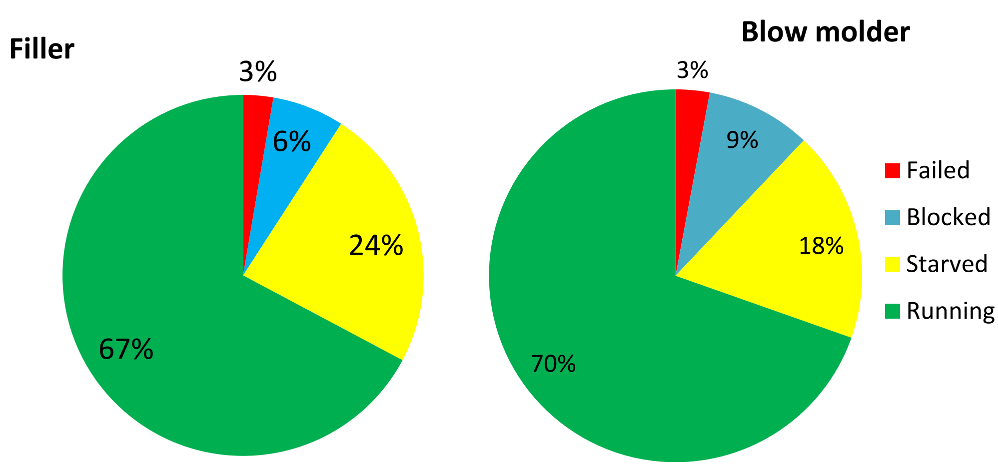


Figure 6.6: pie chart of filling and blowing machine stations events

Actually the block system particularly, the filler is the core machine, which determines the line efficiency. Production time of this station (filler) determines the (maximum) output of the line and loss of production time on the core machine cannot be recovered.

From the pie char it is clear that, both stations has been affected by failure of other stations than their self, that's way 24% ,18% of time of filling and blowing station lost due to starvation, also 6% and 9% of time lost due to blocking.

Thus, capturing the correct dynamic of propagation of blocking and starvation in the system is fundamental for the development of accurate models and methods for the performance analysis of systems [23]. So that focuses of this analysis done on the reduction of unused time (blockage and starvation) to improve the productivity.

5.3.1 Loss propagation to individual stations

As shown in Figure 6.6, the 3% production time of the filler and blow molder was lost due to internal failure of the line core stations itself which is called as Total time failed (TTF).

at the moment filler is failed, the base cooling stopped, the preform feeding, cap feeding components became blocked immediately then, blow molder , heating module dumps bottle and preform inside the stations then heating module and blow molder becomes blocked which called Total time blocked (TTB). Finally, the heating module temperature drops and cooldown. And also preform feeding stays blocked until filler started running and heating module operating temperature reached.

Once a failure is occurred in filler or blow molder, a failure of a either machine affect's and spread out to only individual machines of the block as well as preform feed and cap feed if duration of down time is less than 5 minute.

If the filler is restored to operation / started running, first the heating module starts warming up to reach operating temperature ,at the this time filling station is waiting for a bottles to be processed so filler is said to be starved and this time is called, Total time starved (TTSV). Also the cap feeding stays blocked up to filler start producing.

On the other hand, the units lost (TUL) after the filler during process, during start up and during failure (which is usually less than 1%) may not be considerable. But, the total units lost after blow molder and heating module during failure is the highest lost (usually between 3% and 10%) that affects production time utilization as well as productivity in terms of cost and output. Also this condition has been focused to analyses how down time (failure) spread out through stations and its effects on the process yield or quality loss and how quality losses propagation affects the available production time.

5.3.2 Loss propagation to whole production system

If the duration of down time greater five minutes loss propagates to the entire production system (line), because the accumulated bottles in buffer before stoppage of primary packaging are processed during the block failure for less than 5 minutes, at this moment no bottle flow from filler and no bottles is available for processing in labeling station so this station becomes starved this condition immediately spread out to all secondary section.

As stated in above paragraph, after a failure of any one machine in the block system, Immediately propagates to all the other machines in the block system and cap feeding and preform feeding components, then secondary machines (labeling station)drains the accumulated bottles at high speed, nominal speed , low speed, respectively as per the duration of the short stoppage. This stage is because of buffer between primary and secondary packaging the propagation to secondary is absorbed progressively then becomes starved if down time is greater than or equal to minutes. if the failure(down time) is longer(normally greater than 5 minutes) this down time loss propagates to secondary packaging and the entire production line.

Generally, the production time loss longer (normally greater than 5 minutes) propagates to entire production system due to the down time of the block system machines broken down into three time loss categories as bellow:

1) Break downs on the block machines or bottleneck process itself (capper filler, base cooling, blow molder, heating module), i.e. Total time failed (TTF),

2) Line Downstream breakdowns that block the bottleneck or block machines (capper filler, base cooling, blow molder, heating module) (filler) from running, Total time blocked (TTB). A downstream breakdown includes any breakdown in labeling, wrapping and palletizing stations, stations supply components, and all conveyers in between these stations.

3) Line upstream breakdowns that starve the bottleneck process, i.e. Total time starved (TTSV). This includes a breakdown in any one of input supply components of the block machines which preform feeding and cap feeding are concerned in this case.

Finally ,as a result of this line simulation analysis ,the individual behavior of stations or the whole production system under dynamic situation , the effect of one station for another station and also how time losses (down time , performance, and quality losses)of individual station spread out or propagated through is clearly shown.

5.3.3 Problem description and identified areas by simulation

1. Productivity is highly affected due to blockage and starvation of block stations.

2. Raw material losses high due to failure propagation on blow molding and heating station. Production time loss propagation can be categorized in to three forms of losses, quality, and availability and performance losses.

a) Block Input Components

In order to start production and to have optimal production all inputs should be supplied, flow continuously and sufficiently through the components. But, if one of the input material is not supplied, flow is interrupted, lack of input material may be because of bad quality material, supply component failure/stoppage or human error or other problems, the production process will stopped or interrupted this causes production time losses (unplanned down time loss) which lowers the performance(performance losses) and productivity of line. Figure 21, shows that major problem areas in the input supply are preform supply component's (C3-C4) and cap supply (C7-C8) that cause flow interruption and downtime losses frequently.

b) Block System

Any sudden stoppage in one of the component of the block and or any of downstream machines (heating module, blow molding ,base cooling, filler, cap feeding, capper, single conveyer , date coder, inspection machine) , will inevitably line downtime(down time losses). At the same time the sadden failure causes preform and bottle losses (quality losses) from heating and blowing station. For better understanding, assume any for example if filler fails randomly: the base cooling stopped immediately, this block the blowing and heating station ,then the bottles in side blowing station and preforms inside the heating module rejected.

Then the heating module cools down until the filler starts operation. If the filler starts, first, the bottles inside the filler complete their process and empty out. Second, the heating oven starts warming up to reach set processing temperature. Then, after the desired temperature reached, the preforms enter continuously to the oven and the first preform rejected from the oven discharge then, all other flows to blowing station to form a bottle here the first empty bottle will be rejected in the blowing discharge, all other bottles moves to filling and capping station via base cooling. Figure 21 as bellow, shows that major problem areas in the block system are blow molding machine (M2) and filling/capping station (M4/M5) that cause downtime losses frequently.

Every input of the block machines should be supplied continuously, sufficiently and the block system (all machines of the block) should be available constantly in order to have continuous production. Especially, for the block system ,as blowing molding machine is probably one of the most efficient on any bottling line, but also subjected to damp (rejection) quality preform and bottles under its normal operation ,in case of random failure of other components of block system. Therefore, it should not be stopped under normal operation unless essential. It should be considered the master machine for the line.

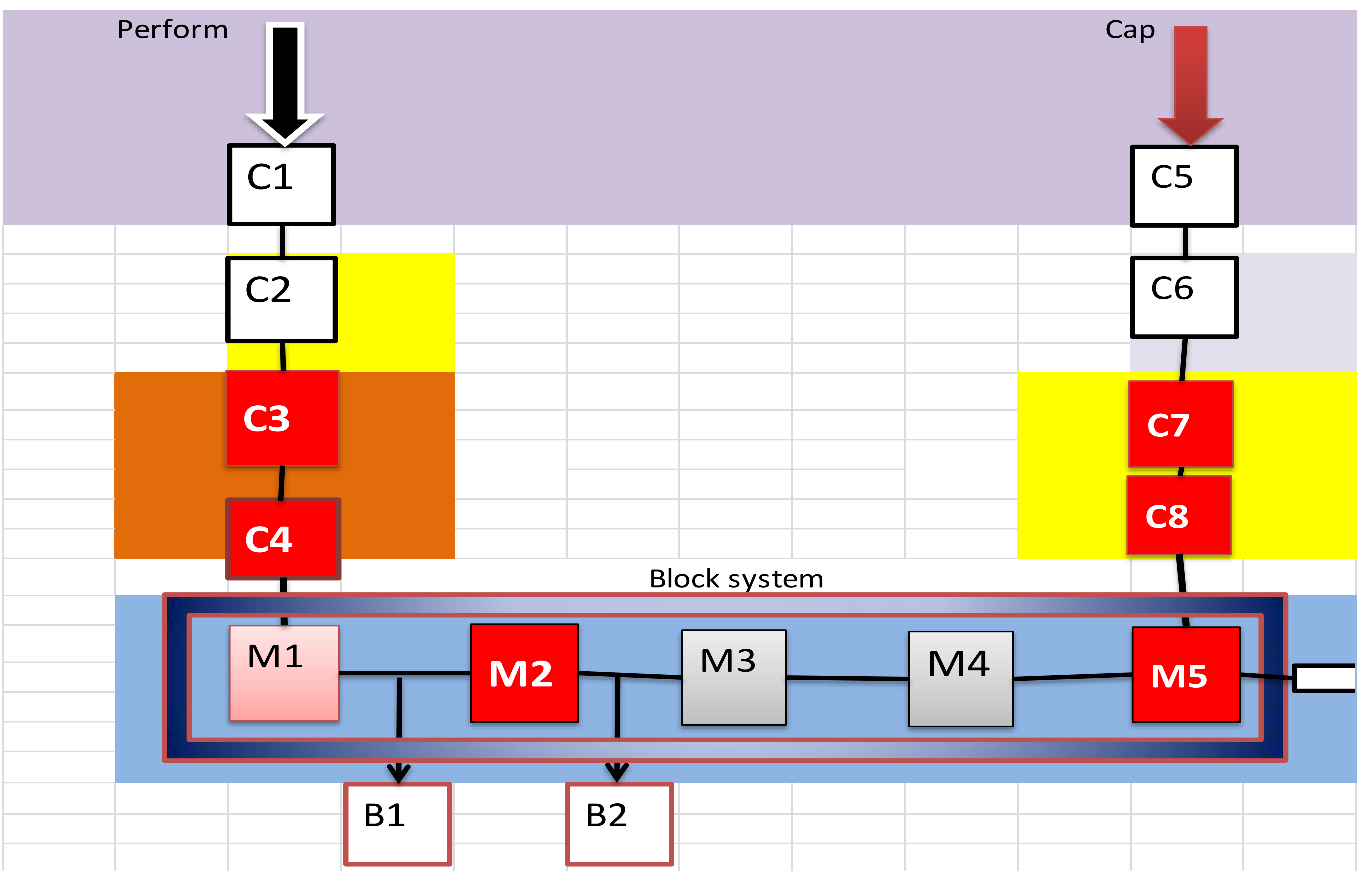


Figure 6.7: the major problem area in supply components and the block system,

To improve line efficiency, performance, productivity and to create continuous follow any failure or start/stop condition on the blow molding-filling block and upstream or input supply components of this block should be minimized or avoided. So the interest here is to maximize its uptime by minimizing block system failure , avoiding supply components disturbance and not letting other downstream machine stoppages affect it. Thus, capturing the correct dynamic of propagation of blocking and starvation in the system is fundamental for the development of accurate models and methods for the performance analysis of systems [23].

According to [35], the focus should be on the bottleneck machine and according to companies should reduce their losses in order to improve the line performance [36]. Therefore, the focus of this study is done based the line OEE model analysis, that identifies the bottleneck system of the line (block system) and its critical inputs that are contributor and responsible for lower efficiency, performance and productivity of the line. So that focuses of this analysis done on the reduction of unused time (blockage and starvation) to improve the productivity. These losses are shown in a pie chart in Figure 6.6. Therefore, focus has been done on the losses of the input supply components and blowing-filling block system.

5.3.4 Improvements and Modification

The current production line has been producing the output blow the planned and at higher production lost and cost due to start/stop situation in performs and Cap supply components as well as the block system (filling –base cooling- blowing stations) which are identified causes. To improve the productivity of the existing line, three possible solution (modifications) have been identified for each problem areas has been selected based on less blockage and starvation time and that give possible maximum up time with higher output. The process of improvement is checked using simulation to assess the impact of parameters and associated losses propagation on the whole line system has been analyzed.

In this study, two modifications are proposed to achieve line improvement in the current situation are: 1) a buffer conveyer was added to perform and cap feeding or supply components and 2) block system is decoupled by introducing buffer conveyer between blowing station and filling station.

The first solution is supposed to absorb the start stop condition or reduced loss propagation among components to component, station/machine to machine, and component to station. The selected feeding components (BC2) were 690 *preforms per minute* and a capacity of 3000 preforms.

The Second solution is supposed, to reduced product loss in process due to failure propagation as well as associated costs. Generally, after that the simulation run has been conducted on the modified model with a buffer conveyer (BC3) of *15meter length, 600bottles* per hour speed the suggested solutions give significant improvements in terms of production time, output cost, losses ,OEE and its factors.

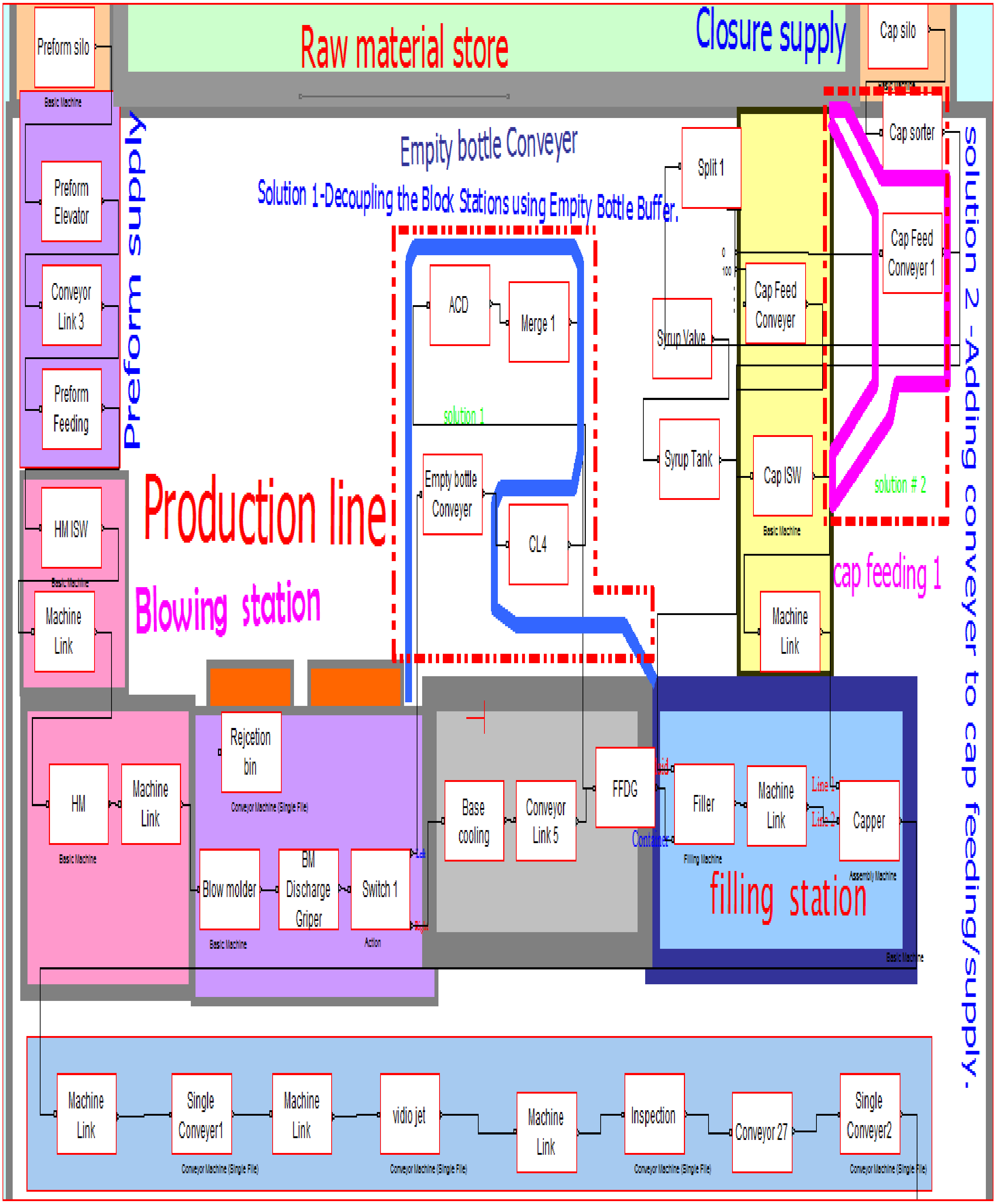


Figure 7.1: Line Simulation Model of the improved or proposed system

5.4 Supposed Solutions and modifications

To avoid production disturbance (start /stop condition) the following are suggested solutions:

- ❖ Solution on supply component is done by changing configuration-reduces availability loss propagation (up stream of bottleneck process) (primary packaging)
- ❖ Solution block system is done by decoupling the block-reduce performance & Quality Losses propagation in block system (bottleneck process)-(primary packaging).

1. On Upstream supply component change in configuration is done to avoid failure propagation.

In the existing, in put component supply to the block components are connected in a series each other and to the block system machine's and downstream stations. This means the operation condition of the block system depends on the state of each input supply components that indicts that availability of each component matters the productivity.

For instance if we consider the block system, production is possible if it's all the input supply components are working. However, the stoppage of each in put component causes the downtime of the whole system this presence of failure propagation kills the line efficiency, performance and productivity. To improve productivity and, to avoid failure propagation from input components to the block system and the whole production process during random stoppage, the component arrangement is changed by introducing redundant component to the existing arrangement. As a result, only the simultaneous downtime of both (the old and new/redundant) components causes the downtime of the whole system. This minimizes the failure propagation and as a result, maximizes efficiency, performance and productivity.

Buffering on an air conveyor can only be considered for short time filler stoppages up to a few has to first reach its operating temperature, even though during a stoppage it may only go back to half heat conditions to allow for more efficient re-starts.

2. Protecting blow molding station from effect loss propagation from other block system machines to eliminate rejection under random short failure of any block system down stations, which means the bottle, is directed toward the new buffer and preform continues flowing to blowing station as in normal condition**.** This will be done by decoupling the heating and blow molding station only in case of random failure. For example, if filler is in short stop, the blow molding station continuous production for certain amount of time normally a minimum of 1 minute, this prevents the rejection and heating oven cooling down time and at the same time prevents supply components (upstream) from idleness (blockage). if filler starts with in minimum of 1minute , bottles from the new buffers moves to the filler immediately until the heating oven warm up (processing temperature reached) and then preform passes through the oven to blowing station which becomes a bottle then move to base cooling here after the empty bottle reaches the discharge of base cooling, then new buffer stops feeding bottle to filler infeed star well ,but ,immediately in coming bottle from blow station reaches at base cooling discharge starts feeding filler infeed star wheel then follow to the filling process. This prevents the filling machine (starvation) idle time due to filler stoppage. And eliminates the inter mitten empty out Process and process time.

3.*Protecting filling station from effect loss propagation out of other block system machines that eliminates starvation (idleness) of under random short failure of block system and its up streams.* Immediately, after failure of base cooling and or blowing station, or empty bottles start filling directly from new buffer and continues flowing to filling station as in normal condition even the blowing station is short failure.

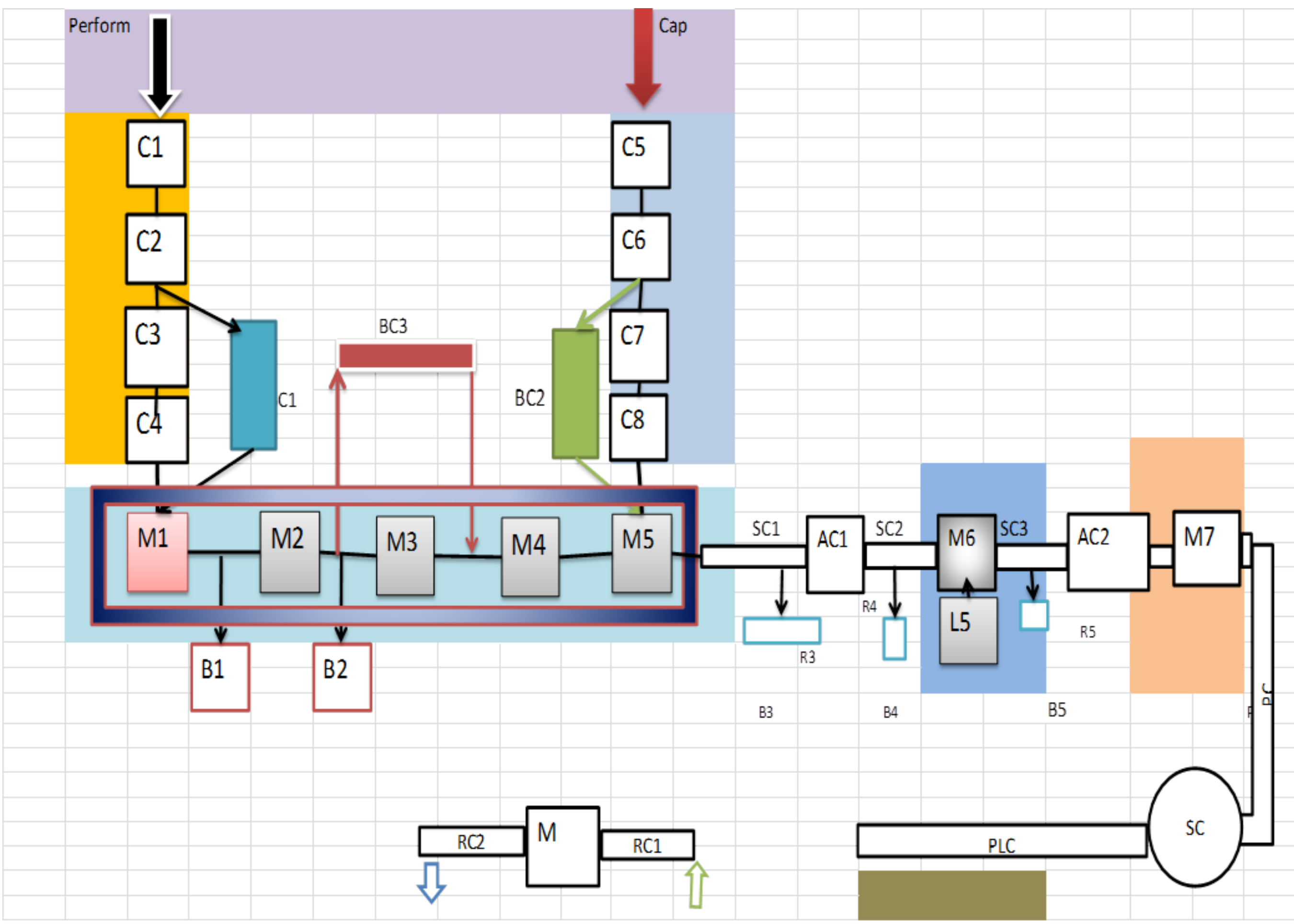


Figure 7.2: improved lay out of the production system

5.5 Productions run and simulation model results

After the simulation model runs for 7889.06 minutes, the results from both models is collected form filling station (filler) and blowing station (blow molder) and then analysis on the output measures is done to relate the results from both systems. To study the propagation of loss around the bottleneck stations (primary packaging section) it is assumed that the effect of the secondary packaging(labeling, shrink wrapping and palletizing) on the core machine(filler) is not considered because of the presence of buffer(accumulation conveyer) in between that can absorbs disturbance's from secondary packaging. This conveyer minimizes the effect of failures from both streams. The same input parameters have been used in existing line model and the improved model to compare and analyze their results.

Table 7.1: collected and summarized result of existing system and improved system

		BM blowing station			filling station		
Output Measures		**Existing**	**Improved**	Improvement	**Existing**	**Improved**	Improvement
Production time		B. molder	B. molder		Filler	Filler	
TTB	Blockage (minutes)	481.3	465	*-16.3*	247.59	178.49	*-69.1*
TTSV	Starvation (minutes)	901.3	35.7716	*-865.52*	1358.08	402.83	*-955.25*
TTR	Running (minutes)	6219.98	7080.4	*860.42*	6012.07	7033.19	*1021.12*
Production output (Bottles)							
TUP	Total units processed	3836095	4248198	*412103*	3607123	4219871	*612748*
TGU	Total good units	3707473	4221882	*514409*	3607123	4219871	*612748*
Units lose(Pcs)							
TUL	Total units lost	128622	30221	*-98401*			
Cost							
CTUL	Cost of units lost(ETB)	488,385.00	114,751.00	*-373,634.*			
Productivity(OEE)							
A	Availability	78.84	89.749	*10.909*	76.2077	89.15	*12.9423*
P	Performance	78.32	89.19	*10.87*	76.2026	89.15	*12.9474*
Q	Quality	96.64	99.38	*2.74*	100	100	*0*
	OEE	59.68%	79.55%	*19.87%*	58.07%	79.48%	*21.4%*

Generally, After data collection and analysis of both systems, the existing and the proposed, a comparison between the model out measures of interest in terms of time for production, and amount of production output (bottles produced), units lost in production, and the costs of units lost, productivity in terms of OEE factors have been summarized as shown in above table 7.1.

5.5 Improvement results and Discussion

From the above comparison table of simulation model output measures of concern between the current system and the modified system, it is clearly assumed that the modified system with the model developed has shown significant improvements in different aspects.

A significant decrease in total blockage time by 69 minutes, total starvation time by 955 minutes and as a result of this the running time (production time) of filling station is maximized to by about 1020 minutes over the existing line situation.

In terms of line output, the amount of produced bottles in the existing situation is 3,607, 123 bottles and in the improved situation about 4,219,871 bottles has been produced which means, about 612,748 bottles has been gained. In terms, total units lost only due to failure is reduced from 128,622 to 30,221 units, this means about 98,401 units are gained as additional good produced bottles instead of rejection. This is mainly because of no rejection in the time of random failure in the improved situation.

A significant amount of resource including energy(for example ,electricity ,water, compressed air),row materials(preform), production time, and associated costs are consumed in the production of rejects or scraps that results , increases production cost and decreases the overall organizational profit later.

In terms of cost of units lost due to failure only, has been significantly reduced. Since, the effect of sudden failure of other stations to blowing station minimized, and the amount of units lost due to failure propagation is totally eliminated as a result this a cost reduction of about 373,634.00 (ETB) has been achieved per 21 production days .

Generally, due to the above benefits from the modified (improved line model), an achievement of about 11% increase in availability, performance and also indirectly from blowing station, the 2.74% quality loss (yield) improvement has been achieved. Thus, an improvement of 21.4% in Line productivity (OEE) has been made from the improved (proposed line simulation model) system.

Accordingly a comparative picture of the five line output measures of the existing and proposed system has been drawn in terms of time, production output, unit lost, cost of lost units and productivity (OEE) and is shown in Figure 7.3 up to Figure 7.7.

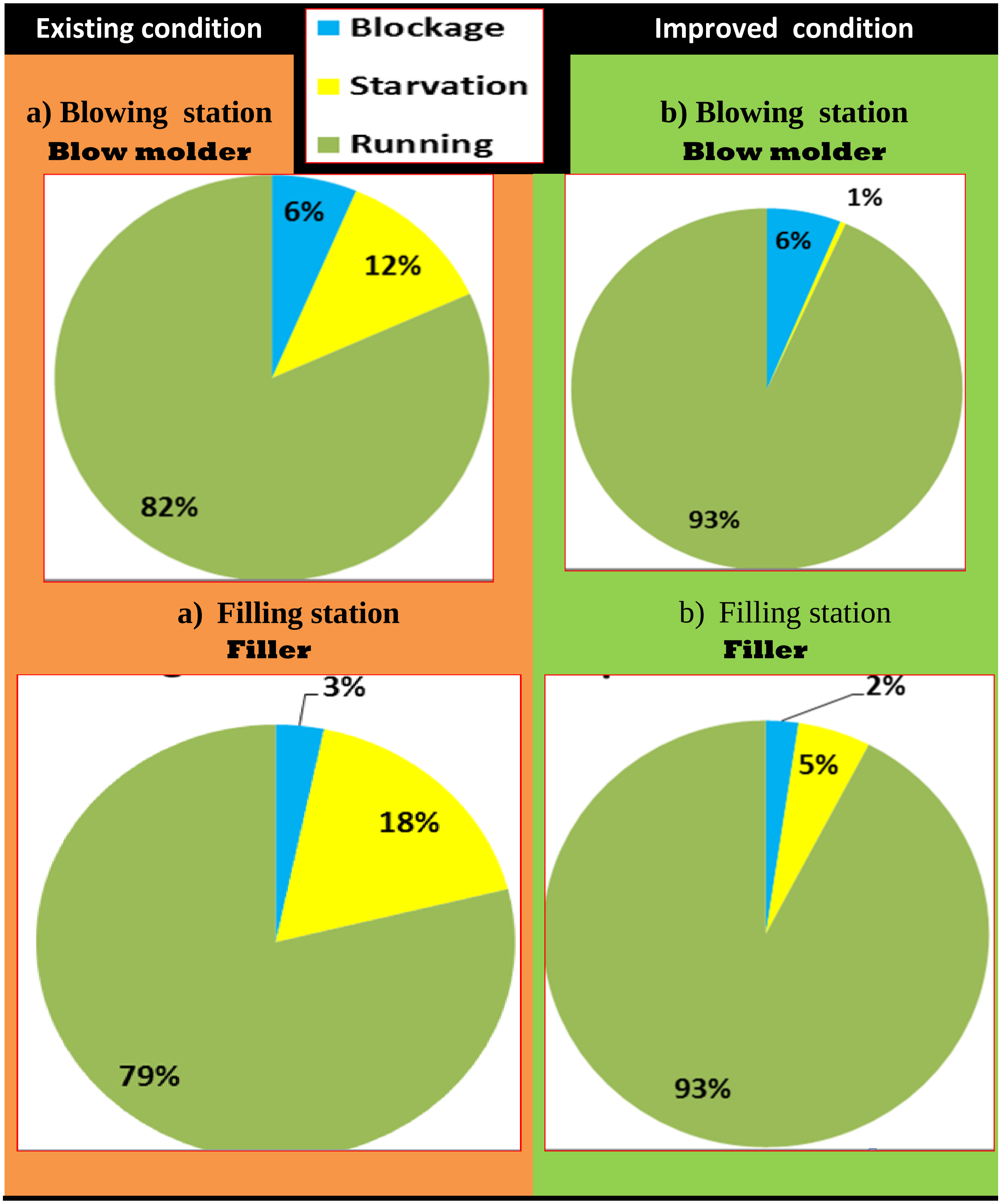


Figure 7.3:Comparsion exsisted and improved condition interms of time blockage and starvation

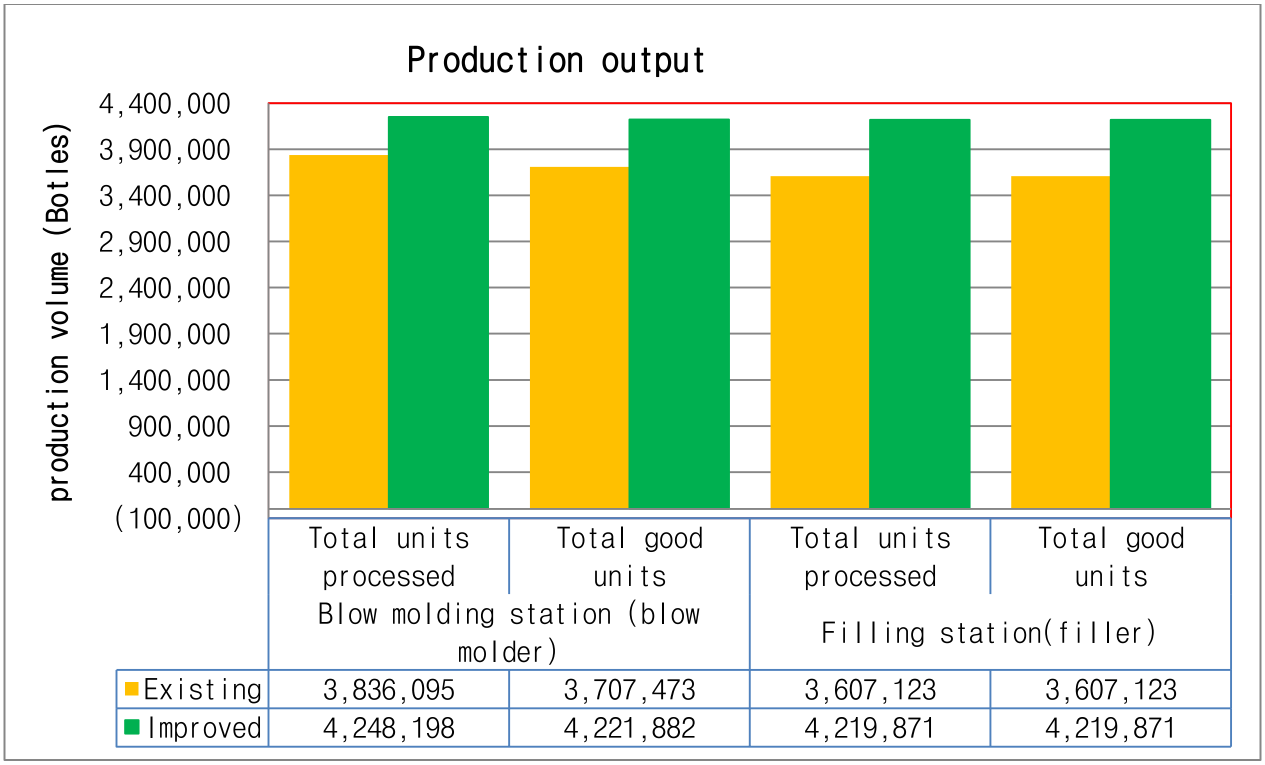


Figure 7.4 comparison exsisted and improved condition in terms of production output (bottles).

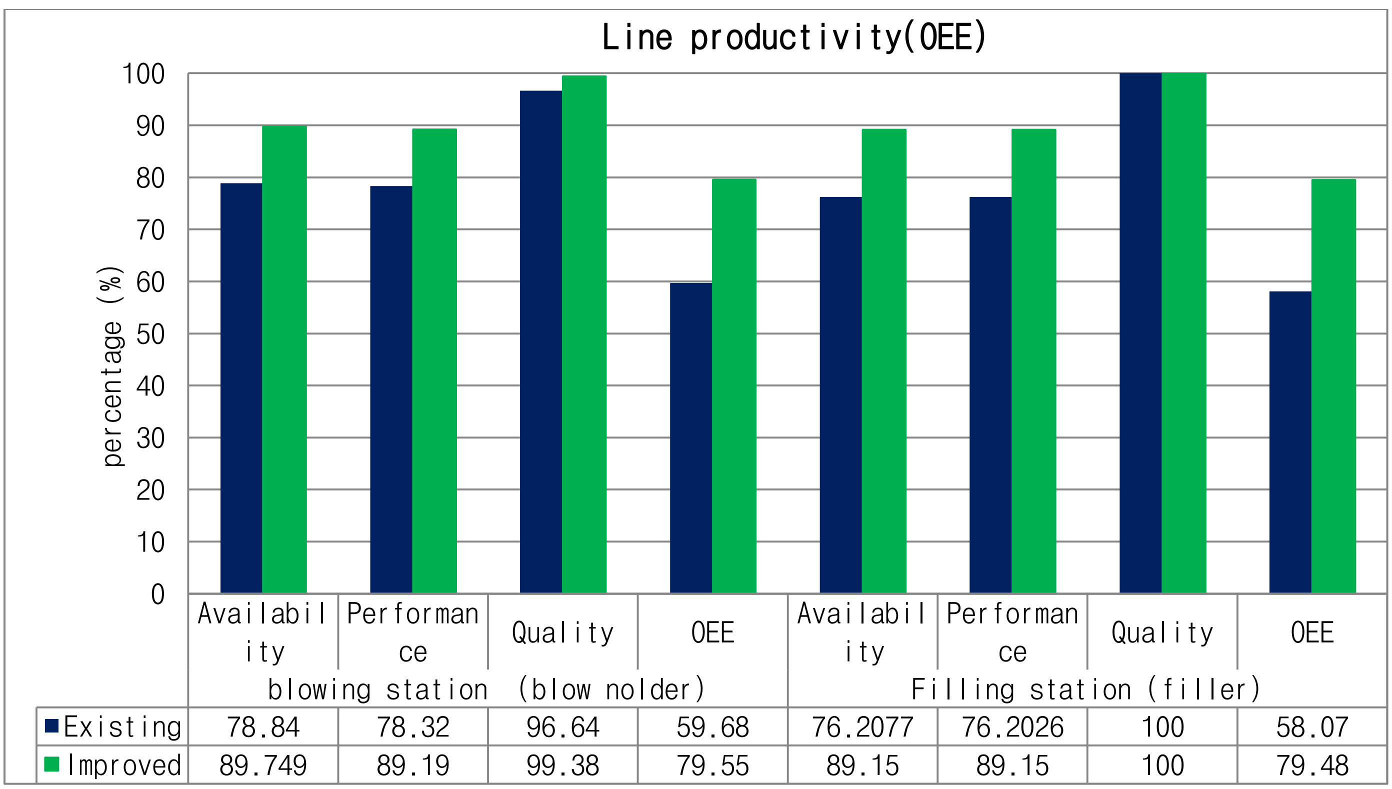


Figure 7.5 Comparsion exsisted and improved condition line productivity (OEE)and its factors.

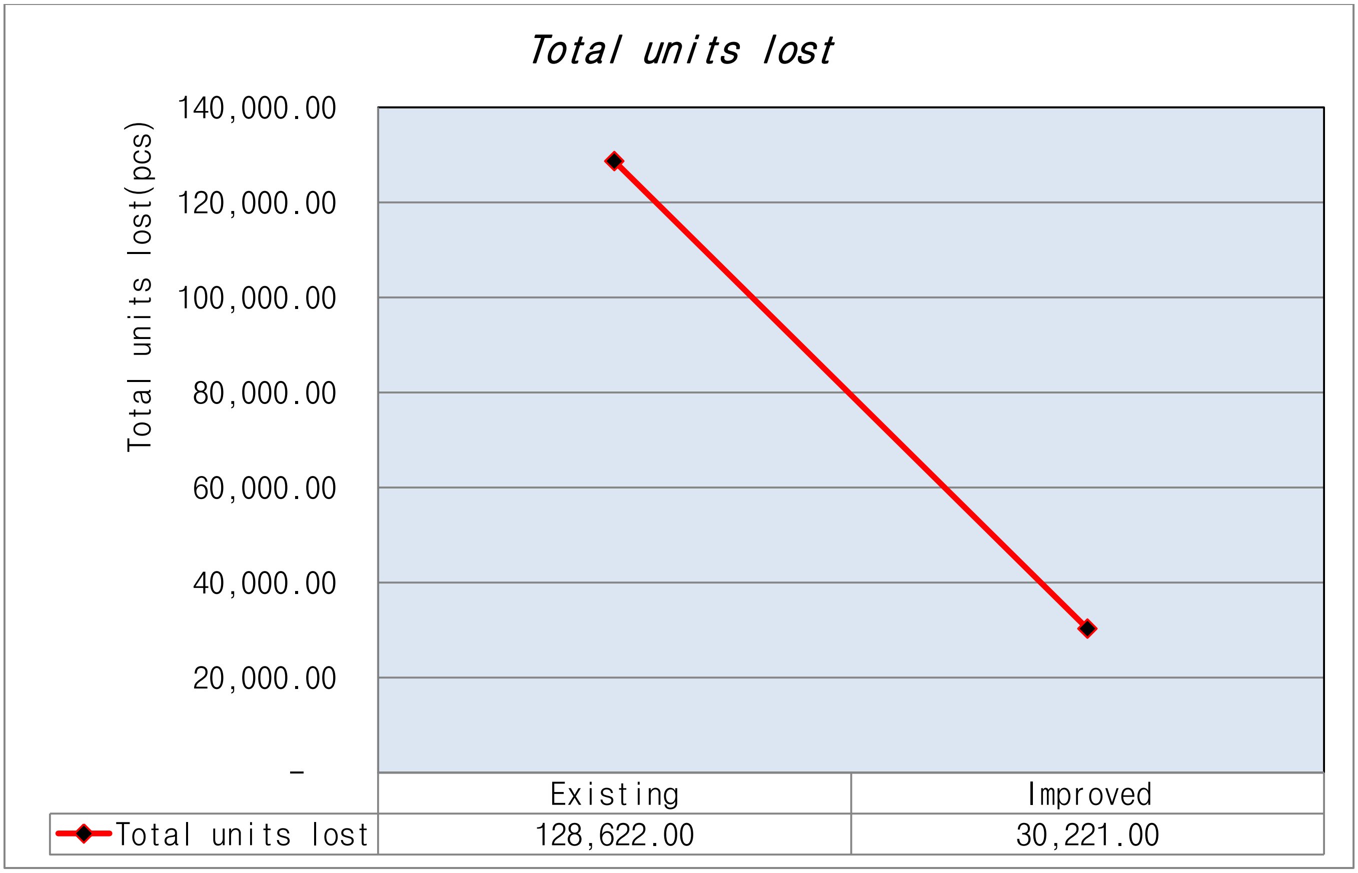


Figure 7.6:comparsion exsisted and improved condition in terms of total unit loss.

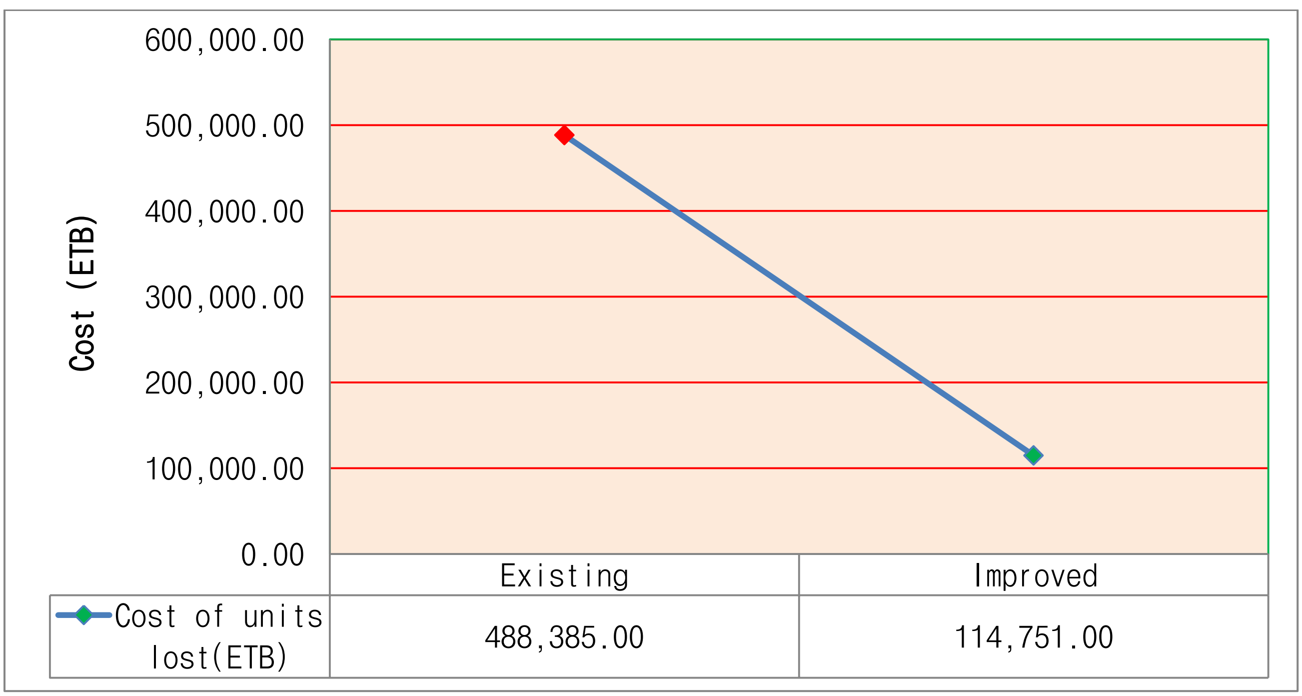


Figure 7.7: comparison exsisted and improved condition in terms of cost of unit lost

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

In this study line efficiency analyses and performance improvement has been done in real bottling production line using OEE and simulation respectively. Line Efficiency analysis has been started with activity of gathering the appropriate data, representing these data in a comprehensible manner, calculating the relevant performance indicators (line OEE) and interpreting these figures, to understand or explain production losses and transform the process data into information on the loss of line efficiency. OEE tool used as performance indicator and used to measures, analysis and identifies line efficiency losses; and to indicate area of improvement, priorities improvement efforts and provides recommended strategy to be implemented to minimize the production losses. Simulation models were built for the production line to provide a deep understanding of the system, to understand real back ground of the efficiency losses, to find as well as to test appropriate improvements before implementing on the actual system to increase efficiency and the performance of the production system. Based on the results of the study, the following conclusions are drawn:

- ✓ In this study, total 22 Operational disturbances that are investigated, and Out of the 22 factors, 10 are external disturbances, 12 are internal disturbances' and totally are responsible for total time lost about 3498 hours throughout the given a year of data collection. out of the 10, three major determinant contributors (Higher planned maintenance, CIP requirement and warehousing) that are classified in the planed or shut down losses, that should be excluded from efficiency analysis because there was no intention of running production (e.g. breaks, lunch, scheduled maintenance, or periods where there is nothing to produce).so that, they are not part of the OEE calculation.
- ✓ OEE of the production line is blow target (management plan) by about 5% and about 14% below the world class. The identified reason for lower OEE is due to lower line availability and line performance as a result of higher manufacturing efficiency losses; namely 31% availability losses and 15% performance losses. The main reasons for lower availability are due to excess machine breakdown, longer set up and adjustment and frequent component

stoppage. The main reasons for lower performance are due to higher speed losses, and frequent short stops.

- ✓ The line block system (blowing and filling station) is identified as a focus of line improvement area that is found that with higher availability and performance losses that highly affect line OEE and responsible for raw materials loss. And also as a result of simulation analysis clearly shown that, the high starvation, high blockage, frequent failure and start/stop situation are reasons for lower productivity
- ✓ Simulation model for the current production line has been developed using ARENA software. line behavior under varying set of circumstances, background of challenges, possibilities of disturbance reduction, and line performance measures in the improvement area has been studied in detail, as a result, high starvation, high blockage , frequent failure and start/stop situation has been identified as reasons for lower efficiency and performance. Thus, capturing the propagation of blocking and starvation to and from in the block system (blowing –filling) were fundamental to start improvements.
- ✓ Finally the following strategies are suggested to improvement line are :

1) Strategies in the forms of action plan to be implemented by the company and the major challenging areas and associated problems are documented for further improvements. Proper implementation has been expected to reduce the current production losses by 40 to 45 %). Then,
2) set of changes and modifications to line model has been suggested and an improved model was developed, where: Blockage and starvation time of reduced by 11%, production output is increased , units lost due to failure, Raw material (preform) losses and cost of unit lost reduced . As a result of about 11% increase in availability, line performance and Line productivity (OEE) is improved by 21.4%.

Thus, company can meet the demand; reduce production cost, increase production capacity to increase its competitiveness and improve its operational as well as performance. Therefore, it can be concluded that the line efficiency analysis and proposed model is beneficial to the company. It had been observed that there are additional possibilities for improving the performance of the company.

6.2 Recommendations

Beside the findings in this study the following are suggested as recommendation:

- ✓ The effect of human factors in not consider in this study , but, considering the contribution of human factors in analyzing efficiency and line performance can be source of significant improvements.
- ✓ OEE analysis covers only the internal (unplanned production losses) 46% only, what is analyzed in this study. But by analyzing the planned losses which 54% of the total time losses so that, it's clear that, the company can be achieve great improvement in productivity.
- ✓ The OEE analysis result reliability is depends on the relevant of data used, so automating data collection in the manufacturing system is recommended.
- ✓ The line simulation model can be further applied to determine the best maintenance strategy, to optimize change over processes, CIP processes and line upgrading. Also model can give better result by combining with other productivity improvement tools and methods.

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Appendix A: Some Data collected

Total number of shifts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Production shifts per day	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Production days	01			02			03			05			06			07			08		
calendar time	24			24			24			24			24			24			24		
working time	24			24			24			24			24			24			24		
load time	19.81			21.71			18.97			17.4			10.38			20.88			22.73		
operating time	12.01			16.38			12.32			14.4			5.64			15.56			14.12		
net operating time	12.05			16.39			12.31			14.41			5.6			15.51			13.53		
value added time	11.89			16.32			12.26			14.39			5.58			15.47			13.49		

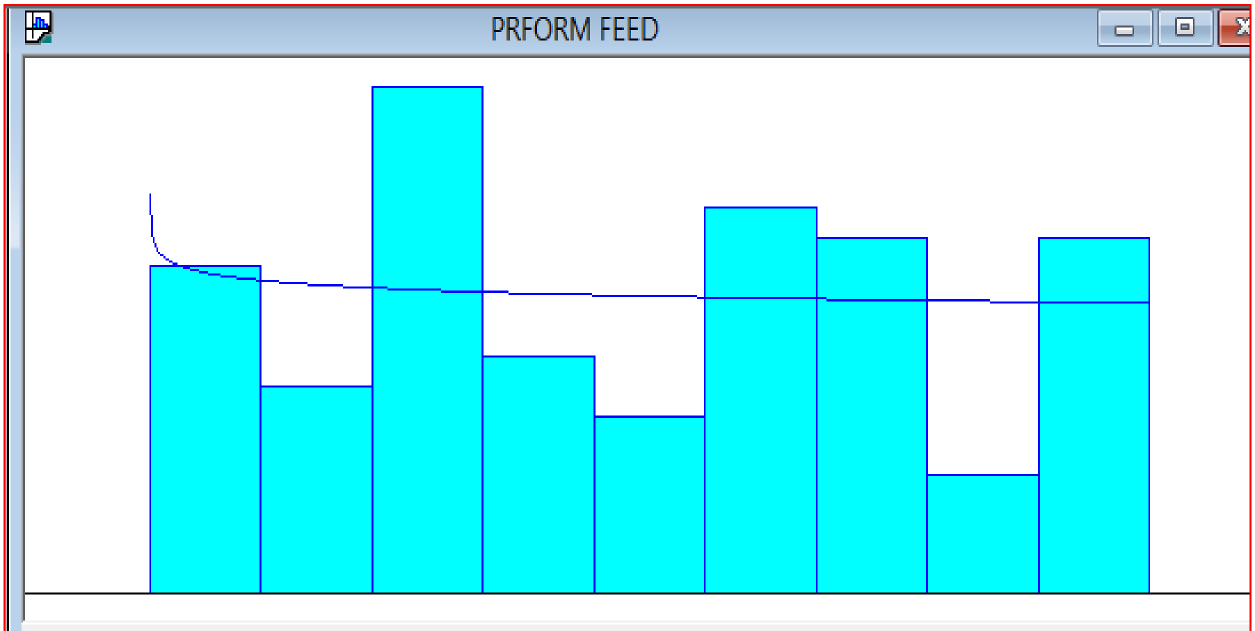
App: A Table1.1 summery of collected data of 21 production shifts in to daily base production time breakdown structure

Total number of shifts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Production shifts per day	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
shut down loss	4.19			2.29			5.03			6.6			13.62			3.12			1.27		
downtime loss	7.8			5.33			6.65			3			4.74			5.32			8.61		
performance loss	-0.04			-0.01			0.01			-0.01			0.04			0.05			0.59		
Quality loss	0.16			0.07			0.05			0.02			0.02			0.04			0.04		

App: A Table1.2 the calculated production losses summery of collected data of 21 production shifts in to daily base production losses time structure.

Total number of shifts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Production shifts per day	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Availability	0.606			0.754			0.649			0.828			0.543			0.745			0.621		
Performance	1.003			1.001			0.999			1.001			0.993			0.997			0.958		
Quality	0.987			0.996			0.996			0.999			0.996			0.997			0.997		
OEE(%)	60.02			75.17			64.63			82.70			53.76			74.09			59.35		
OPE(%)	49.54			68.00			51.08			59.96			23.25			64.46			56.21		

App: A Table1.3 the summery of productivity Calculated in terms of OEE and OPE per day for collected data of 21 production shifts.




```
        Distribution Summary

Distribution:   Beta
Expression:     2 + 1 * BETA(0.966, 1)
Square Error:   0.016153

Chi Square Test
  Number of intervals   = 9
  Degrees of freedom    = 6
  Test Statistic        = 13
  Corresponding p-value = 0.0444

Kolmogorov-Smirnov Test
  Test Statistic        = 0.0572
  Corresponding p-value > 0.15

        Data Summary

Number of Data Points   = 90
Min Data Value          = 2.02
Max Data Value          = 2.99
Sample Mean             = 2.49
Sample Std Dev          = 0.29

        Histogram Summary

Histogram Range         = 2 to 3
Number of Intervals     = 9
```

App: A figure 1.snapshot of input analyzer result for preform feeding (sample input analyzer result)

PREFORM FEED	Distribution: Beta Expression: 2 + 1 * BETA(0.966, 1) Square Error: 0.016153
HEATING MODULE	Distribution: Beta Expression: 1.28 + 0.35 * BETA(1.59, 1.85) Square Error: 0.000372
BLOW MOLDER	Distribution: Lognormal Expression: 2 + LOGN(5.46, 10.1) Square Error: 0.036029
FILLER	Distribution: Beta Expression: 2 + 23 * BETA(0.401, 0.706) Square Error: 0.011935
CAPPER	Distribution: Beta Expression: 1.76 + 0.48 * BETA(1.38, 1.36) Square Error: 0.010882
AC1	Distribution: Triangular Expression: TRIA(0.5, 4, 4.5) Square Error: 0.066122
AC2	Distribution: Beta Expression: 4.05 + 1.95 * BETA(0.611, 0.627) Square Error: 0.095820
SC2	Distribution: Triangular Expression: TRIA(2.39, 3.43, 3.67) Square Error: 0.012984
SC3	Distribution: Gamma Expression: 2.58 + GAMM(0.197, 2.3) Square Error: 0.051844
SC4	Distribution: Lognormal Expression: 3.04 + LOGN(1.6, 1.32) Square Error: 0.111173
Label reel holder	Distribution: Normal Expression: NORM(2.7, 1.03) Square Error: 0.001251
Film reel holder	Distribution: Beta Expression: 1.3 + 2.7 * BETA(1.24, 0.838) Square Error: 0.021385
Pelletier	Distribution: Triangular Expression: TRIA(1.5, 2.26, 2.89) Square Error: 0.014709
LEBLING MACHINE	Distribution: Beta Expression: 15.2 + 8.76 * BETA(0.619, 0.597) Square Error: 0.151012
Vario pack Machine	Distribution: Beta Expression: 10 + 6 * BETA(0.0142, 0.0144) Square Error: 0.127855
Cap feeding	Distribution: Beta Expression: 1.38 + 0.24 * BETA(1.69, 1.82) Square Error: 0.006568

App: A Table1.4 the summery of input analyzer of stations failure f or collected data of 21 production shifts.

Actual production (bottles)	Planned production	differens
427752	452133.864	24381.864
832464	879914.448	47450.448
1495584	1580832.29	85248.288
402036	424952.052	22916.052
3157836	**3337832.65**	**179996.652**

App: A Table1.5 planned and actual production volume (bottles)

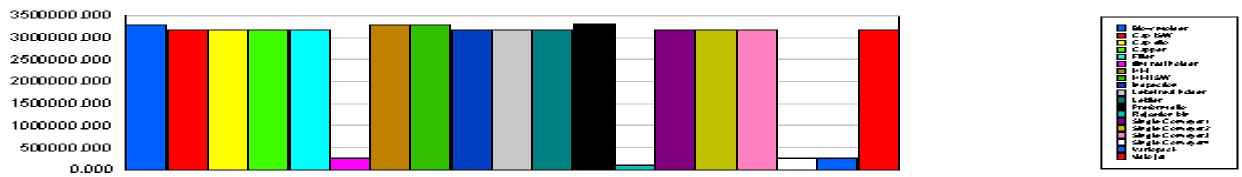
Time distribution	**Hours**	**Minutes**
working time	168	10080
load time	131.88	7912.8
operating time	90.43	5425.8
net operating time	89.8	5388
value added time	89.4	5364
shut down loss	36.12	**2167.2**
downtime loss	41.45	**2487**
performance loss	0.75	**37.8**
Quality losses	0.4	**24**
Availability	*0.686*	
Performance	*0.993*	
Quality	*0.996*	
OEE	*67.8%*	
OPE(%)	*53.21%*	

App: A Table1.6 Summary of calculated average OEE and OPE total as result of 21 shifts

Appendix B : Result report of the current production line simulation

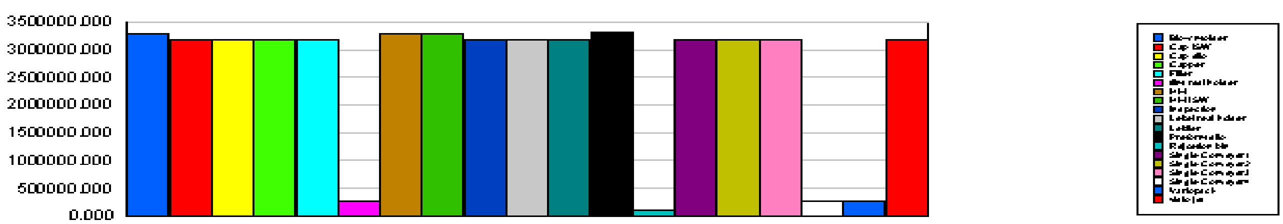
Unit Summary

Total Good Units Produced	Average	Half Width	Minimum Average	Maximum Average
Blow molder	3274931.13	115,066.97	2910217.0000	3636695.0000
Cap ISW	3181596.93	110,976.60	2826026.0000	3523366.0000
Cap silo	3182403.47	110,986.25	2826731.0000	3524215.0000
Capper	3181596.53	110,976.50	2826026.0000	3523365.0000
Filler	3181596.67	110,976.52	2826026.0000	3523365.0000
film real holder	264659.67	9,264.92	235017.0000	293243.0000
HM	3294701.07	115,736.02	2926129.0000	3656279.0000
HM ISW	3296945.13	115,693.57	2929495.0000	3658421.0000
Inspection	3181456.47	110,998.64	2825793.0000	3523364.0000
Lebel real holder	3178100.13	111,196.66	2823315.0000	3521560.0000
Lebller	3178099.67	111,196.64	2823314.0000	3521559.0000
Preform silo	3309384.27	115,311.75	2958139.0000	3662403.0000
Rejcetion bin	93189.73	5,010.03	76280.0000	113331.0000
Single Conveyer1	3181457.93	110,998.52	2825795.0000	3523365.0000
Single Conveyer2	3178099.87	111,196.57	2823314.0000	3521559.0000
Single Conveyer3	3178028.47	111,206.73	2823148.0000	3521559.0000
Single Conveyer4	264490.40	9,263.88	234783.0000	292974.0000
Variopack	264609.80	9,264.90	234953.0000	293193.0000
vidio jet	3181457.07	110,998.55	2825794.0000	3523364.0000



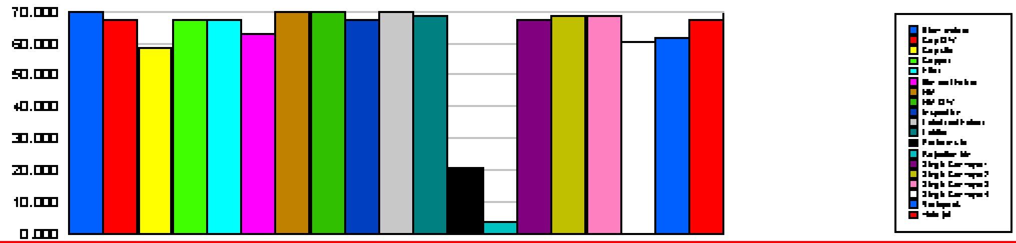
Unit Summary

Total Units Processed	Average	Half Width	Minimum Average	Maximum Average
Blow molder	3294700.93	115,735.97	2926129.0000	3656279.0000
Cap ISW	3181596.93	110,976.60	2826026.0000	3523366.0000
Cap silo	3182403.47	110,986.25	2826731.0000	3524215.0000
Capper	3181596.33	110,976.36	2826026.0000	3523364.0000
Filler	3181668.67	110,965.10	2826146.0000	3523365.0000
film real holder	264666.33	9,265.09	235023.0000	293250.0000
HM	3296945.07	115,693.54	2929495.0000	3658421.0000
HM ISW	3296945.13	115,693.57	2929495.0000	3658421.0000
Inspection	3181457.07	110,998.55	2825794.0000	3523364.0000
Lebel real holder	3178300.53	111,204.82	2823485.0000	3521775.0000
Lebller	3178102.13	111,196.68	2823317.0000	3521562.0000
Preform silo	3309384.27	115,311.75	2958139.0000	3662403.0000
Rejcetion bin	93189.73	5,010.03	76280.0000	113331.0000
Single Conveyer1	3181596.53	110,976.50	2826026.0000	3523365.0000
Single Conveyer2	3178380.87	111,189.96	2823686.0000	3521986.0000
Single Conveyer3	3178099.60	111,196.67	2823314.0000	3521559.0000
Single Conveyer4	264609.67	9,264.88	234953.0000	293193.0000
Variopack	264660.53	9,264.97	235018.0000	293244.0000
vidio jet	3181457.67	110,998.45	2825795.0000	3523364.0000

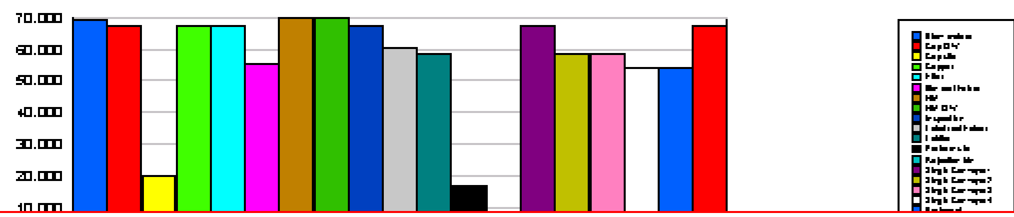


Activity Counter

Utilization	Average	Half Width	Minimum Average	Maximum Average
Blow molder	69.6055	2.45	61.8189	77.2444
Cap ISW	67.2154	2.34	59.7035	74.4357
Cap silo	58.2099	2.03	51.7063	64.4556
Capper	67.2168	2.34	59.7043	74.4425
Filler	67.2168	2.34	59.7043	74.4430
film real holder	63.0586	2.27	55.7621	70.4467
HM	69.6523	2.44	61.8894	77.2889
HM ISW	69.6523	2.44	61.8894	77.2889
Inspection	67.2309	2.35	59.7146	74.4614
Lebel real holder	69.6451	2.55	61.5062	77.9282
Lebller	68.2586	2.41	60.5471	76.0943
Preform silo	21.0103	0.73	18.8270	23.2270
Rejcetion bin	3.8603	0.21	3.1598	4.6946
Single Conveyer1	67.2138	2.35	59.6994	74.4425
Single Conveyer2	68.2461	2.41	60.5387	76.0817
Single Conveyer3	68.2442	2.41	60.5328	76.0727
Single Conveyer4	60.3019	2.11	53.4840	67.1803
Variopack	61.3705	2.16	54.4391	68.4232
vidio jet	67.2309	2.35	59.7146	74.4614

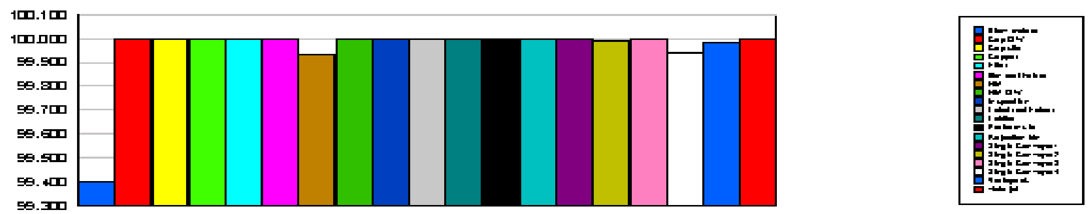


Performance Index	Average	Half Width	Minimum Average	Maximum Average
Blow molder	69.1872	2.43	61.4821	76.8299
Cap ISW	67.2154	2.34	59.7035	74.4357
Cap silo	20.1697	0.70	17.9155	22.3361
Capper	67.2154	2.34	59.7035	74.4357
Filler	67.2133	2.34	59.7009	74.4331
film real holder	55.6525	2.00	49.2474	61.8422
HM	69.6049	2.45	61.8183	77.2437
HM ISW	69.6523	2.44	61.8894	77.2889
Inspection	67.2294	2.35	59.7137	74.4545
Lebel real holder	60.3733	2.18	53.3890	67.1359
Lebller	58.3905	2.04	51.8721	64.7008
Preform silo	16.7796	0.58	14.9987	18.5695
Rejcetion bin	3.8603	0.21	3.1598	4.6946
Single Conveyer1	67.2086	2.35	59.6937	74.4308
Single Conveyer2	58.3767	2.04	51.8584	64.6857
Single Conveyer3	58.3801	2.04	51.8599	64.6900
Single Conveyer4	54.0426	1.89	47.9591	59.8643
Variopack	54.1194	1.89	48.0538	59.9653
vidio jet	67.2295	2.35	59.7137	74.4545



Performance

Yield	Average	Half Width	Minimum Average	Maximum Average
Blow molder	99.40	0.03	99.2946	99.4714
Cap ISW	100.00	0.00	100.0000	100.0000
Cap silo	100.00	0.00	100.0000	100.0000
Capper	100.00	0.00	100.0000	100.0000
Filler	100.00	0.00	99.9958	100.0000
film real holder	100.00	0.00	99.9973	99.9977
HM	99.93	0.01	99.8851	99.9703
HM ISW	100.00	0.00	100.0000	100.0000
Inspection	100.00	0.00	100.0000	100.0000
Lebel real holder	99.99	0.00	99.9913	99.9953
Lebller	100.00	0.00	99.9999	99.9999
Preform silo	100.00	0.00	100.0000	100.0000
Rejcetion bin	100.00	0.00	100.0000	100.0000
Single Conveyer1	99.99	0.00	99.9918	100.0000
Single Conveyer2	99.99	0.00	99.9849	100.0000
Single Conveyer3	100.00	0.00	99.9936	100.0000
Single Conveyer4	99.94	0.02	99.9128	100.0000
Variopack	99.98	0.00	99.9723	99.9866
vidio jet	100.00	0.00	100.0000	100.0000



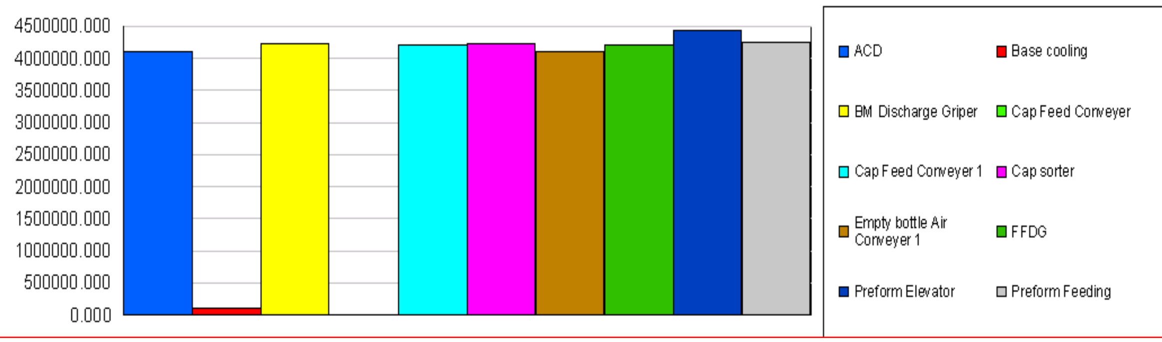
		Simulation Model	
		Filler	Blow molder
	calendar time		
A	working time	10080	10080
B	SRL	7889.06	7889.06
C	TTORGZ	5303.06	5491.22
D	TUP	5302.77	5491.17
E	TGUP	5302.77	5302.79
C/B	Availability	0.672204	0.696055
D/C	Performance	0.999945	0.999991
E/D	Quality	1	0.965695
	OEE	0.672168	0.67217
B/A	capacity	0.782645	0.782645
E/A	asset utilization	0.526068	0.526071
A-B	shut down loss	2190.94	2190.94
B-C	downtime loss	2586.00	2397.84
C-D	performance loss	0.29	0.05
D-E	Quality loss	0.00	188.38

App: B Table1.4 summery result of simulation current production line result.

Appendix C: The simulation result of the current line improvement area.

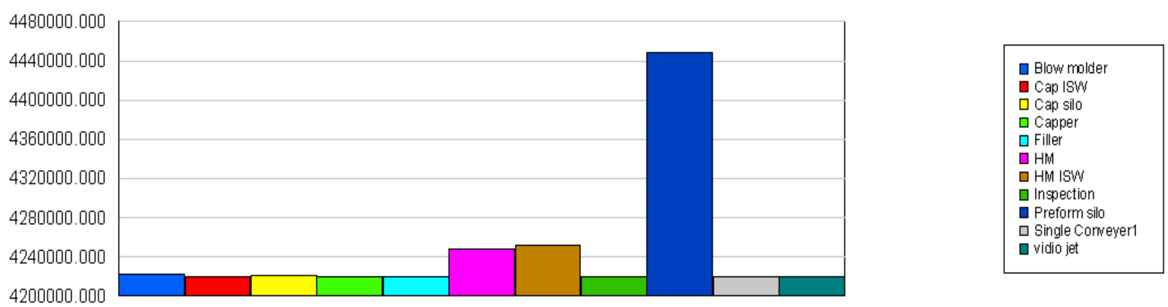
Total Good Units Conveyed

	Value
ACD	4111426.00
Base cooling	108444.00
BM Discharge Griper	4221871.00
Cap Feed Conveyer	0.00
Cap Feed Conveyer 1	4219872.00
Cap sorter	4221265.00
Empty bottle Air Conveyer 1	4111426.00
FFDG	4219871.00
Preform Elevator	4447395.00
Preform Feeding	4251870.00



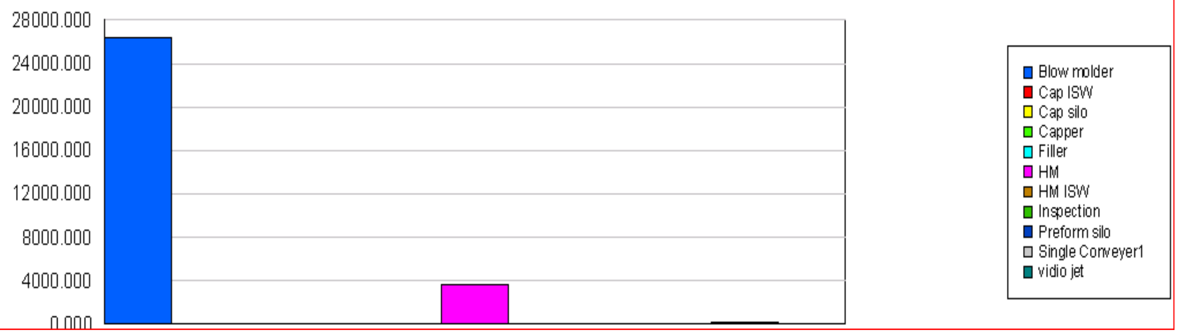
Total Good Units Produced

	Value
Blow molder	4221882.00
Cap ISW	4219872.00
Cap silo	4221424.00
Capper	4219871.00
Filler	4219871.00
HM	4248198.00
HM ISW	4251870.00
Inspection	4219871.00
Preform silo	4448748.00
Single Conveyer1	4219871.00
vidio jet	4219871.00



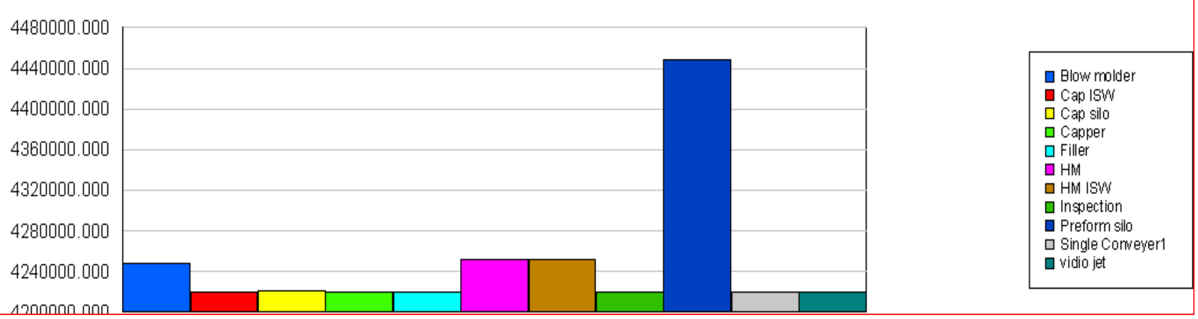
Total Units Lost

	Value
Blow molder	26316.00
Cap ISW	0.00
Cap silo	0.00
Capper	0.00
Filler	0.00
HM	3672.00
HM ISW	0.00
Inspection	1.0000
Preform silo	0.00
Single Conveyer1	231.00
vidio jet	1.0000

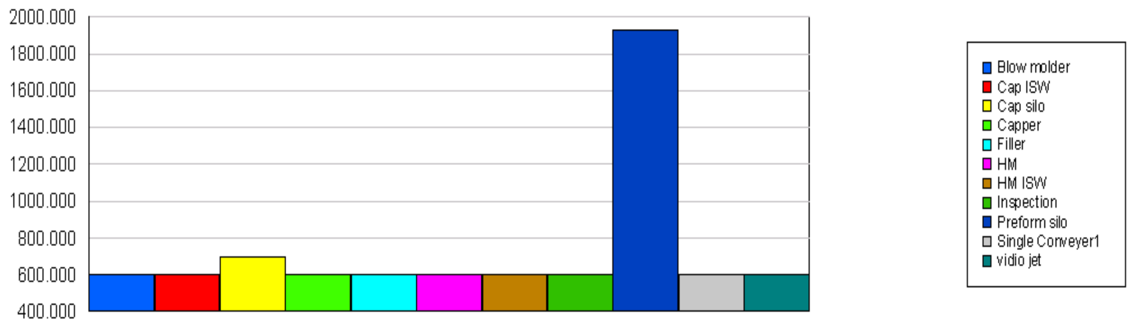


Total Units Processed

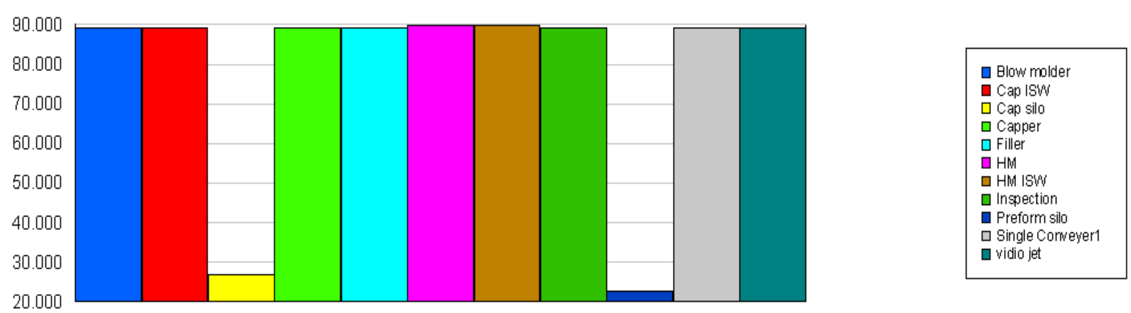
	Value
Blow molder	4248198.00
Cap ISW	4219872.00
Cap silo	4221424.00
Capper	4219870.00
Filler	4219871.00
HM	4251870.00
HM ISW	4251870.00
Inspection	4219871.00
Preform silo	4448748.00
Single Conveyer1	4219871.00
vidio jet	4219871.00



Average Output Rate Greater Than 0	Value
Blow molder	599.99
Cap ISW	600.00
Cap silo	697.39
Capper	599.99
Filler	599.99
HM	600.00
HM ISW	600.00
Inspection	599.99
Preform silo	1930.93
Single Conveyer1	599.99
vidio jet	599.99

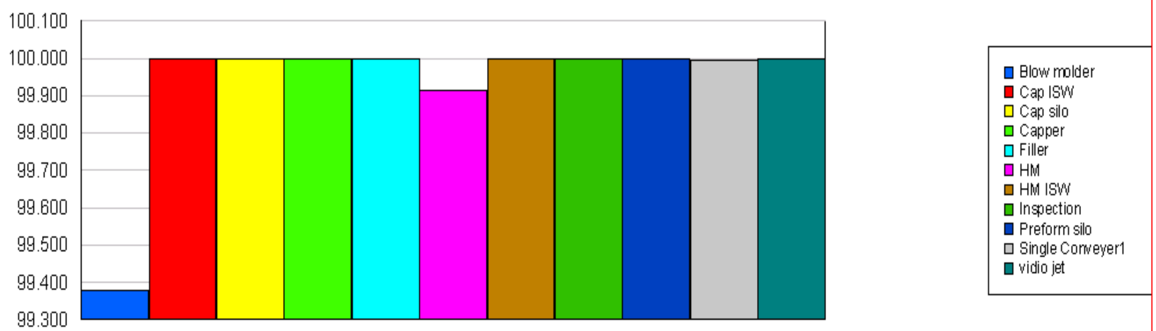


Performance Index	Value
Blow molder	89.1927
Cap ISW	89.1503
Cap silo	26.7549
Capper	89.1503
Filler	89.1503
HM	89.7487
HM ISW	89.8263
Inspection	89.1728
Preform silo	22.5565
Single Conveyer1	89.1454
vidio jet	89.1728



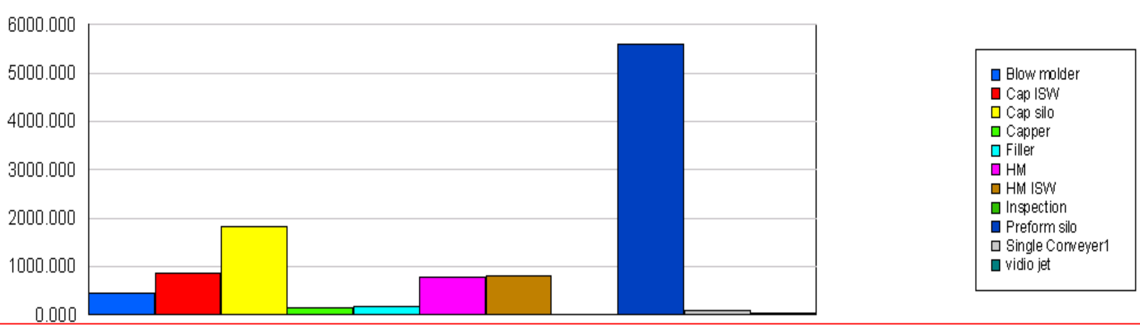
Yield

	Value
Blow molder	99.38
Cap ISW	100.00
Cap silo	100.00
Capper	100.00
Filler	100.00
HM	99.91
HM ISW	100.00
Inspection	100.00
Preform silo	100.00
Single Conveyer1	99.99
vidio jet	100.00



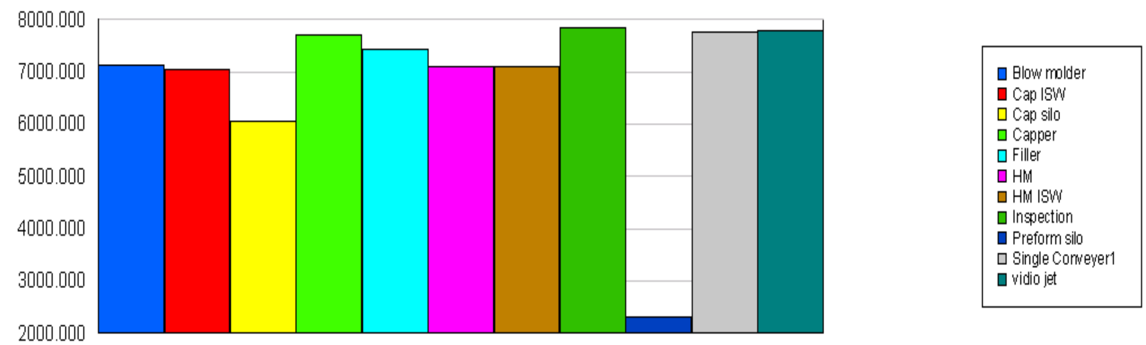
Total Time Blocked

	Value
Blow molder	465.01
Cap ISW	853.91
Cap silo	1835.88
Capper	134.60
Filler	178.49
HM	772.96
HM ISW	801.64
Inspection	0.00
Preform silo	5585.12
Single Conveyer1	93.6801
vidio jet	49.6800



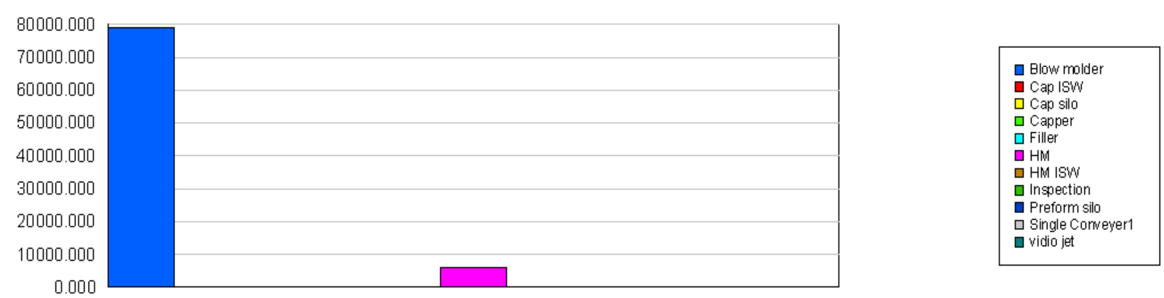
Total Time Working

	Value
Blow molder	7116.17
Cap ISW	7035.15
Cap silo	6053.18
Capper	7711.23
Filler	7436.02
HM	7091.02
HM ISW	7087.42
Inspection	7837.38
Preform silo	2303.94
Single Conveyer1	7754.43
vidio jet	7795.38



Cost of Lost Product

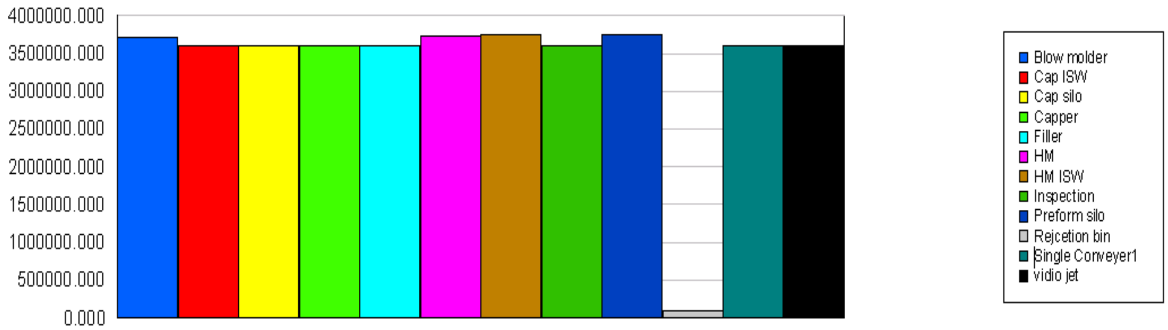
	Value
Blow molder	78948.00
Cap ISW	0.00
Cap silo	0.00
Capper	0.00
Filler	0.00
HM	5875.20
HM ISW	0.00
Inspection	11.5000
Preform silo	0.00
Single Conveyer1	0.00
vidio jet	11.5000



Appendix D: the simulation result of the improved system

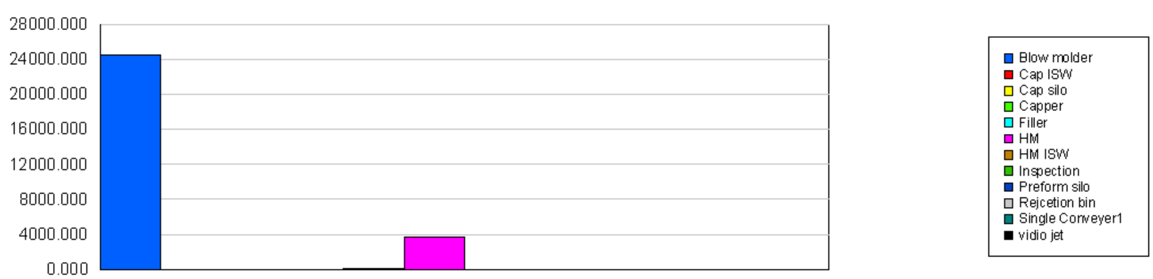
Total Good Units Produced

	Value
Blow molder	3707473.00
Cap ISW	3607124.00
Cap silo	3607974.00
Capper	3607123.00
Filler	3607123.00
HM	3731953.00
HM ISW	3735625.00
Inspection	3607123.00
Preform silo	3738901.00
Rejcetion bin	100349.00
Single Conveyer1	3607123.00
vidio jet	3607123.00

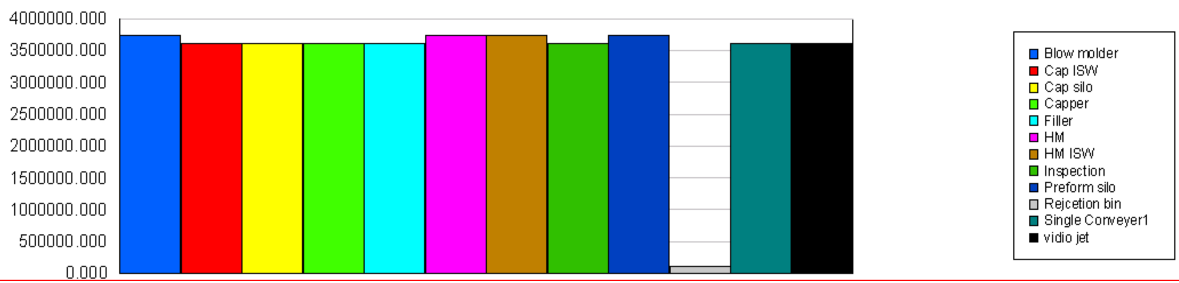


Total Units Lost

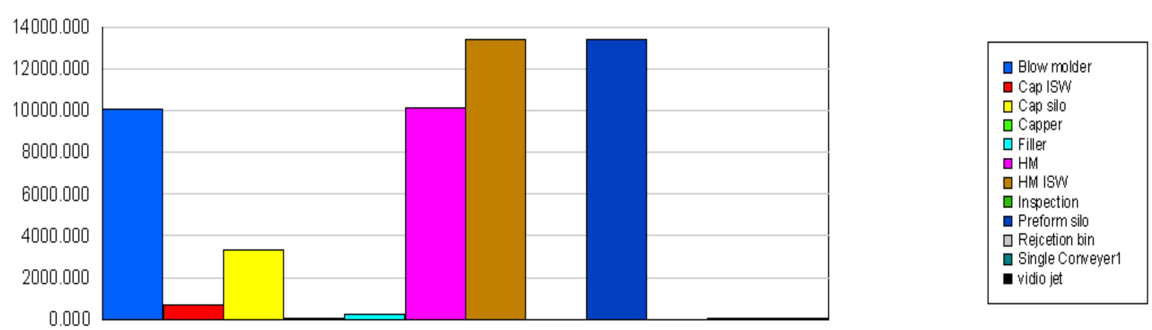
	Value
Blow molder	24480.00
Cap ISW	0.00
Cap silo	0.00
Capper	0.00
Filler	120.00
HM	3672.00
HM ISW	0.00
Inspection	1.0000
Preform silo	0.00
Rejcetion bin	0.00
Single Conveyer1	0.00
vidio jet	0.00



Total Units Processed	Value
Blow molder	3731953.00
Cap ISW	3607124.00
Cap silo	3607974.00
Capper	3607123.00
Filler	3607123.00
HM	3735625.00
HM ISW	3735625.00
Inspection	3607123.00
Preform silo	3738901.00
Rejcetion bin	100349.00
Single Conveyer1	3607123.00
vidio jet	3607123.00

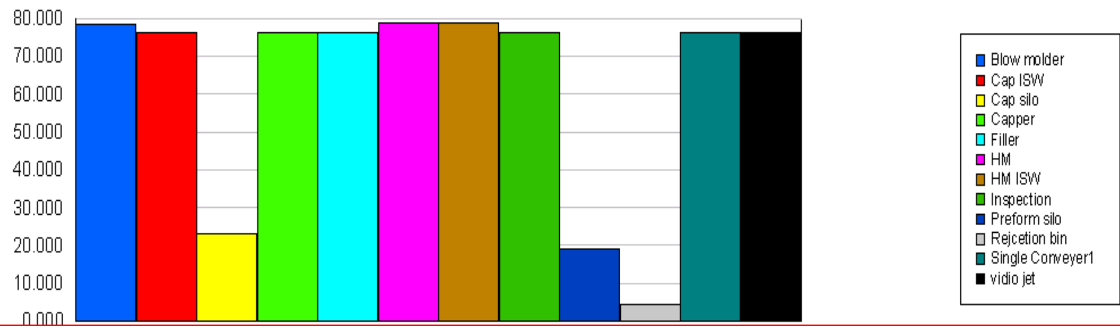


Number of Blockages	Value
Blow molder	10084.00
Cap ISW	686.00
Cap silo	3319.00
Capper	77.0000
Filler	217.00
HM	10163.00
HM ISW	13374.00
Inspection	0.00
Preform silo	13381.00
Rejcetion bin	0.00
Single Conveyer1	54.0000
vidio jet	37.0000



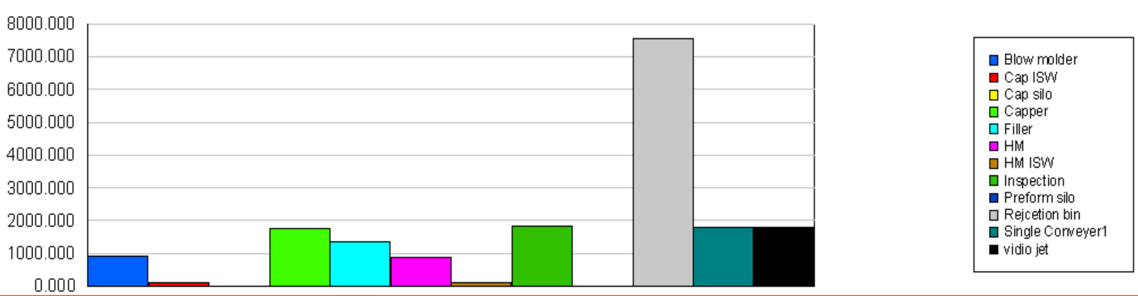
Performance Index

	Value
Blow molder	78.3252
Cap ISW	76.2052
Cap silo	22.8669
Capper	76.2052
Filler	76.2026
HM	78.8424
HM ISW	78.9199
Inspection	76.2245
Preform silo	18.9574
Rejcetion bin	4.1569
Single Conveyer1	76.2052
vidio jet	76.2245



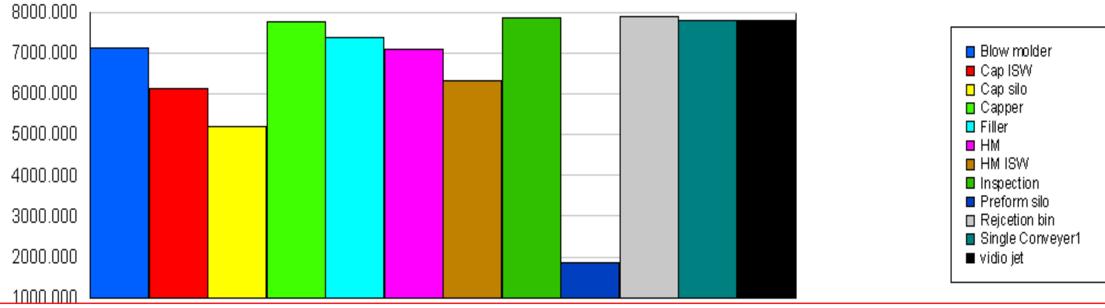
Total Time Starved

	Value
Blow molder	901.31
Cap ISW	117.55
Cap silo	0.00
Capper	1745.99
Filler	1358.08
HM	870.12
HM ISW	94.7450
Inspection	1835.03
Preform silo	0.00
Rejcetion bin	7561.12
Single Conveyer1	1776.12
vidio jet	1803.03



Total Time Working

	Value
Blow molder	7121.29
Cap ISW	6129.42
Cap silo	5207.02
Capper	7758.06
Filler	7370.15
HM	7096.16
HM ISW	6320.79
Inspection	7847.10
Preform silo	1869.90
Rejcetion bin	7889.06
Single Conveyer1	7788.19
vidio jet	7815.10



Utilization

	Value
Blow molder	78.8432
Cap ISW	76.2052
Cap silo	66.0030
Capper	76.2077
Filler	76.2077
HM	78.9199
HM ISW	78.9199
Inspection	76.2271
Preform silo	23.7024
Rejcetion bin	4.1569
Single Conveyer1	76.2077
vidio jet	76.2271