An Approach to Reduce the Manufacturing Waste & Improve The Process Cycle Efficiency of a Food Processing Industry by Using Lean Six Sigma Model

by

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CANDIDATE'S DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

This study was a case analysis of lean tools and Six Sigma methodology implementation in juice and beverage processing lines of X Food industry in Bangladesh. This work addresses the implementation of lean tools and Six Sigma methodology in the observed juice and beverage processing lines in order to evaluate present Process Cycle Efficiency (PCE), Tact time, Value Added (VD) and Non Value Added (NVD) activities and lead time and finally to develop an improved strategy to bring the improved PCE, Tact time and to reduce the lead time and NVD activities. Value Steam Map (VSM) and Pareto analysis were applied to evaluate the present and future state PCE and to find out the NVA activities. By this study the present state PCE of X mango processing line-1, X mango processing line-2, X up processing line, X energy drinks processing line, X Banana flavored juice processing line and X Litchi flavored juice processing line were found consequently as 15.28%, 12.20%, 8.32%, 8.01%, 11.32% and 10.68% that would be 34.05%, 26.91%, 19.46%, 18.84%, 25.60% and 24.45% after the implementation of lean tools and Six Sigma methodology. It is expected that after the implementation of lean tools the existing lead time of X mango processing line-1, X mango processing line-2, X up processing line, X energy drinks processing line, X Banana flavored juice processing line and X Litchi flavored juice processing line could be reduced consequently, by 55.09%, 54.64%, 57.23%, 57.44%, 55.78%, and 56.28%. By this study an economic benefit is also evaluated where it is expected that after the proper implementation of lean tools and Six Sigma methodology the total economic benefit would be 164,746,944 TK. or 2.13 million USD per year. After all the production flow was optimized by minimizing several NVD times such as bottlenecking time, waiting time, material handling time, etc. towards a lean environment establishment in management system of the studied X food industry in Bangladesh.

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LIST OF ABBREVIATION

AM = Agile Manufacturing

DFSS = Design for Six Sigma

DMADV = Define, Measure, Analyze, Design, Verify

DMAIC = Define, Measure, Improve and Control

DPMO = Defects per Million Operations

EPA = Environmental Protection Agency

GDP = Gross Domestic Product

GE = General Electric

JIT = Just In Time

LM = Lean Manufacturing

LSS = Lean Six Sigma

MDG = Millennium Development Goal

MIT = Massachusetts Institute of Technology

NVD = Non Value Added

PCE = Process Cycle Efficiency

RDMAIC = Recognize, Define, Measure, Improve and Control

SS = Six Sigma

SSQ = Six Sigma Quality

TPS = Toyota Production System

TQM = Total Quality Management

VD = Value Added

VSM = Value Stream Map

WIP = Work In Process

1. INTRODUCTION

1.1 Context and Motivation

The World is very competitive where the basic concern of a manufacturing companies is to increase their customers' satisfaction by constantly improving their delivery yet, to keep quality at its best level. At the same time, the companies need to keep their costs and prices as low as possible to be able to compete with others by keeping their profitability. In order to achieve this, a company should have a very good control on its production systems and flavor for betterments wherever possible. From previous study it is revealed that vision is as important as action to have the best control on the production system. A company should have a strong vision and clear idea of its future goals to establish the most effective production system. Lean philosophies, which were initiated in TPS, are seen as bring the revolutionary change in the mindset of manufacturers in the search of quite perfection with its effects to the actions as well as to the visions [1].

In the last century the main focus of any company was the customers. Due to global competitive business, customer's satisfaction has become more and more competitive to manufacturers lead time is defined from the time a customer release an order until the time they receive the finished product [2]. Consequently, to execute the business in a global market, short lead times become the essential key to provide customer satisfaction. Organizations that have focused on cycle time as a productivity measure can reduce delivery time and improve quality, thereby creating more satisfied customer.

Before 1980, customers tolerated long lead times which enabled producers to minimize product cost by using economical batch sizes. Later, customers began to demand shorter lead times and searching the alternative producers, where, they were able to get their product or service earlier. This is when the problem arose and companies started to look for changes to be more competitive. As soon as manufacturers focused on processes, they found waste associated with changeovers, quality defects, process control, factory layout, and machine down time. In an attempt to reduce lead time, businesses and organizations found that in reality 90% of the existing activities are non-essential and could be eliminated. So they tried to find ways to reduce or eliminate waste. By eliminating the NVD activities from the processes and streamlining the flow of value towards the finished products and services significant optimization results can be realized [3].

To compete with the international company, the manufacturing waste would be reduced by keeping the improved PCE. Consequently with the endeavor of a number of reverent personnel, several number of new philosophies for manufacturing improvement have been developed, which include, LM, SS, AM and DFSS. Lean tools and SS would be potentially effective to reduce the lead time and increase the PCE. Lean manufacturing is a generic process management philosophy derived mostly from the TPS in the 1990s and identified as "lean". The implementation of lean tools is focused on getting the right things to the right place at the right time in the right quantity to achieve perfect work flow, while minimizing the waste [4].

Food industry is a booming and one of the largest manufacturing sectors in Bangladesh. In the World it is the second largest manufacturing industry. Based on raw material, geographical condition and work force Bangladesh is highly favorable for the growth of food industry. The demand of processed foods is rapidly increasing in the busy World and consequently, it seems a rapid expansion of food industry in Bangladesh as like as other countries. It needs several processing steps to produce the finished goods from raw materials. The delay and manufacturing wastes is the common seen at every processing unit of food industry and thus the efficiency of production is very low with long lead time. In this regard to minimize and remove NVD time and works the author was invigorated to apply the lean tools and SS in one of the largest food processing industry X of Bangladesh.

1.2 Origin of Lean Philosophy

Empirically lean thinking and lean enterprise started in Japan, with the attempts of the Toyota Motor Company to become a promising leader in the auto mobile manufacturing business thus surpassing American companies like Ford or General Motors. The concepts and principles of what later was going to be known as the lean enterprise model, that had demonstrated their convinced effect in the auto industry in Japan, where were later researched and documented by members of the International Motor Vehicle

Program at the MIT. Based on the results from that research the landmark book 'The Machine that Changed the World' was published in 1990. The book extensively covered the principles and practices of TPS where lean philosophies were successfully applied to the production of cars, and compared those with the more traditional methods of American and European companies. A remarkable change was required to regain competitiveness in the World market and the lean production model and its subsequent lean enterprise was the answer to that required change.

It was soon reasoned that the same methods were applicable to other industries and businesses as well. One of the most important movements towards lean implementations was done by American aerospace industry, a highly competitive and complex business environment. MIT' s lean Aerospace Initiative, a joint effort of the industry, government and academia, was created almost a decade ago to respond to the lean implementation needs in the aerospace industry that was willing to project effectively to the 21st century. A lean enterprise is an integrated entity which efficiently creates value for its multiple stakeholders by employing lean principles and practices [5].

1.3 Socio-Economic Importance

The core goal of our entire endeavor is the happiness where a mother or a father evens a brother or sister of someone's are sacrificing hours after hours to bring the happiness in their personal and family life. But alas! Once upon a time this happiness was a dream rather than virtual, especially to the rural peoples of Bangladesh which could be lucid if we observe the socio-economic indicators of last two decades. In World Development Report, 2008 it is revealed that the Socio-economic indicators of Bangladesh such as GDP, life expectancy, literacy and levels of employment are positively increasing and beyond this agriculture are keeping a great contribution and this credit goes to food industry, because agriculture is the key tool for socio-economic improvement and food industry is the core wheel of agricultural embodiment.

It is a riveting matter that every year huge amount of fruits & vegetables are produced in Bangladesh which are the pivotal raw material of food industry and consequently, the number of food industry are increasing so rapidly that at present there are near about 100 food industry, where more than 10 million peoples of Bangladesh are directly and indirectly involved to conduct their livelihood. Food industry brings the noteworthy socio-economic changes in the impoverished peoples of Bangladesh by giving a big employment and bringing the happiness. This will be more improved and dynamic if the lean production and SS concept is involved in the food industry which is proved after the implementation of lean tools and SS methodology in different manufacturing industries over the World.

In the 21st century, food industry continues to be a fundamental instrument for sustainable development and poverty reduction, where lean thinking will be able to add a new impressive proportion in the development of food industry which could also be considered as the promoter and imperative for meeting the MDG of reducing poverty and hunger by 2015. We know that an idle head is the source of all evil deeds like drug-addiction, prostitution, armed robbery and other forms of criminal activities which were the frequent incidents basically before the establishment of food industry and food business and if lean production is adopted the profit will must be increased and by this the growth of food industry will be flourished and consequently, the socio-economic status will also be improved at least by suppressing the evil deeds of our growing youth.

The life improving social amenities like tap water, medical facilities, accessible roads, electricity, etc. are indirectly but radically developing due to the establishment of food industry where lean and SS could be more impressive integrated part for prompt rise of more immense productive food industry.

The agribusiness and different kind of food industries are very important components of Bangladesh economy as well as for socio-economic condition because of, a big number of indigent and rural mid level peoples are engaged with these industries and consequently, rise and fall of food industry immersed with the sorrow and happiness of those peoples. With a rich natural resource and favorable growing climate, food industry could keep a vital socio-economic importance in Bangladesh. But it’s a piteous matter that by ignoring the booming scope, the proper development in food industry is still at infancy stage in Bangladesh as compared to other developing countries, where lean tools and SS will be a harbinger beyond the proper development of food industry and thus to socio-economic development of involving human being.

1.4 Thesis Objectives

Firm goal or objective is the prime key beyond the success of any endeavor. There is a maxim that “a fickle minded person can do nothing in his life” and similarly with a fickle or fragile objective a thesis work can bring nothing in the success. So, the author of this thesis paper was headstrong with some specific objectives.

The objectives of this study were-

i. To identify and quantify the manufacturing waste
ii. To formulate the present VSM of the process lines
iii. To calculate the VA time and NVA time of process lines
iv. To calculate the present and future PCE
v. To formulate the future VSM of the process lines by using tools & strategies of LSS model in order to reduce the manufacturing waste & lead time and improve the PCE

1.5 Research Approach

The initial step in this research is to systematically study and define the history of the lean manufacturing concept and its different tools and techniques. It will then examine some most used lean manufacturing tools and techniques. This will be followed by the study of the existing production system of the case company for example the existing production layouts, existing manufacturing waste, inventory movement systems, identification of VD and NVD works and times and other different variables which needs to be improved for the betterment of the existing system. The author endeavored to address the current issues of the industry to find out the standard operation time for each operation.

1.6 Thesis Outline

The whole report consists of seven chapters. The first chapter describes the need of the research, research objectives and research approach. Lean concept development with lean manufacturing, lean thinking and common using lean tools are described in chapter two. Concept of SS with its beneficial application in industrial process and some important SS and strategy are described in third chapter. Chapter four is embellished with the LSS involvement in different industry at different corner of the World. The research methodology for this research work is described in chapter five. Chapter six is gathered with the result and discussion of this research work. Chapter seven is the final chapter of this study which is contained with the conclusion, recommendation and limitation of this research work.

2. LEAN CONCEPT REVIEW

2.1 Definition of Lean

Once upon a time the word “lean” was unknown to us, but over the time it has become the most popular jargon which is associated with the lowest cost, highest quality, shortest lead time and with the desirable outcomes of any manufacturing company. The word lean is considered as an approach comprises of a set of tools and practices, which aim to improve efficiency of production line, quality of products and service of any organization and finally the responsiveness to customers. A number of researchers, scientists, engineers and institutions have given the definition of “lean” or “Lean Manufacturing”. From a huge number of definitions of lean, a very few definitions are given in this chapter.

Lean is defined as a comprehensive set of techniques which in combined allows to reduce and eliminate the wastes that makes the company leaner, more flexible and more responsive to customers [6].

Lean is a systematic approach to identifying and eliminating waste through continuous improvement by flowing the product or service at the pull of your customer in pursuit of perfection [7].

EPA (2009) defined the lean as an approach that is used in order to develop the highest quality of products, at the lowest cost, with the shortest lead time by systematically and continuously eliminating waste, while respecting people and the environment.

Lean is considered as a set of tools to create the value to the customer with little or no waste existing in operation [8].

2.2 Lean Principles

With focusing on the improvement of process, product or service, a number of set of lean goals and principles is formed by different engineers, researchers and institutions. Lean principles are defined as a series of actions that must be conducted properly in the proper sequence at the proper time to create value for a customer [9]. Different organizations and different researchers are given the lean principles at different ways, keeping the same focus on process improvement.

Lean principles which were given by the "Lean Enterprise Memory Jogger" as- improving quality, eliminating waste, reducing lead time and reducing total cost of a process [10].

The description of Lean principles were given as-

1. Specify what does and does not create value from the customer's perspective and not from the perspective of individual firms, functions and departments
2. Identify all the steps necessary to design, order and produce the product across the whole value stream to highlight non value adding waste
3. Make those actions that create value flow without interruption, detours, backflows, waiting or scrap
4. Only make what is pulled by the customer
5. Strive for perfection by continually removing successive layers of waste, as they are uncovered [11]

The lean principles were mentioned in the book of "Lean Thinking" as follows-

i. Specify value
ii. Identify the value stream
iii. Smooth process flow
iv. Production based on pull, and
v. Perfection through elimination of muda or waste [8]

In 2009, "Lean Enterprise Institute" assigned five lean Principles as follows-

1. Specify the value of customer requirement
2. Identify the value stream for productions and reduce the waste steps
3. Make sure the remaining valued-added steps can work continuously
4. Introduce pull between steps that are possible for continuous flow
5. Conduct perfect management and eliminate the number of steps, the time and information

It is required less resources to produce products throughout the lean principles as compared to conventional manufacturing principles with some alluring benefits as like as-

- Productivity gains of 300-400%
- Labor productivity increased an average of 25% a year
- Defect rates reduced from more than 2000 to less than 50 parts per million (PPM) and in many to less than 10 PPM.
- Cost of quality cut by over 60%
- Work-in- process inventory slashed by more than 80%
- Revenue per 1000 square feet of factory space was raised 350% [12]

Different set of lean principles focus the common goals of manufacturing of any organization, although these are derived from different sources. To be a lean enterprise, an enterprise needs a specific way of thinking, philosophy and management system. For example Toyota Company was well-known as lean enterprise due its specific philosophy of production which was consisted by following “4P” model. The book “The Toyota Way” with fourteen principles presented the foundation of getting lean at TPS. In this book these fourteen principles were categorized into four all starting with the letter “P” – Philosophy, Process, Peoples and Partners, and Problem Solving. This becomes known as so called “4 P” model of Toyota [13].

2.3 History of Lean

It is well-known that lean started at Toyota in Japan, although Henry Ford had been used similar concept about lean in early 1920’s which established ever the first assembly line in 1913, achieved the production of a vehicle within four minutes with the great success in the market with lower prices [14]. During the World War II the economy of Japan destroyed heavily. To remove this economic situation Toyota conducted a research to induce an approach to remove the manufacturing waste and to reduce the NVD activities and times because of the situation was too much hard to reinvestment in order to produce the profitable production as well as to be internationally competitive [15]. At the same time, Toyota realized that investing in people is more important than investing in bigger size machinery and continues employee training throughout the organization. This motivates all employees and they are more open to the improvement process and everyone started giving their input to the company. Consequently, in 1950, Toyota produced 2,685 vehicles, a tiny fraction of what American manufacturer Ford was producing per day, around 7,000 cars, but later forty years, with 37,000 employees, Toyota was producing four million cars per year, half of General Motors' production of eight million units where the remarkable difference was lean approach [16]. As a result of lean implementation Toyota averaged 45 assembly defects per 100 cars while GM's averaged 130 assembly defects per 100 cars. Following these consequences, lean approach is now well known as a set of promising manufacturing tools which was developed by Taiichi Ohno, Shigeo Shingo and Eiji Toyoda developed the system between 1948 and 1975 [16].

In 1988, the term "lean" was only first coined by John Krafcik, an engineer at the NUMMI, Toyota - GM joint venture. Finally, Toyota established an approach that consisted of a set of tools to reduce the manufacturing waste and to improve the economic situation [9]. Over the time, lean approach was consolidated into a new approach to operations that formed the basis of lean or Toyota Production System which is widely using in the manufacturing World.

2.4 Lean Manufacturing (LM)

After the implementation of lean tools in any manufacturing unit is termed as lean Manufacturing (LM). It is a widely accepted and adopted approach across industries over the World. The ultimate goal of a LM is to create a smooth, high quality finished products at the rate of customer demand in the quality looked-for with slight or no waste. The implementation of lean tools resulted in more efficient and cost effective manufacturing.

There are different manufacturing approaches where LM is one of the most successful philosophies, based on records from other industries such as automobiles, aerospace or pharmaceuticals [10]. The basic principle of LM is reducing all the NVD activities and wastes in the whole supply chain to accomplish high quality, reliability products at an appropriate cost, and to gain the highest profit and reputation at the same time [17].

LM is defined as an initiative, whose goal is to reduce the waste in human effort, inventory, time to market, and manufacturing space to become highly responsive to customer demand while producing world class quality products in the most efficient and economical manner [18].

The lean operating system follows certain principles to deliver value to the customer while minimizing all forms of loss. Each value stream within the operating system must be optimized individually from end to end. Lean tools and techniques are applied selectively to eliminate the three sources of loss: waste, variability and inflexibility [19].

In order to attain the LM the organization should have strong customer focus, should be willing to remove wastes from the processes they operate on daily basis and should have the motivation of growth and survival. The author of this thesis work was endeavored to bring the LM by reducing different forms of loss like waste reduction, removable of NVD activities, unwanted motion of labors from the existing production floor with the smooth implementation of lean tools.

2.5 Manufacturing Waste

A number of researchers and regarding peoples have been given the definition of manufacturing waste where they mentioned that based on lean philosophy the manufacturing waste can be of various types. Waste was defined as any human activity which absorbs resources, but creates no value; they indentified eight primary types of manufacturing waste. These are:

i. Mistakes
ii. Rectification (of mistakes)
iii. Production of items no one wants (as a result, inventories and remaindered goods pile up)
iv. Unnecessary production steps

v. Unnecessary movement or transport of employees

vi. Unnecessary movement or transport of goods

vii. People waiting downstream

viii. Goods or services that do not meet the customer's needs [8]

Unused employee creativity was also added to the list of the eight types of waste. These wastes reduce production efficiency, quality of work as well as increase production lead time [13]. Different kinds of wastes in a process can be categorized in following categories.

1. Overproduction – Producing items more than required at given point of time i.e. producing items without actual orders creating the excess of inventories which needs excess staffs, storage area as well as transportation etc.

2. Waiting – Workers waiting for raw material, the machine or information etc. is known as waiting and is the waste of productive time. The waiting can occur in various ways for example; due to unmatched worker/machine performance, machine breakdowns, lack of work knowledge, stock outs etc.

3. Unnecessary Transport – Carrying of Work In Process (WIP) a long distance, insufficient transport, moving material from one place to another place is known as the unnecessary transport.

4. Over processing – Working on a product more than the actual requirements is termed as over processing. The over processing may be due to improper tools or improper procedures etc. The over processing is the waste of time and machines which does not add any value to the final product.

5. Excess Raw Material - This includes excess raw material, WIP, or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs, and delay. Also, the extra inventory hides problems such as production imbalances, late deliveries from suppliers, defects, equipment downtime, and long setup times.

6. Unnecessary Movement – Any wasted motion that the workers have to perform during their work is termed as unnecessary movement. For example movement during searching for tools, shifting WIP, etc.

7. Defects – Defects in the processed parts is termed as waste. Repairing defective parts or producing defective parts or replacing the parts due to poor quality etc. is the waste of time and effort.

8. Unused Employee Creativity – Loosing of getting better ideas, improvement, skills and learning opportunities by avoiding the presence of employee is termed as unused employee creativity [20, 21].

All these form of manufacturing wastes could not be seen all together in the same manufacturing floor. In this thesis work the work had been identified three types of waste like defect product production, unnecessary movement of labor and waiting time or down time which were identified and quantified in chapter six.

2.6 Lead Time

Lead time is the total required time or a period of time that is required in order to produce certain amount of product. Lead time could be defied from various sources.

Lead-time is the time elapsed in between the receipt of customer order until the delivery of finished goods to the customer [22].

Lead-time is made up of several components besides the fabricating itself: (information) moving time, waiting time, setup time, lot size, and rework time [23].

Lead-time also includes the order transit, supplier lead-time, order preparation, delivery time and set-up time [24]. Furthermore queue time was also added to the lead time [25].

There are different types of lead time. Lead time is consisting of some factors like Moving time, Order transit/ Conveyance, Set-up time, waiting time, Supplier lead time / delivery time, Queue time and Order preparation.

Factor (Information) of Lead time	Definition
Moving time	It was defined as the time needed for moving products, goods or assemblies or information within or between organizations, departments and processes [26].
Order transit/ Conveyance	Transit time is occurred between manufacturers and retailers [27] and conveyance is the movement of goods [28].
Set-up time	Set-up time is the sum total of all of the internal setups involved in processing job [25].
Waiting time	Waiting time was defined as Inventories of goods waiting further processing or consumption [29 & 30]. Furthermore, it is also considered as the time between the arrival of the part and the time it is needed for assembly [31].
Supplier lead time / delivery time	Supplier lead time/ delivery time was defined as “the time that lapses between the time an order is received by a supplier and his shipment of the items” [32]. Later has the same definition, but includes transport time (order transit) from supplier to the customer organization.
Queue time	Queue time is the time spent waiting in line for work centers to become available [25].
Order preparation	Order preparation is the time that is needed between receiving a customer order and starting the processing of that specific order [33].

According to Business Dictionary lead time can be defined as the number of minutes, hours, or days that must be allowed for the completion of an operation or process, or must elapse before a desired action takes place [34]. It is a time period between the order and delivery of a new product or service.

In a broad sense lead time terminology has been defined in greater detail as-

- Order lead time
- Processing lead time
- Delivery lead time
- Manufacturing lead time
- Production lead time

Each lead time is using with specific concern and purposes based on the nature of industries. In this study the processing lead time was considered as lead time. Processing lead time is the time period that is required to process or produce an item or to produce a batch production of an item.

2.7 Cycle Time

Cycle time is defined as how frequently a finished product comes out of a production facility [35]. Cycle time includes all types of delays occurred while completing a job. So cycle time can be calculated by the following formula.

Cycle time = processing time + set up time + waiting time + moving time + inspection time + rework time + other delays to complete the job.

To meet customer demand or monitor productivity the Cycle time and Tact time should be balanced in parallel. The higher cycle time as compare to Tact time may result the late delivery and customer dissatisfaction whereas shorter Cycle time than Tact time may cause the excess inventory or excess use of resource.

2.8 Lean Tools

LM consists of a large number of tools and techniques. Twenty two LM practices are frequently mentioned in literatures and categorized them into four bundles associated with Just-in-Time, Total Quality Management, Total Preventive Management and Human Resource [36, 37]. Some other researchers also categorized the lean tools and techniques according to the area of implementation such as internally and externally oriented lean practices [37, 38]. For example, lean practices were divided into six areas which are process and equipment; manufacturing, planning and control; human resources; product design; supplier relationships; and customer relationships [39]. The first four areas are grouped as internal oriented lean practices, whereas supplier relationships and customer relationships are under external oriented lean practices. But the most frequently used lean tools are Value Stream Mapping, Process Cycle Efficiency, 5S, Kanban, Poka-yoke, Key performance indicators, Overall Equipment Effectiveness, Ishikawa diagram and Spaghetti diagram [40].

Throughout this study Value Stream Mapping, Process Cycle Efficiency, 5S, Kanban and Overall Equipment Effectiveness were applied in order to attain the objectives of this research work.

3. CONCEPT OF SIX SIGMA

3.1 Genesis of Six Sigma (SS)

Once upon a time about 1920's the word 'Sigma' was used by mathematicians and engineers as a symbol for a unit of measurement in product quality variation. In the mid-1980s, SS is developed by Motorola as a customer-centric system to produce almost defect free products by minimizing variability on their respective processes. SS can be viewed as a metric, as a methodology and as a business initiative. In 1995, Jack Welch made the SS as a central focus of his business strategy at GE, later it became well known and today it is used in different sectors of industry.

Besides Motorola and GE, other major corporations have embraced SS including AlliedSignal, Lockheed-Martin, Polaroid, and Texas Instruments. Although SS is originated within manufacturing in the electronics industry, but it has been implemented across many other industries and has spread into the service sector, even though in a few government organizations [41].

At present, SS is considered as a global brand and something of a revolution to the manufacturing World. The maturity of a manufacturing process can be described by a sigma rating indicating its yield or the percentage of defect-free products it creates. A SS process is one in which 99.99966% of the products manufactured are statistically expected to be free of defects, 3.4 DPMO.

3.2 Definitions of SS

From many aspects of quality of any product or service SS is a very promising way of branding and packaging. Over the time, SS brings the different meanings from different corners in case of defect free production of manufacturing World and still now it is evolving with new dimension with its meanings and application.

By SS it is referred to the philosophy, tools, and methods used to seek, find, and eliminate the causes of defects or mistakes in business processes by focusing on the outputs that are important to the customers [42, 43]. It is not a single thing rather than a set of tools and strategies for process improvement [44]. It is also represents a highly disciplined and statistically based approach to quality [41].

The Department of Trade and Industry, UK (June, 2005) said that SS is a data-driven method for achieving near perfect quality. By this method it is focused on the production or service of any element with a strong emphasis on statistical analysis in design, manufacturing and customer-oriented activities.

The SS is considered as a well-structured continuous improvement methodology to reduce process variability and remove waste within the business processes [44-46].

It is defined as a set of statistical tools adopted within the quality management to construct a framework for process improvement [47]. It is also considered as an operational philosophy of management which can be shared beneficially by customers, shareholders, employees and suppliers [48, 49].

SS methodically analyzes underlying data and identifies the root causes of problems as opposed to using subjective opinions. Hence, every step in a process represents an opportunity for a defect to occur, SS seeks to reduce the variation in these steps, which results in the occurrence of fewer defects and the production of higher quality goods and services. By controlling this variation, SS prevents defects from occurring rather than simply detecting and correcting them.
SS intends to help companies to survive in a competitive environment by creating cost savings, improving customer satisfaction, and improving organizational competence for innovation and continuous improvement.

3.3 Central Concepts of SS

Defect production is a common scenario of any manufacturing company, but it’s a concerning matter that what the amount or volume of defect? Is that amount or volume is acceptable or not? With the help of SS rating these questions answer can be achieved. In SS, a defect is defined as any process output that does not meet customer specifications, or that could lead to creating an output that does not meet customer specifications [50].

It is well known that ordinary businesses actually operate at between three and two sigma performance where the defect products are aligned approximately between 66,800 and 308,500 DPMO. A measurement of four sigma equates to approximately 6,200 DPMO, or around 99.4% perfection, this range of perfection of production would arguably be an acceptable level of quality in certain types of business, for instance a roadside cafe, but a 99.4% success rate is obviously an unacceptable level of quality in other types of business, for example, passenger aircraft maintenance. A measurement of five sigma equates to just 233 DPMO, equivalent to a 99.98% perfection rate, and arguably acceptable to many businesses, although absolutely still not good enough for the aircraft industry and pharmaceutical industry. A measurement of SS equates to just 3.4 DPMO, equivalent to a 99.99966% perfection rate, which is widely accepted by whole manufacturing World including aircraft and pharmaceutical industry [50].

Here's a simplified one-to-six sigma conversion scale:

'Long Term Yield' (basically the percentage of successful outputs or operations) %	DPMO	'Process Sigma'
99.99966	3.4	Six
99.98	233	Five
99.4	6,210	Four
93.3	66,807	Three
69.1	308,538	Two
30.9	691,462	One

It is very important to keep in mind that an 'operation' is not limited to the manufacturing processes - an 'operation' can be any process critical to customer satisfaction, for example, the operation of correctly understanding a customer request, or the operation of handling a customer complaint. SS is not restricted to engineering and production - it potentially covers all sorts of service-related activities. What matters is that the operation is identified as being strategically critical and relevant to strategy and customer satisfaction.

3.4 Tools and Techniques of SS

Over the years, companies have developed a number of tools into the approach of SS to make them more effective and to eliminate possible gaps after its application. This tool set includes the statistical and analytical tools both from industrial engineering and operations research fields [51]. Many tools and techniques that can be applied to SS projects are available both in the literature and public arena [52]. Tools of SS are also available in various forms such as models, analysis templates and procedures [53].

It is an important aspect to select the right tools or techniques of SS when embarking any SS project. Different tools and techniques of SS are used for different aspect, so it is important to apply the right tool in the right situation in order to achieve successful results. The output of SS depends on the proper implementation of tools and techniques of SS. Sometimes it seems that simple tools are enough to reduce the defects of a complex manufacturing system [54].

Inspired by Deming's Plan-Do-Check-Act cycle SS projects follow two project methodologies. These methodologies, composed of five phases, each assumes the acronyms DMAIC and DMADV. DMAIC is used for projects aimed at improving an existing business process while DMADV is used for projects aimed at creating new product or process designs [55].

3.5 DMAIC

The DMAIC project methodology has five phases:

- **Define** the problem, specifically identify the voice of the customer, and the project goals;
- **Measure** key aspects of the current process and collect relevant data;
- **Analyze** the data to investigate and verify cause-and-effect relationships. Determine what the relationships are responsible for the problem, and attempt to

ensure that all factors have been considered. Seek out root cause of the defect under investigation;

- **Improve** or optimize the current process based upon data analysis using techniques such as design of experiments, poka yoke or mistake proofing, and standard work to create a new, future state process. Set up pilot runs to establish process capability;
- **Control** the future state process to ensure that any deviations from target are corrected before they result in defects. Implement control systems such as statistical process control, production boards, visual workplaces, and continuously monitor the process;

Some organizations add a recognize step at the beginning, which is to recognize the right problem to work on, thus yielding an RDMAIC methodology [55]. The DMADV project methodology, known as DFSS features five phases [56]:

- **Define d**esign goals that are consistent with customer demands and the enterprise strategy.
- **Measure** and identify CTQs (characteristics that are Critical to Quality), product capabilities, production process capability, and risks.
- **Analyze t**o develop and design alternatives, create a high-level design and evaluate design capability to select the best design.
- **Design** details, optimize the design, and plan for design verification. This phase may require simulations.
- **Verify t**he design, set up pilot runs, implement the production process and hand it over to the process owner(s).

Within the individual phases of a DMAIC or DMADV project, SS utilizes many established quality management tools that are also used outside SS. The following table shows an overview of the main methods used in different regarding research work.

- 5 Whys (five iterations of asking why is generally sufficient to get to a root cause)
- Analysis of variance
- ANOVA Gauge R&R
- Axiomatic design
- Business Process Mapping
- Cause & effects diagram (also known as fishbone or Ishikawa diagram)
- Check sheet
- Chi-squared test of independence and fits
- Correlation
- Cost-benefit analysis
- CTQ tree (critical-to-quality tree)
- Design of experiments
- Failure mode and effects analysis (FMEA)
- General linear model
- Histograms
- Pareto analysis
- Pareto chart
- Process capability
- Quality Function Deployment (QFD)
- Quantitative marketing research through use of Enterprise Feedback Management (EFM) systems
- Regression analysis
- Rolled throughput yield
- Root cause analysis
- Run charts
- Scatter diagram
- SIPOC analysis (**S**uppliers, **I**nputs, **P**rocess, **O**utputs, **C**ustomers)
- Stratification
- Taguchi methods
- Taguchi Loss Function

Many of the publications suggest the DMAIC and DFSS methods as the two most common methodologies to implement SS, although the main objectives of the two techniques are quite different. They also stated that while DMAIC is a problem-solving method which aims at process improvement, DFSS is a process to define, design and deliver innovative products provides competitively attractive value to customers in a manner that achieves the critical-to-quality characteristics for all the significant functions [57]. It is therefore, clear from this definition that DFSS is used in the context of new product development that focuses on quality from the very beginning.

3.6 Benefits of SS

There are many benefits that can be derived from the adoption of Six Sigma. It could enhance product development cycles and process design, shorting product lead times by reducing the cycle time of the overall manufacturing process. The advantages of SS implementation are the increased market share and higher profit margins [58]. SS can be used to find and eliminate the root causes of the problem in the process in order to prevent defects. Reduced costs, reduced project time, improved results and improved data integrity are some of the benefits of SS suggested [54]. Actually, the methodologies of SS provide the guidelines which could help the managerial personnel as well as workers to understand how to carry out the job and train them to solve potential problems and consequently, they become more aware of the production process thereby improving their morale and reducing the human-related defects [59]. With respect to the role of SS in reducing the defects, it has been demonstrated in several studies that the defect rate per unit is reduced after its implementation in manufacturing systems [60].

The adoption of SS has improved both the efficiency of the line and the production capability, including minimizing waste such as reduced need for inspection, removed useless components and excessive movements and decreased time for repair [61]. For this reason, SS can be used to build predictive models based on experiences gathered from earlier uncorrected measures to ensure a continuous improvement of the process [62]. In recent years, knowledge management has contributed to facilitate the implementation of SS and has emerged as a source of competitive advantage within the businesses [63]. SS is also recognized as a strategy that drives the cultural change to improve profitability of the company increasing the benefits from savings generated when the defect is detected at a very early stage [64].

The approach to SS varies between organizations because they integrate different techniques according to their needs, so there might be disagreement regarding the benefits as they depend on the industry and even the country where SS is applied [65]. SS also helps in improving the relationships between the outside and inside of the organization [60]. It can strengthen the customer loyalty by satisfying their needs and expectations and it works as a direct link to company’s management which helps establish a common language from the board to the shop floor. It has many benefits and, unsurprisingly, the most frequently cited are the reduction and prevention of defects which affect the quality of both products and processes.

4. LEAN SIX SIGMA INVOLVEMENT IN INDUSTRIES

4.1 Lean Six Sigma (LSS) model

LSS is a combination of two popular promising philosophies for industrial establishment- lean and SS. Typically lean and SS concentrate on improving the production and transactional processes of an organization. Although each uses different tools and methodologies to stimulate the improvement, both have complementary effects. Each of these methodologies has been individually popularized by successful implementations at companies such as Toyota, General Electric, and Raytheon. Many companies are now recognizing the powerful synergy that is produced when these two methodologies are combined and have successfully implemented lean or SS [66]. The principle of LSS is "the activities that cause the customer's critical-to-quality issues and create the lowest time delays in any process offer the greatest opportunity for improvement in cost, quality, capital, and lead time" [67]. This prim highlights is the strength of focusing on customer needs and shortening lead times. Although lean and SS focus on different improvement goals, the reduction of waste and process variation, a thorough analysis of each method shows that the methods complement each other. While the fundamental principle of SS is to take an organization to an improved level of sigma capability through the rigorous application of statistical tools and techniques, lean production has a role in eliminating waste and NVD activities across the entire supply chain [68]. The theories guiding lean and SS methodologies are different but complementary. While lean concentrates on the identification and elimination of waste, SS seeks to reduce process variation. Lean removes the NVD and SS adds value to the VD step of the process by reducing variation. Lean tools focus on removing the waste that will speed up the process thereby improving business performance while SS methodologies focus on reducing the variations of that process towards promising the business performance; ultimately both seek to improve the process.

LSS can be involved at any employee's desk as an individual contributor to a company. Without sacrificing or modifying policies of any company or enterprise, LSS can be implemented to the entire department. It is applied for faster, better and more cost-effective production of any product or service.

4.2 Involvement of LSS in Industries

With the flow of time and iridescent aptitude of consumer, today's manufacturing industries are undergoing more and more competition in local and global marketing system to come up with the desired product or service within a limited period of time. The comedy in competitive marketing environment is "Timing". Whatever the quality, price of the goods, the distance of origin of production, just important thing is "Be there by time with the product". Otherwise someone will get the proof of the adages "What falls behind is left behind". To keep themselves competitive in global business environment different types of companies from different corners of the World have been involving with the lean thinking by making lean production.

The methodologies of LSS have been successfully applied in many manufacturing organizations such as General Electric, Boeing, DuPont, Kodak, Honeywell, Texas Instruments, etc. From literature review, it is seen that along with the manufacturing LSS is also successfully applied in hospitals, pharmaceutical, housing and paper industry [69]. It is estimated that throughout the World by adopting LSS in pharmaceutical industry a cost could be saved up to $ 90 billion per year [69]. In 1999, Motorola University calculated that LSS significantly brought the benefits of $ 20 billion to Motorola Inc. since 1986. The success story of Motorola inspired many companies in various industrial sectors to adopt LSS. In 1995, Jack Welch, the CEO of GE, further expanded the application of LSS by adopting the techniques in GE. During the first five years of the implementation, GE roughly gained a benefit of $10 billion. Several hospitals in different countries have been started to work with LSS and savings obtained with these projects ranges from $57,000 to $229,000 annually [26, 52, 70]. In USA, it is reported that a food manufacturing industry has gained the benefit of $2 million per year by adopting lean tools [71].

From a literature it is seen that the programs of SS have been brought the promising financial impact in a number of companies over the World. For example, with the involvement of SS programme, Volvo Cars in Sweden has been gained more than 55 million Euros from its normal gain during the time between 2000 and 2002 [72, 73]. The Business Unit of Transmission & Transportation Networks at Ericsson located in Bora's, Sweden is the another company that has been successful in profit maximization with the successful involvement of SS programme. With 1,100 employees the Ericsson in Bora's started their SS programme in 1997. It was at Ericsson where SS was firstly defined towards solving the problems. Today, they consider SS as a business excellence model rather than a methodology in order to reach at their business goals. Ericsson in Bora's has been executed approximately 50 Black Belt projects and 200 Yellow Belt projects which have been brought with a savings of approximately 200-300 million Euros between 1997 and 2003 [73].

In 2008, Motorola University stated that between 1986 and 2007, Motorola Inc. has been saved over $20 billion dollars and the Return on Investment (ROI) has been between 10:1 to 50:1. It was showed that a frozen fish industry would able to improve its PCE from 5.02% to 17.46% by adopting LSS model [74].

By this study the author was also tried to bring the economic benefit or improved production by using efficient lean tools and SS methodologies in one of the largest food industry, X of Bangladesh.

5. RESEARCH METHODOLOGY

Throughout this study, it was endeavored to demonstrate the application of lean tools and SS methodology into the juice and beverage sector of X food industry. Each tool and methodology of LSS was evaluated in terms of its impact on the performance of the project. The required data of the production process of the studied factory is simulated based on the information from personal observation of production floor and document review. The required data were collected and designed based on purpose of the study.

5.1 Research Field Component

5.1.1 Population

In this study, X Food Industry was the population where its different fruit juice and Carbonated Soft Drinks (CSD) processing lines were the samples.

5.1.2 Primary data collection

The primary data was documented from personal observations of researcher from studied production floor at different processing steps. The primary data were collected and documented by the observation of set up time, change over time, machine function, material and labor flow at each and every processing stages of the production line. The regarding data collection tools were prepared by following the principles of different tools and strategies of LSS model.

5.1.3 Secondary data collection

The secondary data will be taken from the internet, books, journals, related studies and other sources of information.

5.2 Statistical Analysis

Each type of data was collected for at least three times where mean and standard error of mean of these collected data were analyzed by using the statistical software tool of SPSS for windows (version, 17).

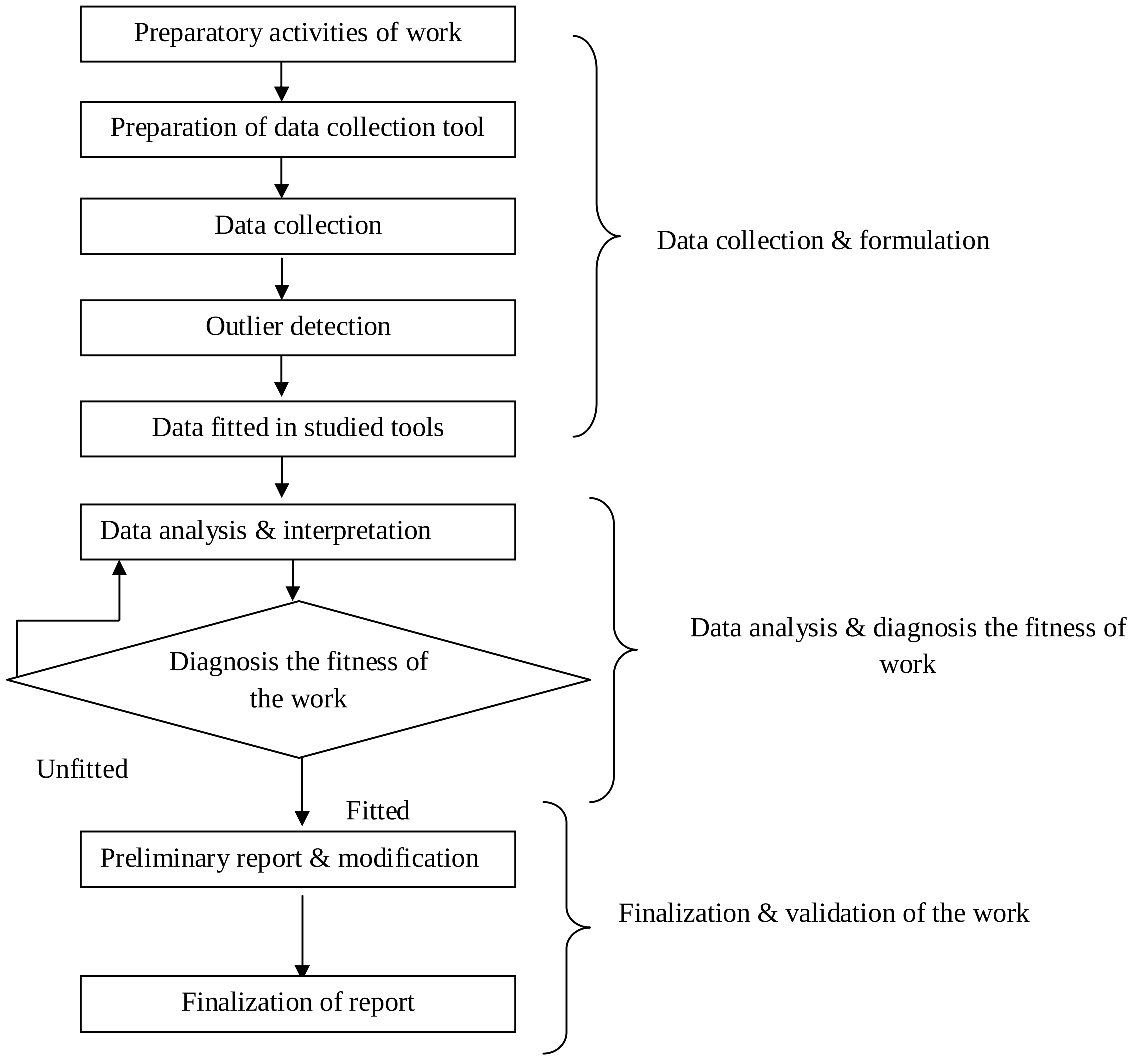


Fig: Complete Methodology for the study

5.3 Lean Tools and SS

Lean tools like VSM, PCE, Tact time and Pareto ratio were applied to analyze the collected data and two basic SS methodologies 5S and DMAIC were adopted to formulate the improvement strategy.

5.3.1 Value Stream Map (VSM)

VSM is a lean manufacturing technique used to analyze and design the flow of materials and information required to bring a product or service to a consumer [34]. At Toyota, where the technique originated, it is known as "material and information flow mapping". The Lean Aerospace Initiative at MIT described the objective of VSM as an important lean practice to eliminate waste and make the VD steps 'flow' in meeting customer requirements [75]. The VSM was further described by Womack and Jones in lean Thinking: “A VSM identifies every action required to design, order, and make a specific product. The actions are sorted into three categories: (1) those that actually create value as perceived by the customer; (2) those which create no value but are currently required by the product development, order filing, or production systems; and (3) those actions which don’t create value as perceived by the customer and can be eliminated immediately” [8].

5.3.2 Project Cycle Efficiency (PCE)

It is the ratio of value added time and total time of a process line. Mathematically it is expressed as follows-

PCE= {(VD time /total time of a process) * 100}

Here, Total time= VD time + NVD time [74]

5.3.3 Tact time

Tact time is defined as the time required producing one unit of daily salable quantity [76]. The purpose of Tact time is to precisely match production with demand. It provides the heartbeat of a lean production system. Tact time first was used as a production management tool in the German aircraft industry in the 1930s. Tact time can be first determined with the formula:

$$T = \frac{T_a}{T_d}$$

Where,

T = Tact time, e.g. [work time between two consecutive units]

T_a = Net time available to work, e.g. [work time per period]

T_d = Time demand (customer demand), e.g. [units required per period]

Net available time is the amount of time available for work to be done. This excludes break times and any expected stoppage time (for example scheduled maintenance, team briefings, etc.).

5.3.4 Kanban

Kanban is a scheduling system for lean and JIT production. It is one means through which JIT is achieved [29]. It is not an inventory control system rather a scheduling system that helps to determine what to produce, when to produce it, and how much to produce. Kanban became an effective tool to support the running of the production system as a whole. In addition, it is reported as an excellent way for promoting improvements [77].

5.3.5 Poka-yoke

Poka-yoke (poka joke) is a Japanese term that means "fail-safing" or "mistake-proofing". A poka-yoke is any mechanism in a lean manufacturing process that helps an equipment operator avoid (*yokeru*) mistakes (*poka*). The purpose of Poka-yoke is to eliminate product defects by preventing, correcting, or drawing attention to human errors as they occur [77]. It was originally described as *baka-yoke*, but as this means "fool-proofing" (or "idiot-proofing") the name was changed to the milder *poka-yoke*. More broadly, the term can refer to any behavior-shaping constraint designed into a process to prevent incorrect operation by the user. Similarly, a constraint that is part of the product (or service) design is considered Design for Manufacturability or Design for X. A good example of a poka-yoke design is the shape of a cell phone SIM card which can only be inserted in the cell phone in the correct way.

5.3.6 5S

5S is the name of a workplace organization method that uses a list of five Japanese words: *seiri, seiton, seiso, seiketsu,* and *shitsuke*. Transliterated or translated into English, they all start with the letter "S". The list describes how to organize a work space for efficiency and effectiveness by identifying and storing the items used, maintaining the area and items, and sustaining the new order. There are five primary 5S phases: sorting, set in order, systematic cleaning, standardizing, and sustaining [78].

i. **Sorting:** Eliminate all unnecessary tools, parts, and instructions. Go through all tools, materials, and so forth in the plant and work area. Keep only essential items and eliminate what is not required, prioritizing things per requirements and keeping them in easily-accessible places. Everything else is stored or discarded.

ii. **Straightening or Setting in Order:** Arranging tools, parts, and instructions in such a way that the most frequently used items are the easiest and quickest to locate. The purpose of this step is to eliminate time wasted in obtaining the necessary items for an operation.

iii. **Sweeping or Shine:** Clean the workspace and all equipment, and keep it clean, tidy and organized. At the end of each shift, clean the work area and be sure everything is restored to its place. This makes it easy to know what goes where and ensures that everything is where it belongs.

iv. **Standardizing:** All work stations for a particular job should be identical. All employees doing the same job should be able to work in any station with the same tools that are in the same location in every station. Everyone should know exactly what his or her responsibilities are for adhering to the first 3 S. Synonym : Systemize

v. **Sustaining the Practice:** Maintain and review standards. Once the previous 4 S have been established, they become the new way to operate. Maintain focus on this new way and do not allow a gradual decline back to the old ways. While thinking about the new way, also be thinking about yet better ways. When an issue arises such as a suggested improvement, a new way of working, a new tool or a new output requirement, review the first 4 S and make changes as appropriate. It should be made as a habit and be continually improved.

5.3.7 Pareto analysis

It is a statistical technique in decision making that is used for selection of a limited number of tasks that produce significant overall effect. It uses the Pareto principle – the idea that by doing 20% of work, 80% of the advantage of doing the entire job can be generated. Or in terms of quality improvement, a large majority of problems (80%) are produced by a few key causes (20%). The Pareto Principle – also known as the "80/20 Rule" – which is the idea that 20% of causes generate 80% of results [78]. With this tool, we're trying to find the 20% of work that will generate 80% of the results that doing all of the work would deliver.

Pareto analysis is a formal technique useful where many possible courses of action are competing for attention. In essence, the problem-solver estimates the benefit delivered by each action, then selects a number of the most effective actions that deliver a total benefit reasonably close to the maximal possible one. Pareto analysis is a creative way of looking at causes of problems because it helps stimulate thinking and organize thoughts. However, it can be limited by its exclusion of possibly important problems which may be small initially, but which grow with time. It should be combined with other analytical tools such as failure mode and effects analysis and fault tree analysis for example. This technique helps to identify the top portion of causes that need to be addressed to resolve the majority of problems. Once the predominant causes are identified, then tools like the Ishikawa diagram or Fish-bone Analysis can be used to identify the root causes of the problems. While it is common to refer to pareto as "20/80", under the assumption that, in all situations, 20% of causes determine 80% of problems, this ratio is merely a convenient rule of thumb and is not nor should it be considered immutable law of nature. The application of the Pareto analysis in risk management allows management to focus on those risks that have the most impact on the project [77].

Steps to identify the important causes using simple rote (20/80) Pareto analysis [79]-

- Step 1: Form an explicit table listing the causes and their frequency as a percentage.
- Step 2: Arrange the rows in the decreasing order of importance of the causes (i.e., the most important cause first)
- Step 3: Add a cumulative percentage column to the table
- Step 4: Plot with causes on *x*- and cumulative percentage on *y*-axis
- Step 5: Join the above points to form a curve
- Step 6: Plot (on the same graph) a bar graph with causes on *x*- and percent frequency on *y*-axis
- Step 7: Draw line at 80% on *y*-axis parallel to *x*-axis. Then drop the line at the point of intersection with the curve on *x*-axis. This point on the *x*-axis separates the important causes (on the left) and trivial causes (on the right)
- Step 8: Explicitly review the chart to ensure that at least 80% of the causes are captured

5.3.8 Pareto chart

A Pareto chart, named after Vilfredo Pareto, is a type of chart that contains both bars and a line graph, where individual values are represented in descending order by bars, and the cumulative total is represented by the line.

These charts can be generated by simple spreadsheet programs, such as OpenOffice.org Calc and Microsoft Excel and specialized statistical software tools as well as online quality charts generators. The Pareto chart is one of the seven basic tools of quality control [80].

5.3.9 Cost–benefit analysis (CBA)

Sometimes it is called benefit–cost analysis (BCA), is a systematic process for calculating and comparing benefits and costs of a project, decision or government policy (hereafter, "project"). CBA has two purposes [80]:

- To determine if it is a sound investment/decision (justification/feasibility)
- To provide a basis for comparing projects. It involves comparing the total expected cost of each option against the total expected benefits, to see whether the benefits outweigh the costs, and by how much.

By this study the existing manufacturing wastes in the research process lines were indentified, quantified and finally the quantified wastes were valued in terms of money and dollar in order to unveil the benefit of applied lean tools and SS methodologies.

6. RESULT AND DISCUSSION

This study was driven to find out and quantify the different types of manufacturing waste at different processing stages of six juice and beverages processing lines of X food industry in Bangladesh. The present Value Stream Map (VSM) of the studied processing lines were prepared and analyzed in order to formulate the future VSM with the improved PCE, Tact time, reduced manufacturing wastes and reduced lead time by using lean tools and Six Sigma methodologies.

The required data were collected from X mango juice processing line-1, X mango juice processing line-2, Carbonated Soft Drinks (CSD) of "X up" and X energy drinks processing lines, X Banana flavored juice, and X Litchi flavored juice. Value Added (VD) time, Non Value Added (NVD) time and manufacturing wastes were deeply observed in the studied processing lines. The expected result of this study can be deduced by data analysis from the different tables and graphs.

6.1 X Mango Juice Process Line-1

It was a mango juice processing line where the processed juice contained mango pulp at least 14%, xanthan gum 0.15%, sodium chloride 0.025%, potassium sorbet 0.024% B-carotine 0.017%, mango flavor 0.070%, sugar 10.48%, ascorbic acid 0.020%, sodium benzoate 0.96%, and water 75.118%. These ingredients came from different sources which were mixed together that termed as blending or syrup that was finally formulated into X mango juice through a number of processing stages.

The basic stages of X mango juice processing line-1 were as follows-

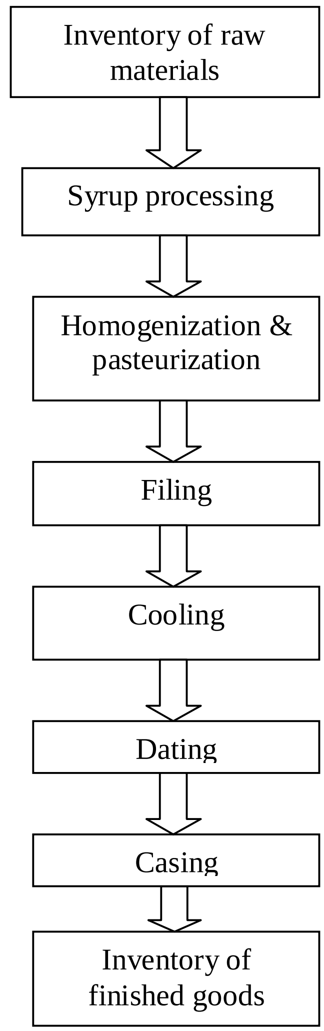
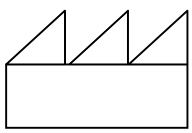
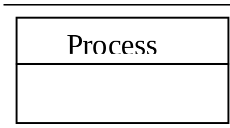
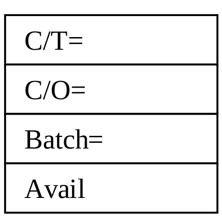
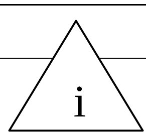


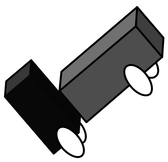
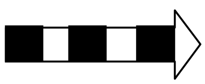
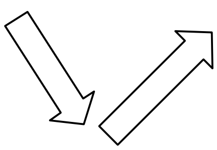
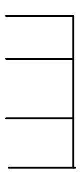
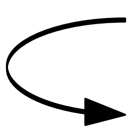
Fig 6.1.1: Basic stages of X mango juice processing line-1

6.1.1 Present Value Stream Mapping (VSM) of X mango juice processing line-1

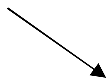
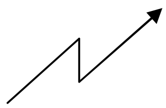
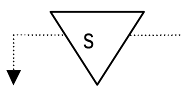
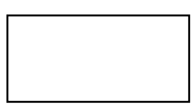
VSM was used to evaluate the VD and NVD time. Cycle time (C/T), Up time (U/T), Changeover time (C/T) and lead time were very important factor to build the VSM. Cycle time is the time that elapses between one parts coming off the process to the next part coming off. Uptime is the time when the equipment system is in a condition to perform its intended function. It includes productive, standby, and engineering time, and does not include any portion of downtime or nonscheduled time. Processing lead time can be defined as total time it takes to process an item, including queue time, setup time, run time, move time, inspection time, and put away time. It is the time interval between the initiation and the completion of a production process. For make-to-stock products, it is the time taken from the release of an order to production and receipt into finished goods inventory.

To depict the production process there are different types of symbols used in the VSM. In the pursuit of gathering information on the processing floor, it is essential to understand all of the symbols that are used to represent the product processes and information flows. The symbols used in this thesis paper can be divided into three categories [34].

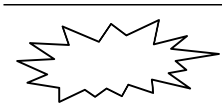
Material flow symbols		
Symbol	Title	Definition
	Customer/Supplier	This symbol represents the supplier when in the upper left as well as the starting point for material flow. The customer is also represented by it when placed in the upper right meaning the usual end point for material flow.
	Dedicated process	This symbol denotes a process, operation, machine or department, through which material flows.
	Data box	This symbol is used to summarize essential information for a process, machine, or department, especially demand, batch sizes, and frequency.
		This symbol denotes raw material levels, the

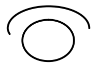
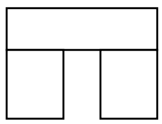
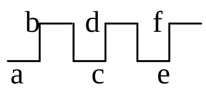
	Inventory	inventory build-up between process steps, and finished product levels.
	External shipment	These symbols represent the shipments from suppliers or to customer using external transport.
	Push arrow	This symbol represents the pushing of material from one process to the next process. Here, push means that a process produces a product, goods or something regardless of the immediate needs of downstream processes.
	Shipment arrow (Receiving or shipping)	This symbol denotes movement of incoming raw materials, and movement of finished goods out of the plant.
	Supermarket	Here this is an inventory "supermarket" (kanvan stockpoint). Like a supermarket a small inventory is available and one or more downstream customer comes to the supermarket to pick out what they need. The upstream work-centre then replenishes stocks as required.
	Material pull	This symbol denotes the withdrawal (pull) of materials from a supermarket inventory for downstream processing

Information flow symbols

Symbol	Title	Definition
	Manual information	This symbol denotes manual flow of information (hardcopies, memos, notes).
	Electronic information	This symbol denotes electronic flow of information (email, fax, phone, computerized data transmission).
	Signal Kanvan	This symbol denotes a material pull, but when inventory levels have dropped to a minimum level.
	Production control	This box represent a central production scheduling or control department, parson or operation

General symbols

Symbol	Title	Definition
	Kaizen Burst	This symbol denotes a potential process change that can be used to improve the Current State.

	Human operator	This symbol denotes a human operator at a specific workstation. The number of operators should be noted.
	Work-cell	This symbol denotes a work-cell where several processes are integrated.
	Timeline	This symbol called the time line that shows VD times (cycle time) and NVD times (wait time) and used to calculate the lead time.

PCE and Tact time were also applied for every processing line to identify its process capability.

The present VSM of this process line was consisted with the syrup preparation, homogenization & ultra heat treatment, filling, cooling, labeling and wrapping which were considered as the pivotal steps in the VSM. Throughout the VSM the Cycle Time (C/T), Change over Time (C/O), Uptime (U/T), and Batch size were drawn. The present required operator, assistant operator and worker were also mapped at present VSM. The Inventory (I) and Shipment were also the component of VSM where inventory was the initial stage and Shipment was the last stage. All required data regarding to build the current VSM were collected and documented in Table 6.1.1 and Table 6.1.2, summarized the overall activities associated with the production line along with their processing time.

Table 6.1.1: Present State Down Time (C/T), Cycle Time (C/T) and Up Time (U/T) data of X mango juice process line-1

Times	Filler			Labeler			Wrapping machine		
	D/T (sec)	C/T (sec)	U/T (%)	D/T (sec)	C/T (sec)	U/T (%)	D/T (sec)	C/T (sec)	U/T (%)
1st	1116	6060	81	1416	6120	76	1368	4680	65
2nd	1105	6060	82	1415	6120	77	1349	4680	66
3rd	1105	6060	82	1399	6120	78	1341	4680	66
Average	1108	6069	82	1410	6120	77	1352	4680	66

Note: Filler speed: 276 BPM; Labeler speed: 274 BPM ; Wrapping machine speed: 18 case per min. Batch- 7000 L; BPM: Bottle Per Minutes; D/T- the time that is wasted due to breakdown of machine; C/T- the time that is required to produce a single batch production; U/T- the time that is available for machine work or production

Table 6.1.1 reveals the D/T, C/T, and U/T of X mango processing line-1. In this processing line the D/T due to different bottlenecks were observed in the stage of filer, labeler and wrapping machine which stages were mainly responsible for D/T. In the stage of filer, average U/T was 82% and C/T was 6060 sec. In the stage of labeler average U/T was 77% and C/T was 6120 sec. In wrapping machine stage, C/T was 4680 sec and U/T was 66%. The percentage of available time for machine work or processing of desire product is known as the U/T. By observing the U/T of different unit stage of production line, it can be assumed the efficiency of processing line. At present state, the U/T of X mango process line-1 varies from 66% (wrapping stage) to 82% (filer stage). By this study it was attempted to increase the U/T in the future state as well as to reduce the D/T and to reduce the ultimate lead time.

Table 6.1.2: Present State VD and NVD time of X mango juice processing line-1

Processing stage	VD time (Sec)	NVD time (Sec)
Receiving Inventory	00	32400
Syrup processing	600	1800
Homogenization & pasteurization	1680	300
Filling	4775	1525
Cooling	0	1770
Labeling	4683	1857
Wrapping	3532	1748
Shipping Inventory	00	43200
Total	15270 (15.28%)	84600 (84.72%)

Note: VD time- the time that is desired which add the value to goods or service; NVD time- the time that is not desired or that does not add any value to goods or service

The VD and NVD time of different processing stages of X mango juice processing line-1 were documented in Table 6.1.2. At present state, in the stages of receiving inventory, cooling and shipping inventory there were no VD time rather than NVD time, but in this process line, this NVD time or these stages were required for the mango juice processing. By this study, it was tried to increase the percentage of VD time by reducing the NVD time with the proper implementation of lean tools and SS methodologies.

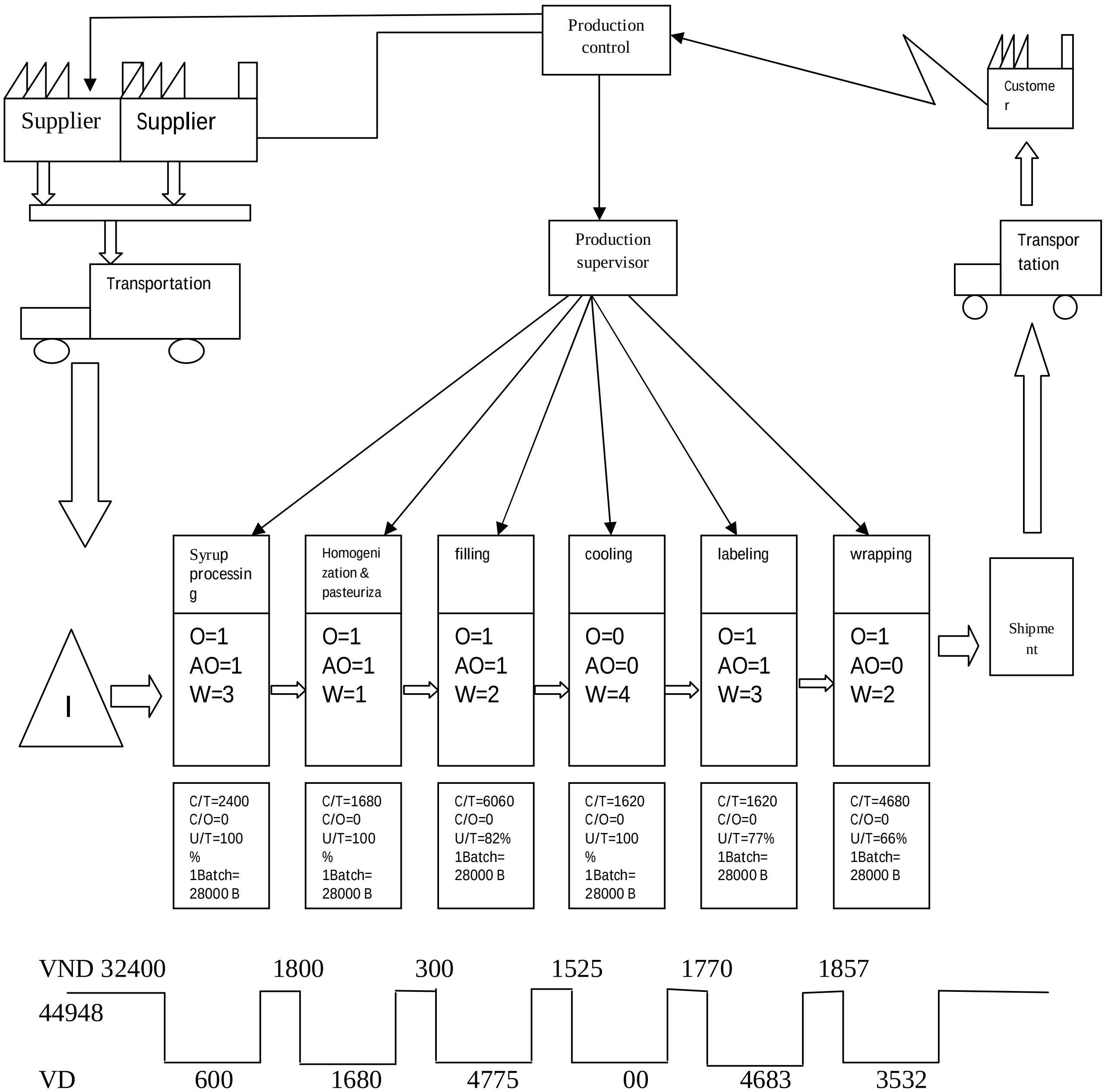


Fig 6.1.2: Present VSM of X mango juice Processing Line-1

Note: Throughout the present VSM the whole processing system of X mango juice process line-1 were depicted with the flow of order, raw materials, labor, information, and VD & NVD times. It helps to draw the required processing stage like syrup processing, homogenization & pasteurization, filing, cooling, labeling and wrapping *with mentioning required labor, C/T, U/T, C/O and batch size. By observing the present scenario of regarding processing line, it can be known like as what number of labor is needed at different processing unit? How much VD & NVD time is present? Where & what kind of improvement should be done? It helps to calculate the PCE, lead time and Tact time.*

Fig 6.1.2 represents the present VSM of X mango juice process line-1. At present VSM, it revealed that the production of mango juice was controlled by production supervisor. In this processing line, the production starts by taking the order of production from the customers. In order to fulfill the customer demand the required raw materials were collected from the different regarding suppliers. These required raw materials were brought in the raw materials inventory which was considered as the first stage of mango juice production that followed by syrup processing, homogenization & pasteurization, filing, cooling, labeling, wrapping and shipment of goods. As observed from the present VSM of X mango juice process line-1, different types of NVD activities are present in the flow of process line at different stages. The different types of bottlenecks at different processing stages were identified and quantified in terms of time as shown in the Fig 6.1.2. The VD and NVD times were shown at the bottom line of present VSM. It was found that in X mango juice process line-1, about 15270 sec out of 99870 sec or 15.28% were VD activities while 84600 sec or 84.72 % were NVD activities. By this study it was endeavored to increase the percentage of VD activities and time by reducing the NVD activities and time. The Up time (U/T) of filer, labeler and wrapping machine were consecutively 82%, 77% and 66%. At present state, total labor were 25 over the different stages of this processing line. After the implementation of lean tools and SS methodologies it was expected that U/T could be improved and total labor and manufacturing waste could be reduced.

6.1.2 Value chain of X mango juice process line-1

According to "Cambridge University: Institute for Manufacturing ", the idea of the value chain is based on the process view of organizations, the idea of seeing a manufacturing or service organization as a system, made up of subsystems each with inputs, transformation processes and outputs.

The value chain concept was introduced in the book of “Competitive Advantage: Creating and Sustaining Superior Performance” where it was mentioned that the value chain is a series of activities a product/service must pass through until it serves its final purpose of solving a customer need. In each phase of the value chain the product/service gains some value. If a phase is malfunctioning the chain will break down and the mission of generating value for the customer will not be accomplished [81].

A value chain is a chain of activities that a firm operating in a specific industry performs in order to deliver a valuable product or service for the market [82]. The value chain is a systematic approach to examining the development of competitive advantage [83].

Value chain of X mango juice process line-1

Raw material inventory	Syrup processing	Homogenization & pasteurization	Filing	Cooling	Labeling	Wrapping
In this stage all required raw materials were gathered, but there was no value added towards the finished goods, although	All regarding raw materials were mixed in this stage in order to formulate syrup towards get the finished goods i.e. mango juice. In	In this stage the syrup was given ultra heat treatment (129º C for 15 sec) in order to increase the self life by destroying the presence microbes without adding considerable	In this stage the syrup was bottled towards giving the more finished goods of mango juice. In this stage the value was added by 31.27%	In this stage the hot bottle were cooled without adding any value but this stage was necessary in order to attain the finished goods.	In this stage the bottle juice were labeled with label foil that contains the details identity of product. In this stage value was	In this stage the bottle juice were wrapped with the case. 24 bottles were wrapped in a single case. In this stage value was added by 23.13%

this stage was required for finished goods.	this stage value was added by 3% (VD time 600sec of total 15270 sec)	any value.	(VD time 4775 sec of total 15270 sec)	added by 30.66%. (VD time 4683 sec of total 15270 sec).	(VD time 3532 sec of total 15270 sec)

Note: VD: Value Added; The percentage of value addition was calculated- the VD time of each processing unit was divided by the total VD time of whole processing line.

6.1.3 Present PCE of X mango juice process line-1

In the X mango juice process line-1,

Value Added time = 15270 Sec

Non Value Added time = 84600 Sec

Lead time = Value Added time + Non Value Added time

= 15270 Sec + 84600 Sec = 99870 Sec

$$\text{PCE} = \frac{\text{Value Added time} \times 100}{\text{Lead time}}$$

15.28 %

It was seen that the present VSM of X mango juice processing line-1 was 15.28% which was the below of internationally competitive level 25% [74]. Throughout this study it was attempted to improve the present PCE with the proper implementation of lean tools and SS methodologies.

6.1.4 Present Tact time calculation of X mango juice process line-1

Net available time			**Customer / production scheduled demand**		
Working shifts / day	2	Shifts	Customer demand/day	5094	cases
Hours / shift	10	Hours			
Available time / shift	600	Minutes			
Prepare time / shift	40	Minutes			
Lunch time / shift	0	Minutes	Net available time / day	67200	seconds / day
Planned downtime / shift	0	Minutes	Customer demand / day	5094	cases / day
Net working time / shift	560	Minutes			
Net working time / shift	33600	Seconds	**Tact time**	13.19	seconds / case
Net available time / day	67200	Seconds			

Note: Tact time- is considered as the rate at which the product/service should be produced at least equal to Tact time to meet the customer demand.

Tact time is considered as the heart beat of any process line. The present Tact time of X mango juice processing line-1 was 13.19 sec. i.e. it takes 13.19 sec to produce a single case of mango juice production. Each case contains 24 bottle of mango juice where a single bottle contains 250 ml. juices. One of the basic objectives of this study was to reduce this present Tact time after the proper implementation of lean tools and SS methodologies.

6.1.5 Manufacturing wastes of X mango juice process line-1

Waste is a very common seen at every manufacturing industry, especially to the industry of developing countries due to the lack of high technological and modern strategies involvement and the observed X mango juice manufacturing floor was not beyond this. From different types of manufacturing waste, the most frequent observed manufacturing wastes like as down time, defect bottle were documented.

6.1.5.1 Down Time (D/T) calculation for X mango juice processing line-1

Waiting time or down time was documented in Table 6.1.3 which was observed at different processing stages of the studied X mango juice processing line-1.

Table 6.1.3: Down time (D/T) of X mango juice processing line-1

Step	Causes for D/T	D/T (sec)	Average D/T (Sec)	C/T	% D/T
Filler	Caper sensor (Machine) problem	557		6060	
		539	546		14.11
		547			
	Bottle short in supply	368			
		370	367		9.48
		363			
	Bottle queue in supply	138			
		146	141		3.64
		139			
	Bottle queue in front	53			
		50	53		1.39
		56			
Labeler	Bottle short in supply	667		6120	
		673	666		17.21
		659			
	Sensor (machine) problem	310			
		316	312		8.06
		309			
	Label changing	269			
		262	263		6.79
		258			
	Label wrapping in machine	170			

		164 173	169	4.36
Wrapping	Insufficient bottle supply	823		3900
		815 820	819	21.16
	Case cover changing	318 311 305	311	8.03
	Sensor (machine) problem	165		
		155 151	157	4.05
	Case queue in front	62 68 65	65	1.68
Total			3869	

In X mango juice processing line-1, the most important processing stages were filing, labeling and wrapping where the most frequent D/T was observed due to different causes that were documented in Table 6.1.3.

6.1.5.2 Waste or defect bottle calculation of X mango juice processing line-1

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites, and unnecessary motion in the work place. In a single processing line all types of wastes could not be seen. Base on the nature of production the manufacturing wastes were varied. Among these manufacturing wastes, defect production was very common in the X mango juice processing line-1. In this processing floor defect bottle was considered as the defect production. The amount of defect bottle was documented in Table 6.1.4.

Based on central SS concept it seems that if the amount of defect product is more than 6,210 but less than 66,807 per million product of production then it is considered as the

Table 6.1.4: Wasted bottle calculation of X mango juice processing line-1

Filling	1	22					Contains at three Sigma level
	2	20					
	3	18	20	120	714	711	
	4	21					
	5	17					
Date coding	1	195					
	2	187					
	3	120	170	1020	6071	6068	
	4	160					
	5	190					
Labeling	1	208					
	2	210					
	3	215	206	1236	7357	7354	
	4	197					
	5	201					
Wrapping	1	3					
	2	3					
	3	2	3×24=72	432	2571	2568	
	4	3					
	5	3					
Total			**468**	**2808**	**16713**		

*Note: *Opportunity: a situation or a condition for attainment of a goal; here it indicates to get the chance of total number of bottle production in both case of defect and defect free* [83].

three Sigma productions. From Table 6.1.4, it seems that the total defect product of X mango juice process line-1 was 16713 per million product of production which was considered as the three Sigma productions. But the prime target of any manufacturing industry should be SS production where the amount of defect product should not be more than 3.4 per million product of production. Throughout this study it was expected that 80% of the present manufacturing waste could be reduced after the implementation of lean tools and SS methodologies.

6.1.5.3 Labor waste of X mango juice processing line-1

The unnecessary motion of labor in the processing floor was considered as one of the most common the manufacturing wastes which was also most common in the processing floor of X mango juice processing line-1. After lean tools implementation it was expected that a number of labor could be eliminated from the processing line. The expected number of eliminated labor was documented in the Table 6.1.5.

Table 6.1.5: Present and expected labor of X mango juice processing line-1

Name of Stages	No of labor at present state			No of labor at future state		
	O	AO	W	O	AO	W
Syrup processing	1	1	3	1	0	3
Homogenization & pasteurization	1	1	1	1	0	1
Filing	1	1	2	1	1	1
Cooling	0	0	4	0	0	2
Labeling	1	1	3	1	1	1
Wrapping	1	0	2	1	0	1
Total	6	4	15	5	2	10

At present state, from Table 6.1.5, it was seen that throughout the different processing stages of X mango juice processing line-1, total labor were 25 where operator (O), assistant operator (AO) and worker (W) were consecutively 6, 4 and 15. At future state, if the lean tools and SS methodologies will implement, it was expected that different types of bottlenecks and NVD activities will be reduced thus the present number of labor will also be reduced because of a number of unwanted labor were engaged to manage the different types of bottlenecks and NVD activities.

6.1.6 Pareto analysis of X mango juice process line-1

Pareto analysis was performed by drawing the Pareto chart consisting of causes for delay along the X axis and percentage and cumulative percentage of down time along the Y axis. The highest frequency of NVD activities or down time was found for bottle short in supply at the X mango juice processing line-1, while bottle queue in front of filer machine showed the lowest frequency.

Table 6.1.6:Cumulative D/T of X mango juice processing line-1for Pareto analysis

Causes of delay times	Down Time(D/T)	Percentage of (D/T)	Cumulative of percentage
Bottle short in supply	1852	47.86766	47.86766
Caper sensor problem of filer machine	546	14.11217	61.97983
Machine sensor problem	469	12.12199	74.10182
Case cover changing at wrapping machine	311	8.03825	82.14007
Label changing at labeler	263	6.79762	88.93769
Label wrapping in labeler	169	4.36805	93.30574
Bottle queue in supply at filer machine	141	3.64435	96.95009
Case queue in front of wrapping machine	65	1.68002	98.63011
Bottle queue in front of filer machine	53	1.36989	100.00000

Different causes of NVD activities or down time at different processing stages of X mango juice processing line-1 with their frequency in terms of percentages and cumulative percentages were documented in Table 6.1.6. The causes for NVD activities were arranged in downward movements in terms of their frequency.

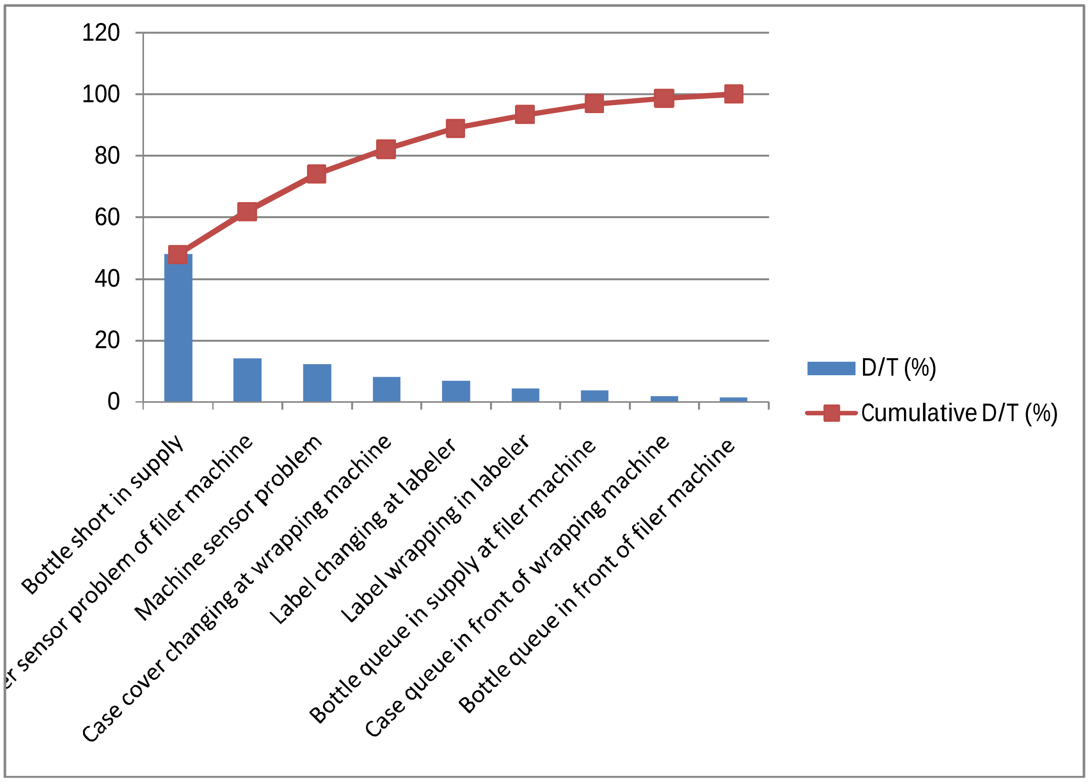


Fig 6.1.3 Pareto chart of X mango juice processing line-1

From Pareto table (Table 6.1.6); the Pareto chart (Fig 6.1.3) was depicted by aligning the different causes along with X axis; percentage and cumulative percentage of these causes for NVD activities were aligned along with the Y axis. From Fig 6.1.3, it seems that the pioneer causes beyond the different types of bottlenecks and NVD activities were bottle short in supply (47.86%) at different processing stages especially in the filing, cooling, labeling and wrapping, caper sensor problem of filer machine (14.11%), machine sensor problem (12.12%), case cover changing at wrapping machine (8.03%), label changing at labeler (6.79%), label wrapping in labeler (4.36%), bottle queue in supply at filing machine (3.64%), case queue in front of wrapping machine (1.68%) and bottle queue in front of filer machine (1.36%). From Pareto chart the most responsible causes were easily observed and the effective initiatives can be taken to remove these causes. From

Pareto chart (Fig 6.1.3) it was expected that if the most frequent first three causes like as bottle short in supply (47.86%), caper sensor problem of filer machine (14.11%), machine sensor problem (12.12%) could be removed, the 80% NVD activities or down times could be removed. Based on previous study, it was averred that 5S, JIT, TPM, DMAIC and other improving strategies could be effective initiatives to remove these most frequent causes.

6.1.7 Improvement points at present VSM of X mango juice processing line-1

Throughout the observation it was seen that there were some improvement points at different stages of X mango juice processing line-1. The nature of improving point differs from each and another stages.

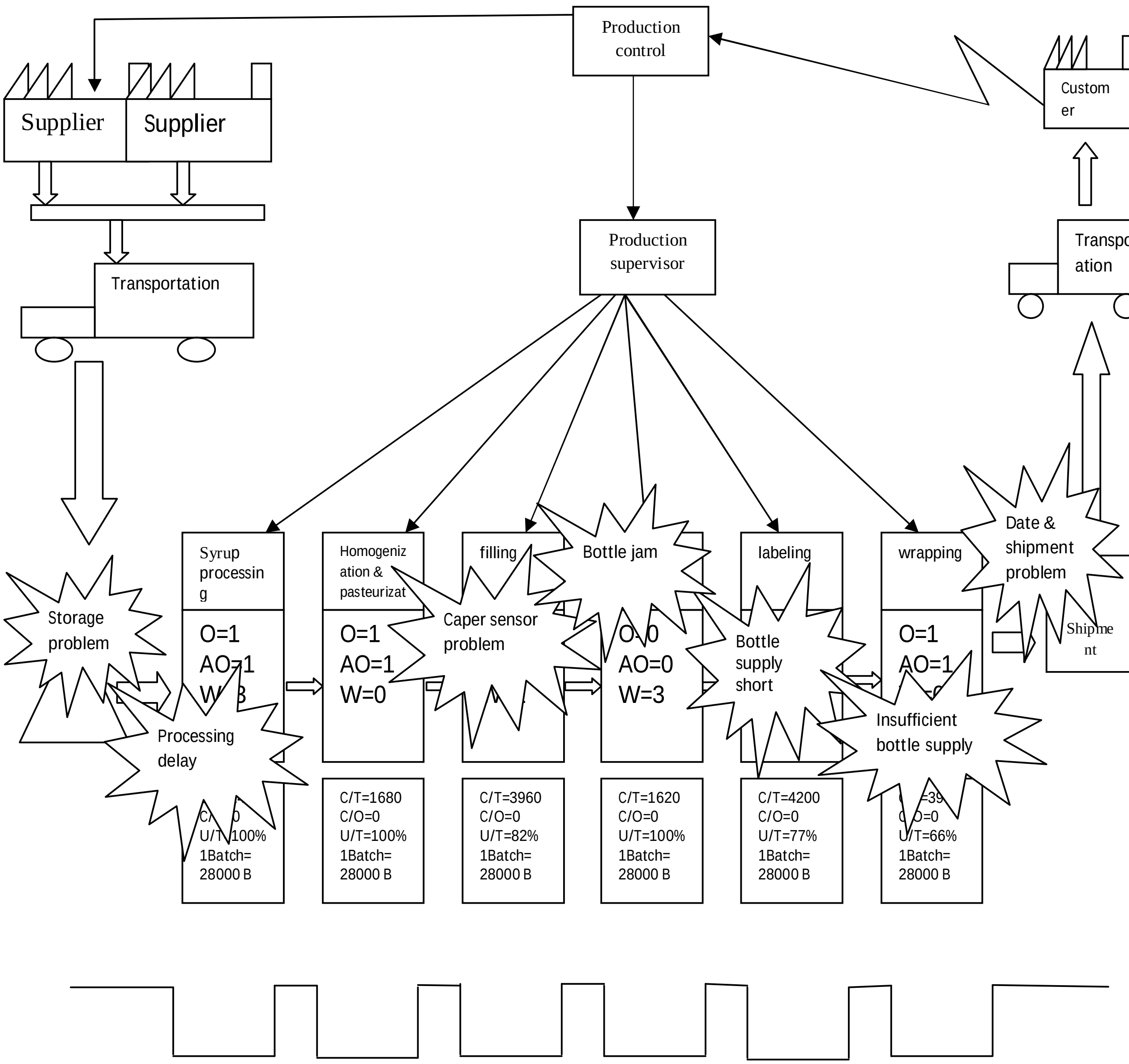


Fig 6.1.4: Present VSM of X mango juice process line-1 with improvement point

The crucial improvement points were pointed in Fig 6.1.4. In the stage of raw material inventory, delay handling of raw materials towards the next stage of syrup processing was observed as the prime point that should be removed in order to reduce the lead time as well as to improve the PCE. Besides these, conventional movement of raw materials like as carry of raw materials sack by labor instead of conveyor belt movement, open air inventory storage, congested stairways were most common. In the syrup processing stage, the delay of syrup processing was the main hindrance beyond the NVD activities and bottlenecks. No cause was indentified that need to solve in the stage of homogenization and pasteurization, because of it was difficult to detect any barrier beyond the bottleneck due to fully pipe flow of syrup towards the next filing stage, but it was observed that this stage was smoothly running and based on previous experience of regarding personnel it was also known that there was no mentionable barrier for bottlenecks. In the filing stage the basic causes were caper sensor problem, bottle short in supply, bottle queue in supply in bottle queue in front of filing. In the stage of cooling bottle jam was observed as the only one problem both in enters and exit of cooling chamber. In the stage of labeling the main causes for bottlenecks or breakdown of machine were bottle short in supply, machine sensor problem, label changing and label wrapping in label machine. In case of wrapping stage the basic problems were pointed as insufficient bottle supply, case cover changing, sensor (machine) problem and case queue in front labeling. In the stage of shipment the basic barrier were irregular shipment and insufficient space for movement. In Fig 6.1.4 only the most frequent cause at different stages of X mango juice processing line-1 were pointed. These pointed causes or barriers should be removed in order to reduce the manufacturing wastes and improve the PCE. Based on previous study it was expected that 80% of pointed causes could be removed by reducing 20% most frequently occurring barriers.

6.1.8 Future VSM of X mango juice processing line-1

In the future VSM, after an intense observation and brainstorming analysis on the X mango juice processing line-1, the VD and NVD time were calculated and documented in Table 6.1.7.

Table 6.1.7: Future State VD and NVD time of X mango juice processing line-1

Processing stage	VD time (Sec)	NVD time (Sec) (Expected reduction)
Receiving Inventory	00	16200 (50%)
Syrup processing	600	900 (50%)
Homogenization & pasteurization	1680	300
Filling	4775	305 (80%)
Cooling	0	354 (80%)
Labeling	4683	371 (80%)
Wrapping	3532	350 (80%)
Shipping Inventory	00	10800 (60%)
Total	**15270 (34.05%)**	**29580 (65.95%)**

*Note: VD time- the time that is desired which add the value to goods or service; NVD time- the time that is not desired or that does not add any value to goods or service; third column *NVD time in sec (% of time that is reduced)*

The Fig 6.1.5 was the future VSM of X mango juice processing line-1. The future VSM indicated the materials, information and labor flow of single batch production of X mango juice processing line-1. Each batch contained 7000 L syrup that produced 28000 bottle (B) of mango juice. The basic components of future VSM were customers, production control, production supervisor, suppliers, transportation, different stages of processing line like as receiving inventory, syrup processing, homogenization and pasteurization, filing, cooling, labeling, wrapping and shipment inventory. Production control was consisted by one manager and two assistant managers. The production started with taking the order from customers by electric signal like as over telephone or email. Later required raw materials were collected from the regarding suppliers. Finally, raw materials were transformed into finished mango juice throughout the receiving inventory stage to shipment stage.

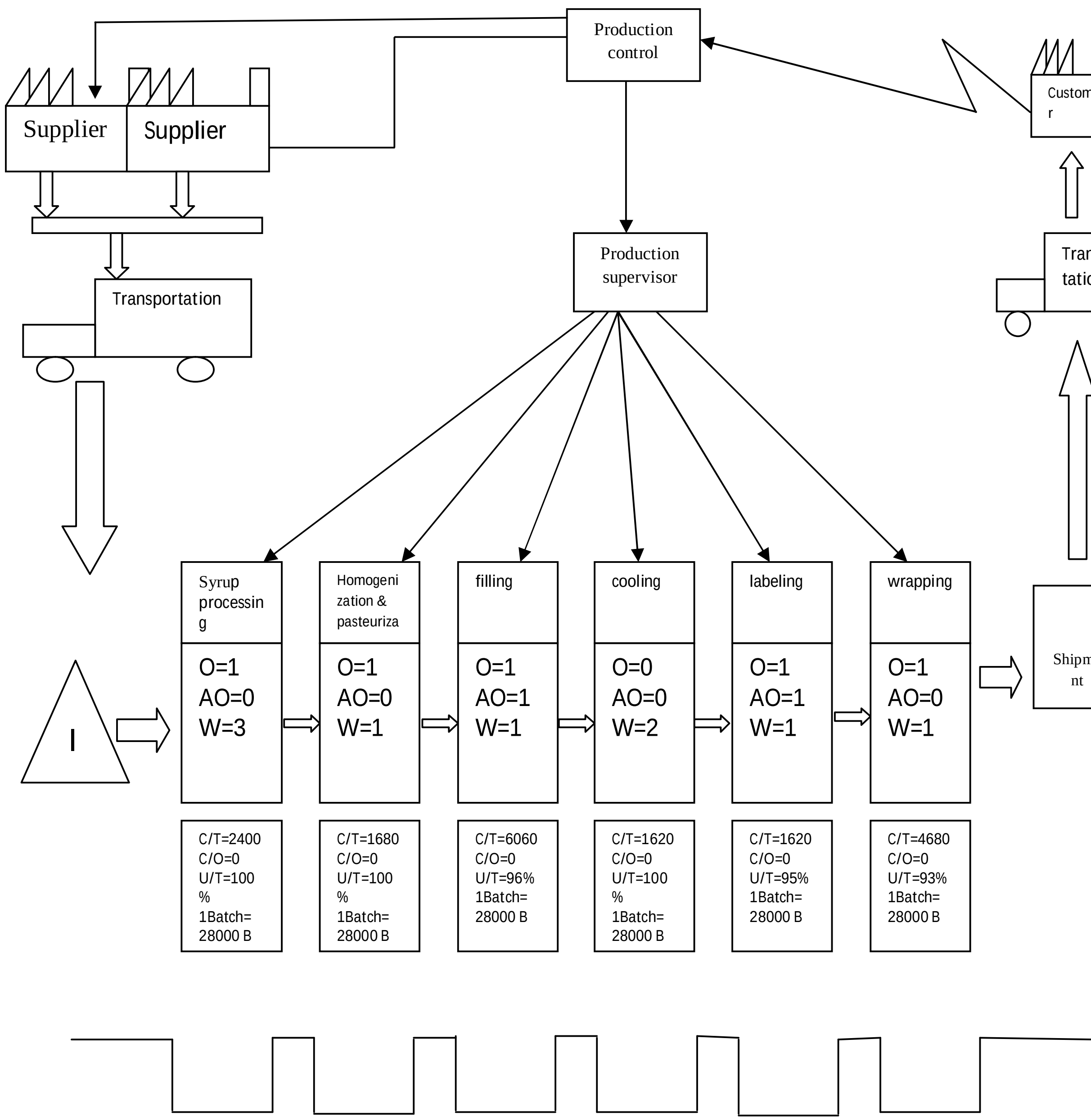


Fig 6.1.5: Future VSM of X mango juice processing line-1

It was expected that, after the implementation of lean tools and SS methodologies the present state NVD activities or times could be reduced at least up to 80%. In this study, based on intense observation, brainstorming and previous regarding studies it was assumed that the NVD time of receiving stage of X mango juice processing line-1 could be reduced at least 50% (16200 sec) and the NVD time of syrup processing could also be reduced at least 50% (900 sec). The NVD time of filing, cooling, labeling and wrapping could be reduced at least 80% from the present state and in the future state these NVD times could be consecutively 305 sec, 354 sec, 371 sec and 350 sec which could be seen in Table 6.1.7.

In this future VSM, the pivotal promising changes were the reduction of total number of labor which were seen at every processing stage, reduction of NVD time and improved up time (U/T). In future VSM, it was expected that the total labor including operator, assistant operator and worker could be 17 which was 25 at present VSM i.e. after the implementation of lean tools and SS methodologies at least 7 labor could be reduced.

It was also anticipated that after the proper implementation of lean tools and SS methodologies, the U/T of filer, labeler and wrapping machine could be consecutively 96%, 95% and 93% while the U/T of that machines were found consecutively 82%, 77% and 66% at present state of the observed processing line.

6.1.9 Expected PCE of X mango juice processing line-1

In the X mango juice processing line-1,

Value Added time = 15270 Sec

Non Value Added time = 29580 Sec

Expected Lead time = Value Added time + Non Value Added time

= 15270 Sec + 29580 Sec = 44850 Sec

$$\text{PCE} = \frac{\text{Value Added time} \times 100}{\text{Lead time}}$$

34.05 %

After the proper implementation of lean tools and SS methodologies it was expected the PCE of X mango juice processing line-1 could be 34.05% while the present PCE was 15.28%, the NVD time could be reduced from 84600 sec to 29580 sec and lead time could be reduced from 99870 sec to 44850 sec.

6.1.10 Expected Tact time of X mango juice process line-1

Net available time			Customer / production Demand		
Working shifts / day	2	Shifts	Customer demand/day	5094	cases
Hours / shift	10	Hours			
Available time / shift	600	minutes			
Prepare time / shift	40	minutes			
Lunch time / shift	0	minutes	Net available time / day	67200	seconds / day
Planned downtime / shift	0	minutes	Customer demand / day	5211	cases / day
Net working time / shift	560	Minutes			
Net working time / shift	33600	Seconds	**Tact time**	12.89	seconds / cases
Net available time / day	67200	Seconds			

Note: Tact time- is considered as the rate at which customers need products i.e. the products should be produced at least equal to Tact time to meet the customer demand.

In earlier, it was mentioned that Tact time is the heart beat of production of any manufacturing industry. As it is lower indicates the faster of production. Throughout this study it was tried to reduce the Tact time. The present Tact time of X mango juice processing line-1 was 13.19 sec per case production and it was expected that after the adoption of lean tools and SS methodologies this could be reduced to 12.89 sec per case production.

The versatile promising advantages and outcomes that was drawn with the adoption of lean tools and SS methodologies were discussed in the discussion portion of this thesis paper where, it was delineated the percentage of improvement of PCE, Tact time, VD & NVD time, lead time and labor improvement at present state and future state of production.

6.2 X Mango Juice Process Line-2

It's processing line, regarding steps and ingredients were as like as X mango juice process line-1, but the basic difference in the speed of different processing stages like filling, labeling and wrapping. To construct the present VSM all regarding data were collected and formulated in Table 6.2.1 and Table 6.2.2. The basic stages of X mango juice processing line-2 were as follows-

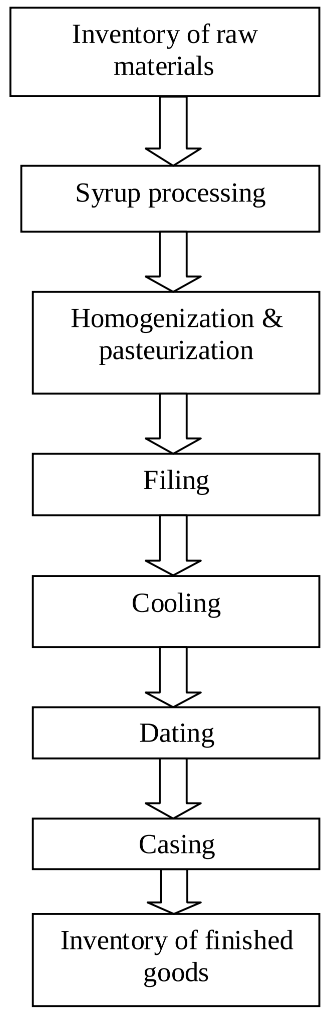


Fig 6.2.1 Basic stages of X mango juice processing line-2

6.2.1 Present VSM of X mango juice process line-2

Relevant informations were collected to construct the present VSM of X mango juice processing line-2. As a pre work, different types of activities at different process stages were observed associated with the production line along with their required processing time. Data related to assembly line such as processing time, inventory storages, inspections, rework loops, number of workers and operational hours per day were collected and well documented. To draw the completion of VSM, a timeline was added at the bottom of the map recording the VD & NVD time. The required data for the formation of present VSM were documented in Table 6.2.1 and Table 6.2.2.

Table 6.2.1: Down time (D/T), Cycle time(C/T) and Up time(U/T) data of X mango juice process line-2

Times	Filler			Labeler			Wrapping machine		
	D/T (sec)	C/T (sec)	U/T (%)	D/T (sec)	C/T (sec)	U/T (%)	D/T (sec)	C/T (sec)	U/T (%)
1st	1068	3960	73	888	4200	79	525	3900	87
2nd	1064	3960	73	884	4200	79	528	3900	86
3rd	1077	3960	72	886	4200	79	526	3900	87

Note: Filler speed: 420 BPM; Labeler speed: 400 BPM; Wrapping machine speed: 18 case per min. Batch-7000 L; BPM: Bottle Per Minutes; D/T- the time that is wasted due to breakdown of machine; C/T- the time that is required to produce a single batch production; U/T- the time that is available for machine work or production.

The D/T, C/T, and U/T of X mango juice processing line-2 were documented in Table 6.2.1. In this processing line the stage of filer, labeler and wrapping machine were mainly responsible for D/T. In the stage of filer, average U/T was 73% and C/T was 3960 sec. In the stage of labeler average U/T was 79% and C/T was 4200 sec. In the stage of wrapping, C/T was 3900 sec and U/T was 87%. The percentage of available time for machine work or processing of desire product could be known as the U/T. By observing the U/T of different unit stage of production line, it could be assumed the efficiency of the whole production line. At present state, the U/T of X mango juice process line-2 varies from 73% (filing stage) to 87% (wrapping stage). By this study it was attempted to increase the U/T in the future state as well as to reduce the D/T towards reducing the ultimate lead time.

Table 6.2.2: VD and NVD time of X mango juice processing line 2

Processing stage	VD (Sec)	NVD Time (Sec)
Receiving Inventory	00	32400
Syrup processing	600	1800
Homogenization & UHT	1680	300
Filling	3144	1056
Cooling	0	1620
Labeling	3415	1265
Wrapping	2764	1796
Shipping Inventory	00	43200
Total	**11603 (12.21%)**	**83437 (87.79%)**

Note: VD time- the time that is desired which add the value to goods or service; NVD time- the time that is not desired or that does not add any value to goods or service

The VD and NVD time of different processing stages of X mango juice processing line-2 were documented in Table 6.2.2. At present state, there were no VD time except NVD time in the stages of receiving inventory, cooling and shipping inventory, but in this process line, this NVD time or these stages were required for the mango juice processing. In this mango juice processing line, the total VD time were 11603 sec (12.21%) and the total NVD time were 83437 sec (87.79%). By this study, it was tried to increase the percentage of VD time by reducing the NVD time with the proper implementation of lean tools and SS methodologies.

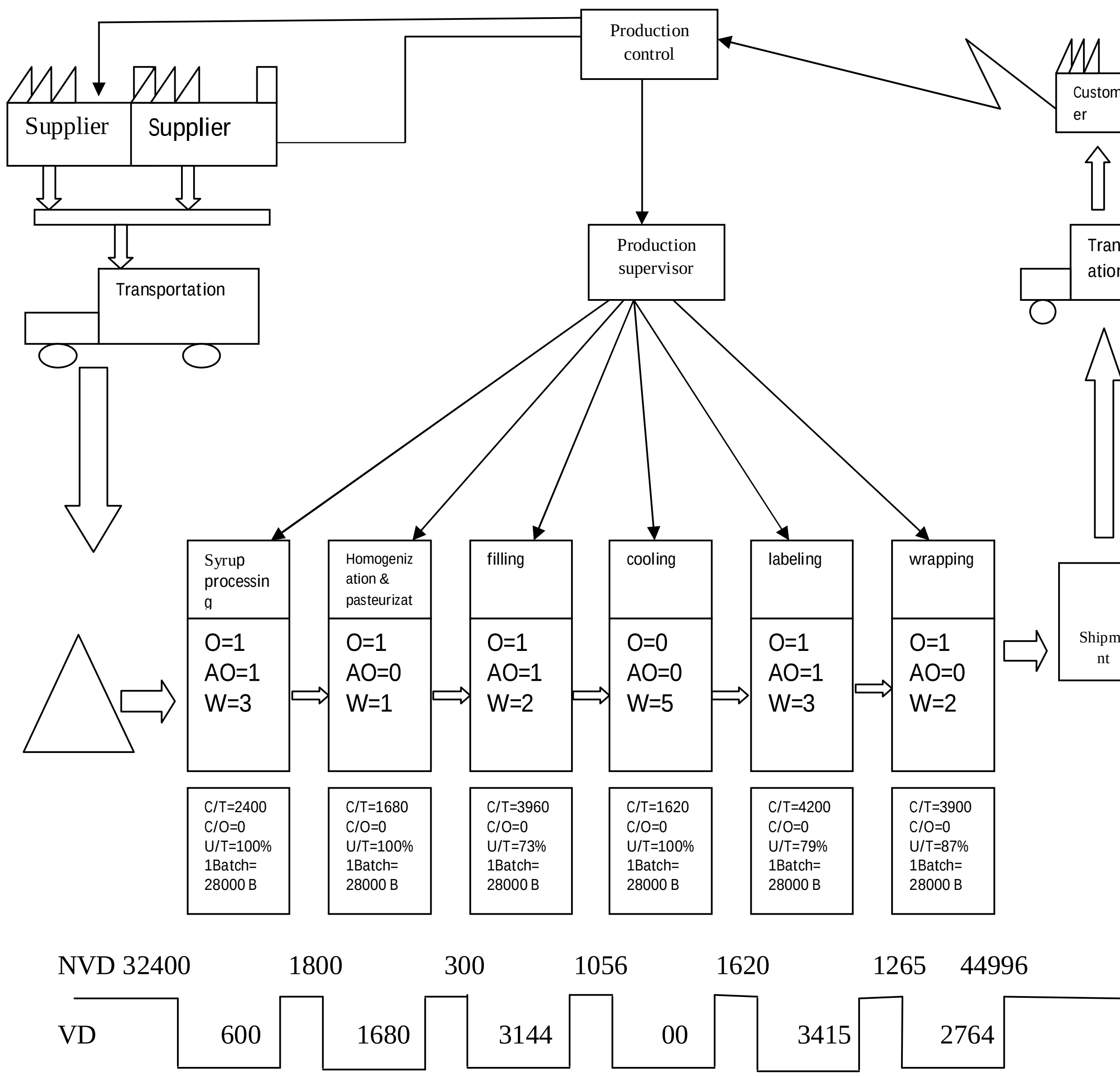


Fig 6.2.2: Current VSM of X mango juice process line-2

Note: Throughout the present VSM the whole processing system of X mango juice process line-2 were depicted with the flow of order, raw materials, labor, information, VD & NVD times. It helps to draw the required processing stage like syrup processing, homogenization & pasteurization, filing, cooling, labeling and wrapping with mentioning required labor, C/T, U/T, C/O and batch size. By observing the present scenario of regarding processing line, it can be known like as what number of labor is needed at different processing unit? How much VD & NVD time is present? Where &

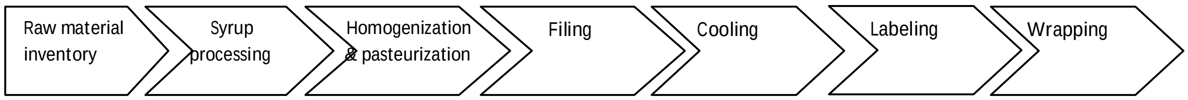
what kind of improvement should be done? It helps to calculate the PCE, lead time and Tact time.

Fig 6.2.2 represents the present VSM of X mango juice process line-2. At present VSM, the production of mango juice was controlled by production manager, assistant manager and supervisor. In this processing line, the production starts by taking the schedule of production from the production manager. In order to fulfill the customer demand the required raw materials were collected from the different regarding suppliers. These required raw materials were brought in the raw materials inventory which is considered as the first stage of mango juice production that followed by syrup processing, homogenization & pasteurization, filing, cooling, labeling, wrapping and shipment of finished goods. As observed from the present VSM of X mango juice process line-2, different types of NVD activities were present in the flow of process line at different stages. The different types of bottlenecks at different processing stages were identified and quantified in terms of time as shown in the Fig 6.2.2. The VD and NVD times were shown at the bottom line of present VSM. It was found that in X mango juice process line-2, about 11603 sec out of 95040 sec or 12.21% were VD activities while 83437 sec or 87.79 % were NVD added activities. By this study it was endeavored to increase the percentage of VD activities and time by reducing the NVD activities and time. The Up time (U/T) of filer, labeler and wrapping machine were consecutively 73%, 79% and 87%. At present state of this processing line over the different stages total labor were 24. After the implementation of lean tools and SS methodologies it was expected that U/T could be improved and total labor could be reduced.

6.2.2 Value chain of X mango juice process line-2

The value chain is a systematic approach to examining the development of competitive advantage. The value chain of X mango juice process line-2 was depicted as follows-

Value chain of X mango juice process line-2



In this stage all required raw materials were gathered, but there was no value added towards the finished goods, although this stage was required for finished goods.	All regarding raw materials were mixed in this stage in order to formulate syrup towards get the finished goods i.e. mango juice. In this stage value was added by 5.17% (VD time 600sec of total	In this stage the syrup was given ultra heat treatment (129^{o} C for 15 sec) in order to increase the self life by destroying the presence microbes without adding considerable any value.	In this stage the syrup was bottled towards giving the more finished goods of mango juice. In this stage the value was added by 27.09% (VD time 3144 sec of total 11603sec)	In this stage the hot bottle were cooled without adding any value but this stage was necessary in order to attain the finished goods.	In this stage the bottle juice were labeled with label foil that contains the details identity of product. In this stage value was added by 29.43%. (VD time 3415 sec of total 11603	In this stage the bottle juice were wrapped with the case. 24 bottles were wrapped in a single case. In this stage value was added by 23.82% (VD time 2764 sec of total 11603 sec)

11603 sec). sec)

Note: VD: Value Added; The percentage of value addition was calculated- the VD time of each processing unit is divided by the total VD time of whole processing line.

6.2.3 Present PCE of X mango juice process line-2

In the X mango juice process line-2,

Value Added time = 11603 Sec

Non Value Added time = 83437 Sec

Lead time = Value Added time + Non Value Added time

= 11603 Sec + 83437 Sec = 95040 Sec

$$\text{PCE} = \frac{\text{Value Added time} \times 100}{\text{Lead time}}$$

12.20 %

It was observed that the present VSM of X mango juice processing line-2 was 12.20% which was the below of internationally competitive level 25% [74]. Throughout this study it was tried to improve the present PCE with the proper implementation of lean tools and SS methodologies.

6.2.4 Present Tact Time of X mango juice process line-2

Net available time			**Customer / production Demand**		
Working shifts / day	2	Shifts	Customer demand/day	8167	cases
Hours / shift	10	Hours			
Available time / shift	600	Minutes			
Prepare time / shift	40	Minutes			
Lunch time / shift	0	Minutes	Net available time / day	67200	seconds / day
Planned downtime / shift	0	Minutes	Customer demand / day	8167	cases / day
Net working time / shift	560	Minutes			
Net working time / shift	33600	Seconds	**Tact time**	8.22	seconds / cases
Net available time / day	67200	Seconds			

Note: Tact time- is considered as the rate at which customers need products i.e. the products should be produced at least equal to Tact time to meet the customer demand.

Tact time is considered as the heart beat of any process line. The present Tact time of X mango juice processing line-2 was 8.22 sec. i.e. it takes 8.22 sec to produce a single case of mango juice production. Each case contains 24 bottle of mango juice where a single bottle contains 250 ml. juice. One of the basic objectives of this study was to reduce this present Tact time after the proper implementation of lean tools and SS methodologies.

6.2.5 Manufacturing waste of X mango juice process line-2

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites, and unnecessary motion in the work place. Among this defect production, wasted time due to different causes and unnecessary motion of labor were very common in the X mango juice processing line-2.

6.2.5.1 Down Time (D/T) calculation for X mango juice processing line-2

The down time for different causes in the processing floor of X mango juice processing line-2 were documented in Table 6.2.3.

Table 6.2.3: Down time (D/T) of X mango juice processing line-2

Step	Causes for D/T	D/T (sec)	Average D/T	C/T	% D/T
Filler	Bottle short in supply	672		3960	27.19
		675	675		
		679			
	Bottle queue in cooling line	210			
		205	209		8.42
		211			
	Crock changing	106			
		99	103		4.15
		104			
	Machine (sensor) problem	80			
		85	83		3.34%
		83			
Labeler	Bottle short in supply	214		4200	
		207	211		8.50
		212			
	Sensor (machine) problem	240			
		248	244		9.83
		244			
	Label changing	115			
		111	113		4.55
		113			
	Label wrapping in	214			

	machine				
		210	213		8.58
		216			
	Over glue in label	105			
		108	105		4.23
		101			
Wrapping	Insufficient bottle supply	210		3900	
		208	207		8.34
		203			
	Case cover changing	194			
		197	197		7.93
		200			
	Sensor (machine) problem	55			
		59	55		2.21
		52			
	Case queue in front	56			
		53	57		2.29
		61			
	Fulfilling 24 bottle in a case	10			
		11	10		0.40
		10			
Total			2482		

In X mango juice processing line-2, the most important processing stages were filing, labeling and wrapping where the most frequent D/T was observed due to different causes that were documented in Table 6.2.3.

6.2.5.2 Wasted bottles calculation of X mango juice processing line-2

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites, and unnecessary motion in the work place. In a single processing line all types of wastes could not be seen. Based on the nature of production the manufacturing wastes are varied. Among these manufacturing wastes, defect production was very common in the X mango juice processing line-2. In this processing line defect bottle was considered as the defect production. The amount of defect bottle was documented in Table 6.2.4.

Table 6.2.4: Wasted bottles of X mango juice processing line-2

Name of stage	No of observation	Rejected bottles per batch	Average rejected bottle per batch	Average rejected bottle per day (per day 9 batch	Rejected bottle per million opportunity	Gap at Six Sigma level	Remarks
Filling	1	12					Contains at three Sigma level
	2	14					
	3	9	12	108	429	426	
	4	13					
	5	10					
Date coding	1	270					
	2	265					
	3	276	264	2376	9429	9426	
	4	259					
	5	251					
Labeling	1	190					
	2	181					
	3	200	186	1674	6643	6640	
	4	172					
	5	187					
Wrapping	1	3					
	2	3					
	3	4	3×24=7	648	2571	2568	

			2		
	4	2			
	5	3			
Total			**534**	**4806**	**19072**

*Note: *Opportunity: a situation or a condition for attainment of a goal; here it indicates to get the chance of total number of bottle production in both case of defect and defect free [83].*

Based on central SS concept it seems that if the amount of defect product is more than 6,210 but less than 66,807 per million product of production then it is considered as the three Sigma productions. From Table 6.2.4, it seems that the total defect product of X mango juice process line-2 was 19072 per million product of production since it was considered as the three Sigma productions. But the prime target of any manufacturing industry should be Six Sigma production where the amount of defect product should not be more than 3.4 per million product of production. Throughout this study it was expected that 80% of the present manufacturing waste could be reduced after the implementation of lean tools and SS methodologies.

6.2.5.3 Wasted labors of X mango juice processing line-2

After lean tools implementation it was expected that a number of labor could be eliminated from X mango juice processing line. The unnecessary motion of labor in the processing line was also considered as the manufacturing waste. The expected number of eliminated labor were documented in the Table 6.2.5

Table 6.2.5: Present and expected Labor of X mango juice processing line-2

Name of Stages	No of labor at present state			No of labor at future state		
	O	AO	W	O	AO	W
Syrup processing	1	1	3	1	1	1
Homogenization & pasteurization	1	0	1	1	0	0
Filing	1	1	2	1	0	1

Cooling	0	0	5	0	0	2
Labeling	1	1	3	1	1	1
Wrapping	1	0	2	1	0	1
Total	5	3	16	5	2	6

At present state, from Table 6.2.5, it was seen that throughout the different processing stages of X mango juice processing line-2, total labor were 24 where operator (O), assistant operator (AO) and worker (W) were consecutively 5, 3 and 16. At future state, if the lean tools and SS methodologies will implement, it was expected that different types of bottlenecks and NVD activities will be reduced thus the present number of labor will also be reduced from 24 to 13 where operator (O), assistant operator (AO) and worker (W) were consecutively 5, 2 and 6. Because of a number of unwanted labors were engaged to manage the different types of bottlenecks and NVD activities.

6.2.6 Pareto analysis for X mango juice processing line-2

Pareto analysis was performed by drawing the Pareto chart consisting of causes for delay along the X axis and percentage and cumulative percentage of down time along the Y axis. The highest frequency of NVD activities or down time was found for insufficient bottle supply in X mango juice processing line, while bottle fulfilling of 24 bottle in a case at Wrapping machine showed the lowest frequency.

Table 6.2.6: Required data for Pareto analysis of X mango juice processing line-2

Causes of delay times	Down Time(D/T)	Percentage of (D/T)	Cumulative of percentage
Insufficient bottle supply	1093	44.03706	44.03706
Problem in sensor of machine	382	15.39081	59.42787
Label wrapping in label machine	213	8.58178	68.00965
Bottle queue in cooling line	209	8.42062	76.43027

Case cover changing of Wrapping machine	197	7.93714	84.36741
Label changing of labeler	113	4.55278	88.92019
Over glue in label at label machine	105	4.23045	93.15064
Crock Changing in filler	103	4.14987	93.30051
Case queue of wrapping machine in front of outlet	57	2.29653	99.59704
Fulfilling of 24 bottle in a case at wrapping machine	10	0.40296	100.00000

Different causes of NVD activities or down time at different processing stages of X mango juice processing line-2 with their frequency in terms of percentages and cumulative percentages were documented in Table 6.2.6. The causes for NVD activities were arranged in downward movements in terms of their frequency.

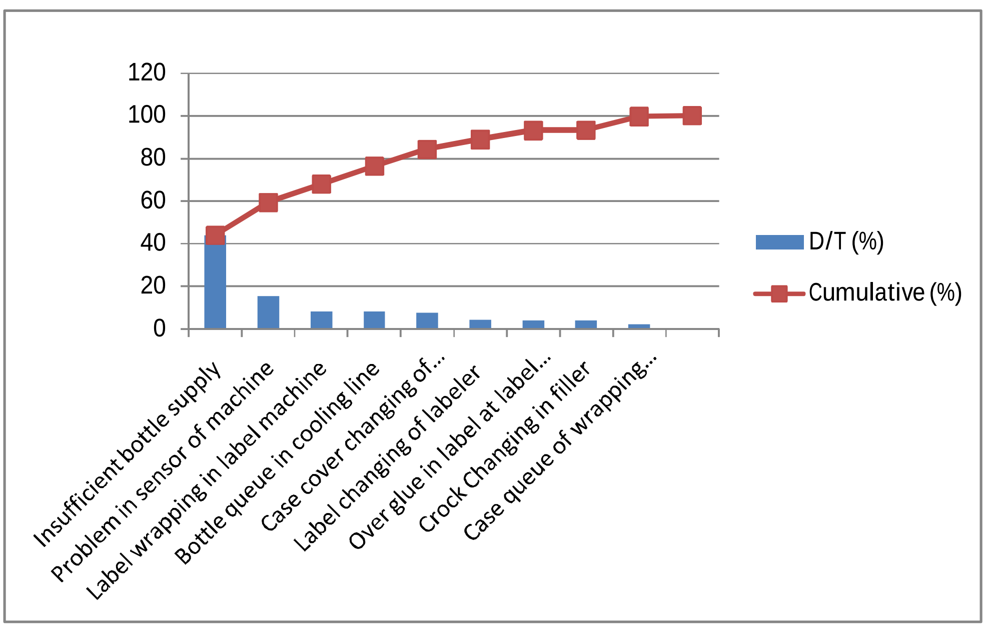


Fig 6.2.3 Pareto chart of X mango juice processing line-2

Pareto chart (Fig 6.2.3) was depicted from Pareto table (Table 6.2.6) by aligning the different causes along with X axis; percentage and cumulative percentage of these causes for NVD activities were aligned along with the Y axis. From Fig 6.2.3, it seems that the pioneer causes beyond the different types of bottlenecks and NVD activities were insufficient bottle supply (44.03%), problem in sensor of machine (15.39%), label wrapping in label machine (8.58%), bottle queue in cooling line (8.42), case cover changing of wrapping machine (7.93%), label changing of labeler (4.55%), over glue in label at label machine (4.23%), crock changing in filler (4.14%), case queue of wrapping machine in front of outlet (2.29%), fulfilling of 24 bottle in a case at wrapping machine (0.40%). From Pareto chart the most responsible causes were easily observed and the effective initiatives can be taken to remove these causes. From Pareto chart (Fig 6.2.3) it was expected that if the most frequent first three causes like as insufficient bottle supply (44.03%), problem in sensor of machine (15.39%), label wrapping in label machine (8.58%) could be removed, the 80% NVD activities or down times could be removed. 5S, JIT, TPM, DMAIC and other improving strategies could be effective initiatives to remove these most frequent causes.

6.2.7 Improvement points at present VSM of X mango juice process line-2

Throughout the observation it was seen that there were some improvement points at different stages of X mango juice processing line-2. The nature of improving point differs from each and another stages.

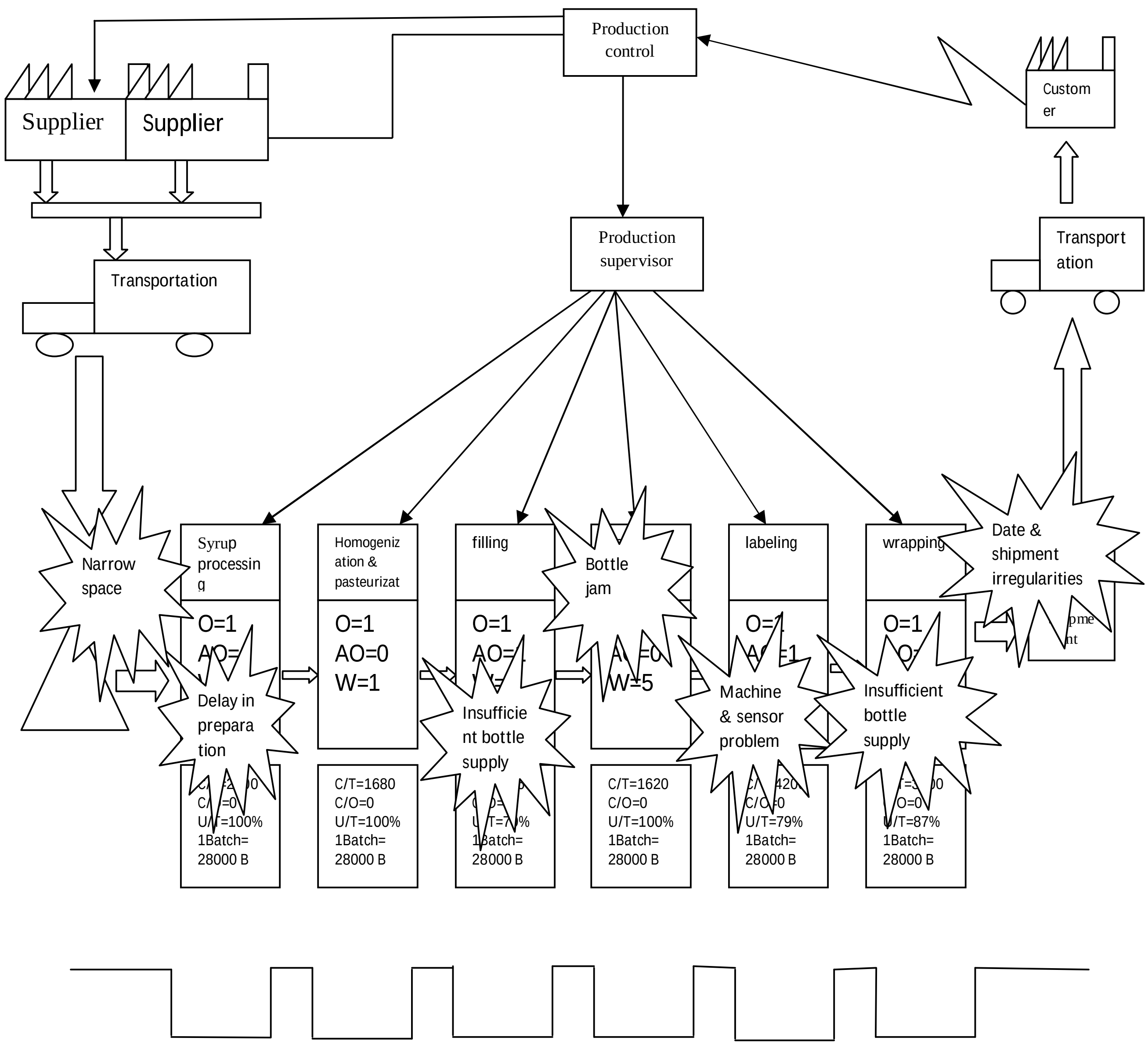


Fig 6.2.4 Present VSM of X mango juice process line-2 with improvement points

The crucial improvement points were pointed in Fig 6.2.4. In the stage of raw material or receiving inventory, delay handling of raw materials towards the next stage of syrup processing was observed as the prime point that should be removed in order to reduce the lead time as well as to improve the PCE. Besides these, conventional movement of raw materials like as carry of raw materials sack by labor instead of conveyor belt movement, open air inventory storage, congested stairways were most common. In the syrup processing stage, the delay of syrup processing was the main hindrance beyond the NVD activities and bottlenecks. No cause was indentified that need to solve in the stage of homogenization and pasteurization, because of it was difficult to detect any barrier beyond the bottleneck due to fully pipe flow of syrup towards the next filing stage, but it was observed that this stage was smoothly running and based on previous experience of regarding personnel it was also known that there was no mentionable barrier for bottlenecks. In the filing stage the basic causes were bottle short in supply, bottle queue in cooling line, crock changing and machine sensor problem. In the stage of cooling bottle jam was observed as the only one problem both in enters and exit of cooling chamber. In the stage of labeling the main causes for bottlenecks or breakdown of machine were bottle short in supply, machine sensor problem, label changing delay, label wrapping in machine and over glue in label. In case of wrapping stage the basic problems were pointed as insufficient bottle supply, case cover changing, sensor (machine) problem, case queue in front and fulfilling 24 bottles in a case. In the stage of shipment the basic barrier were irregular shipment and insufficient space for movement. In Fig 6.2.4 only the most frequent cause at different stages of X mango juice processing line-2 were pointed. These pointed causes or barriers should be removed in order to reduce the manufacturing wastes and improve the PCE.

6.2.8 Expected future VSM of X mango juice process line-2

In the future VSM after an intense observation on the X mango juice processing line-2 and brainstorming analysis the VD and NVD time were calculated and documented in Table 6.2.7.

Table 6.2.7 : Future State VD and NVD time of X mango juice processing line-2

Processing stage	Value Added Time (Sec)	Non Value Added Time (Sec)
Receiving Inventory	00	16200 (50%)
Syrap processing	600	**900 (50%)**
Homogenization & pasteurization	1680	**300 (0%)**
Filling	3144	**211 (80%)**
Cooling	0	**324 (80%)**
Labeling	3415	**252 (80%)**

Wrapping	2764	**359 (80%)**
Shipping Inventory	00	**12960 (70%)**
Total	**11603 (25.18%)**	**31506 (74.82%)**

Note: VD time- the time that is desired which add the value to goods or service; NVD time- the time that is not desired or that does not add any value to goods or service

It was expected, after the implementation of lean tools and SS methodologies the present state NVD activities or times could be reduced at least up to 80%. In this study, based on intense observation, brainstorming and previous regarding studies it was assumed that the NVD time of receiving stage of X mango juice processing line-2 could be reduced at least 50% (16200 sec) and the NVD time of syrup processing could be also be reduced at least 50% (900 sec). The NVD time of filing, cooling, labeling and wrapping could be reduced at least 80% from the present state and in the future state these NVD times could be consecutively 211 sec, 324 sec, 252 sec and 359 sec which could be seen in Table 6.2.7.

The Fig 6.2.5 was the future VSM of X mango juice processing line-2. The future VSM indicates the materials, information and labor flow of single batch production of X mango juice processing line-2. Each batch contains 7000 L syrup that produce 28000 bottle (B) of mango juice.

The basic components of future VSM were customers, production control, production supervisor, suppliers, transportation, different stages of processing line like as receiving inventory, syrup processing, homogenization and pasteurization, filing, cooling, labeling, wrapping and shipment inventory and finally the VD and NVD times that were depicted at the bottom of future VSM.

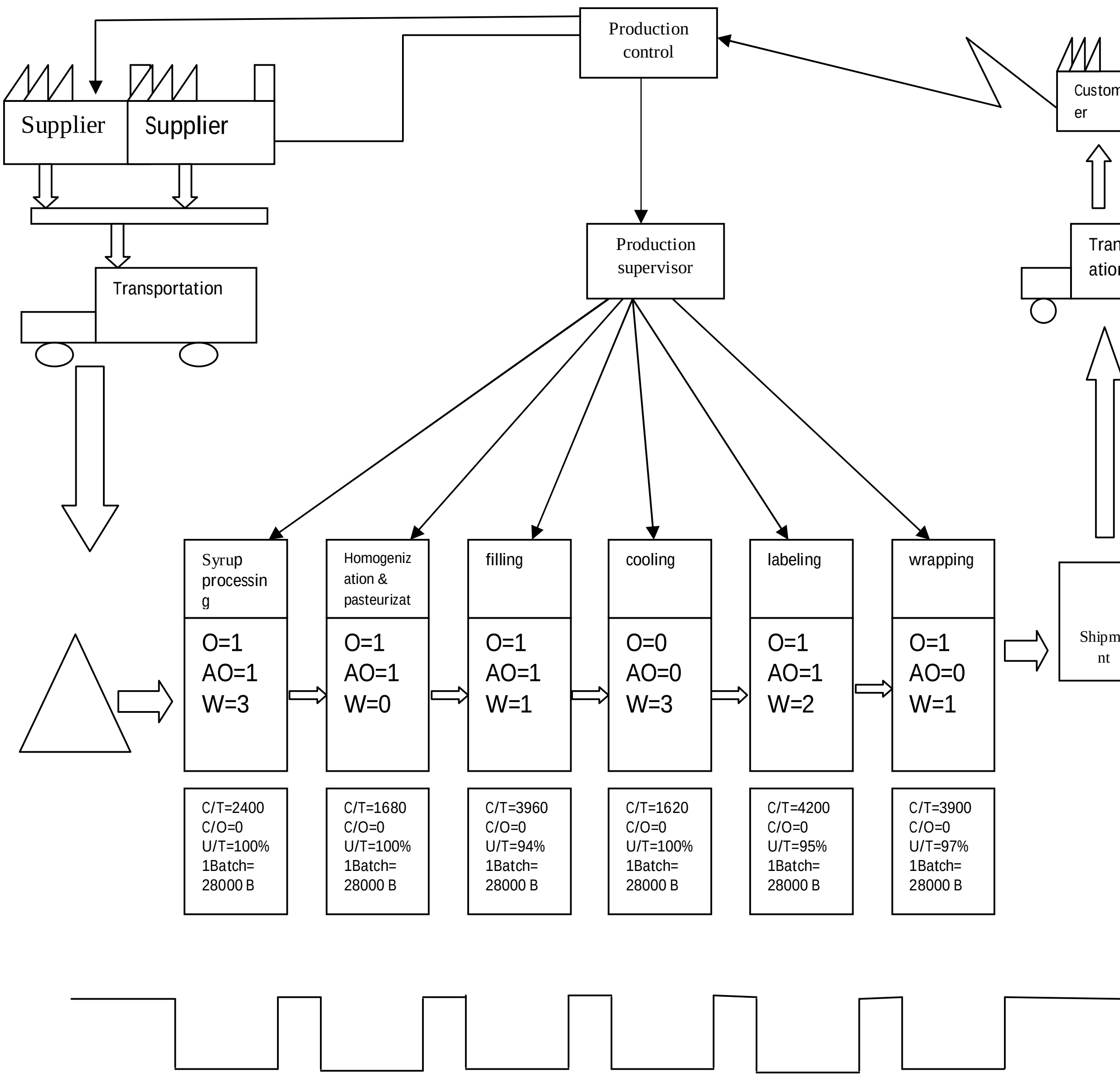


Fig 6.2.5 Future VSM of X mango juice process Line-2

Production control consists of one production manager and two assistant production managers. The production starts with taking the order from customer by electric signal like as over telephone or email. Later required raw materials were collected from the suppliers. Finally raw materials were transformed into finished mango juice throughout the receiving inventory stage to shipment stage.

In this future VSM, the basic promising changes were the reduction of total number of labor, reduction of NVD time and improved Up time (U/T) at every processing stage of X mango juice processing line-2.

In future VSM the total labor including operator, assistant operator and worker could be 13 which was 24 at present VSM i.e. after the implementation of lean tools and SS methodologies it was expected at least 11 labors could be reduced. The U/T of filer, labeler and wrapping machine could be consecutively 94%, 95% and 97% but at present state the U/T of filer, labeler and wrapping machine were consecutively 73%, 79% and 87%.

6.2.9 Expected PCE of X mango juice processing line-2

In the X mango juice processing line-2,

Value Added time = 11603 Sec

Non Value Added time = 31506 Sec

Expected Lead time = Value Added time + Non Value Added time

= 11603 Sec + 31506 Sec = 43109 Sec

$$\text{PCE} = \frac{\text{Value Added time} \times 100}{\text{Lead time}}$$

26.91 %

After the proper implementation of lean tools and SS methodologies, it was expected the PCE of X mango juice processing line-2 could be 26.91% while the present PCE was 12.20%, the NVD time could be reduced from 83437 sec to 31506 sec and lead time could be reduced from 95040 sec to 43109 sec.

6.2.10 Expected future Tact time of X mango juice process line-2

Net available time			**Customer / production Demand**		
Working shifts / day	2	Shifts	Customer demand/day	8167	cases
Hours / shift	10	Hours			
Available time / shift	600	Minutes			
Prepare time / shift	40	Minutes			
Lunch time / shift	0	Minutes	Net available time / day	67200	seconds / day
Planned downtime / shift	0	Minutes	Customer demand / day	8367	cases / day
Net working time / shift	560	Minutes			
Net working time / shift	33600	Seconds	**Tact time**	8.03	seconds / cases
Net available time / day	67200	Seconds			

Note: Tact time- is considered as the rate at which customers need products i.e. the products should be produced at least equal to Tact time to meet the customer demand.

As earlier it was mentioned that Tact time is the heart beat of production of any manufacturing industry. As it is lower indicates the faster of production. Throughout this study it was tried to reduce the Tact time. The present Tact time of X mango juice processing line-2 was 8.22 sec per case production and it was expected that after the adoption of lean tools and SS methodologies this could be reduced to 8.03 sec per case production. So, it seems that the lean tools and SS methodologies could bring the revolution beyond the speed of production of any processing line.

6.3 Carbonated Soft Drinks (CSD) “X up” Processing Line

It was a Carbonated Soft Drinks (CSD), “X up” processing line. This beverage was formulated by incorporating with different unique components as compare to mango juice. The basic stages of CSD, “X up” processing line were as follows-

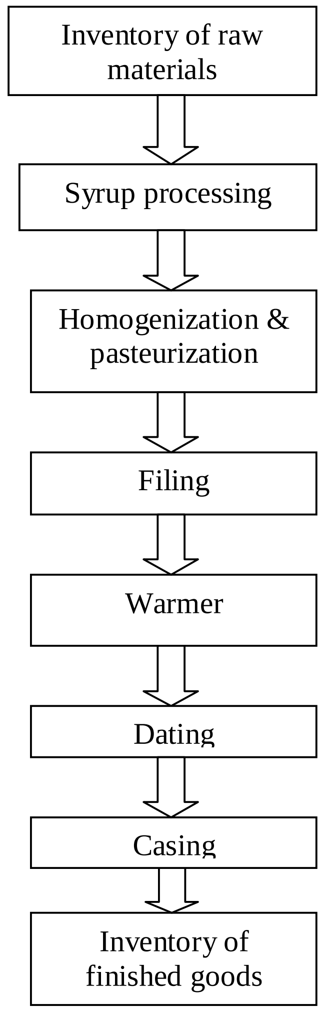


Fig 6.3.1 Basic stages of CSD “X up” processing line

6.3.1 Present Value Steam Mapping (VSM) of “X up” processing line

To draw the present VSM relevant data, like as VD and NVD time, Cycle time, Change Over time, Uptime, Lot size, quantity to deliver, delivery time were observed and information related to assembly line such as processing time, inventory storages, inspections, rework loops, number of workers and operational hours per day were collected and documented in Table 6.3.1 and Table 6.3.2. To draw the completion of present VSM of CSD, "X up" processing, a timeline was added at the bottom of the map recording the VD and NVD time.

Table 6.3.1: Down Time, Cycle Time and Up Time data of CSD, "X up" processing line

Times	Filler			Labeler			Wrapping machine		
	D/T (sec)	C/T (sec)	U/T (%)	D/T (sec)	C/T (sec)	U/T (%)	D/T (sec)	C/T (sec)	U/T (%)
1st	474	2760	83	862	2400	64	384	1620	76
2nd	487	2760	82	869	2400	64	385	1620	76
3rd	474	2760	83	849	2400	65	388	1620	76

Note: Filler speed: 350 BPM; Labeler speed: 400 BPM; Wrapping machine speed: 25 case per min. Batch-4000 L; BPM: Bottle Per Minutes; D/T- the time that is wasted due to breakdown of machine; C/T- the time that is required to produce a single batch production; U/T- the time that is available for machine work or production.

The D/T, C/T, and U/T of CSD, "X up" processing line were documented in Table 6.3.1. In this processing line the stage of filer, labeler and wrapping machine were mainly responsible for D/T. In the stage of filer, average U/T was 83% and C/T was 2760 sec. In the stage of labeler average U/T was 64% and C/T was 2400 sec. In the stage of wrapping, C/T was 1620 sec and U/T was 76%. The percentage of available time for machine work or processing of desire product is known as the U/T. By observing the U/T of different unit stage of production line, it can be assumed the efficiency of the whole production line. At present state, the U/T of CSD, "X up" process line varies from 64% (labeling stage) to 83% (filing stage). By this study it was attempted to increase the U/T in the future state as well as to reduce the D/T and to reduce the ultimate lead time.

Table 6.3.2: VD and NVD time of CSD, “X up” processing line

Processing stage	VD Time (Sec)	NVD Time (Sec)
Receiving Inventory	00	28800
Syrup processing	600	1200
Homogenization & UHT	1200	240
Filling	2297	703
Warmer	0	672
Labeling	1650	1372
Wrapping	1231	702
Shipping Inventory	00	43200
Total	**6978 (8.32 %)**	**76889 (91.68 %)**

Note: VD time- the time that is desired which add the value to goods or service; NVD time- the time that is not desired or that does not add any value to goods or service

The VD and NVD time of different processing stages of CSD, “X up” processing line was documented in Table 6.3.2. At present state, there were no VD time except NVD time in the stages of receiving inventory, warming and shipping inventory, but in this process line, this NVD time or these stages were required for the CSD, “X up” processing.

In this CSD, “X up” processing line, the total VD time were 6978 sec (8.32 %) and the total NVD time were 76889 sec (91.68 %). By this study, it was tried to increase the percentage of VD time by reducing the NVD time with the proper implementation of lean tools and SS methodologies.

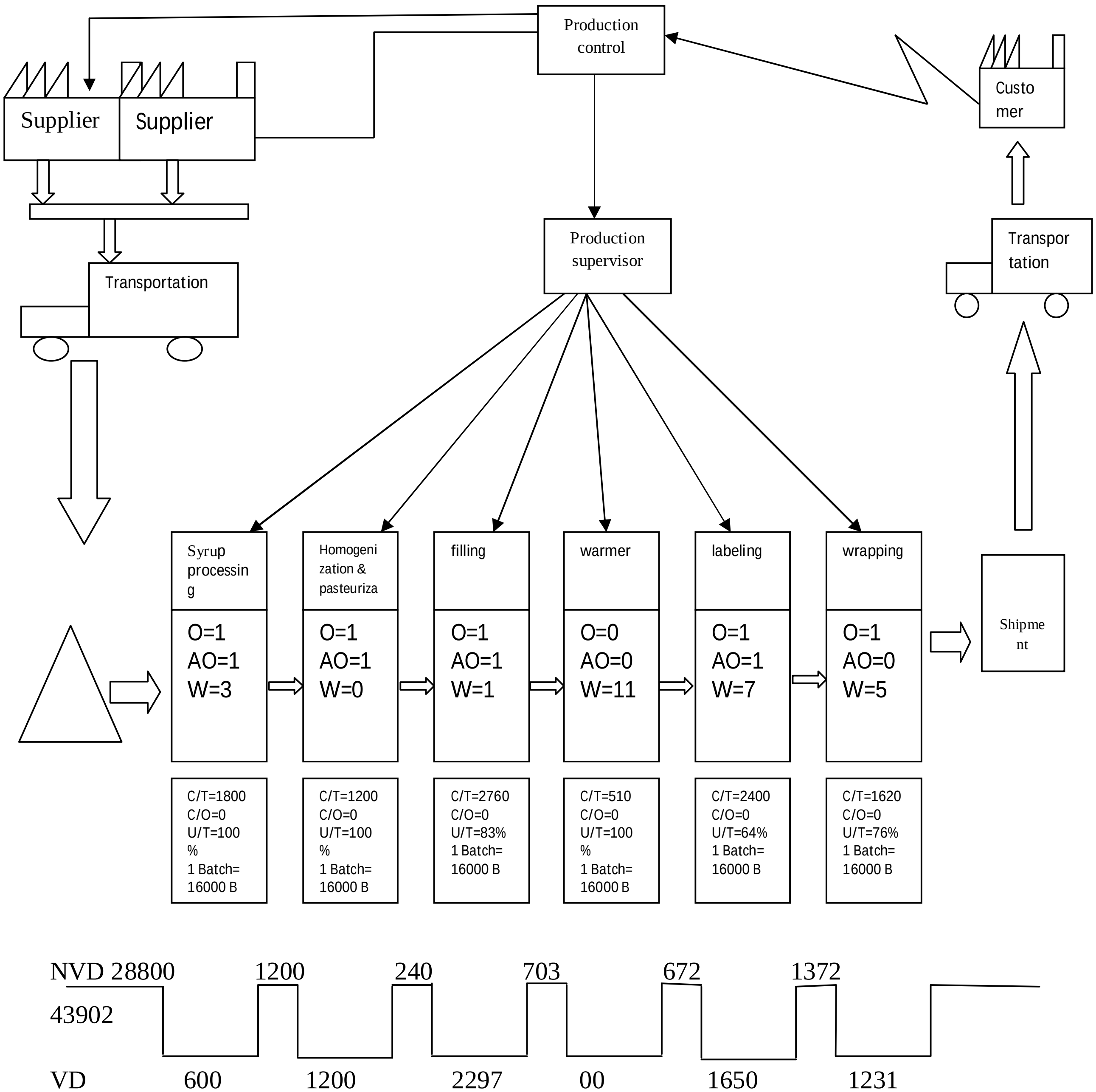


Fig 6.3.2 Current VSM of CSD, “X up” process

Note: Throughout the present VSM the whole processing system of “X up” *process line were depicted with the flow of order, raw materials, labor, information, VD & NVD times. It helps to draw the required processing stage like syrup processing,* *homogenization & pasteurization, filing, cooling, labeling and wrapping with mentioning required labor, C/T, U/T, C/O and batch size. By observing the present scenario of regarding processing line, it can be known like as what number of labor is needed at different processing unit? How much VD & NVD time is present? Where & what kind of improvement should be done? It helps to calculate the PCE, lead time and Tact time.*

Fig 6.3.2 represents the present VSM of CSD, “X up” process line. At present VSM, the production of CSD, “X up” was controlled by production manager, assistant manager and supervisor. In this processing line, the production starts by taking the order of production from the customers. In order to fulfill the customer demand the required raw materials were collected from the different regarding suppliers. These required raw materials were brought in the raw materials inventory which was the first stage of CSD, “X up” production that followed by syrup processing, homogenization & pasteurization, filing, warming, labeling, wrapping and shipment of finished goods. As observed from the present VSM of CSD, “X up” process line, different types of NVD activities were present in the flow of process line at different stages. The different types of bottlenecks at different processing stages were identified and quantified in terms of time as shown in the Fig 6.4.2. The Up time (U/T) of filer, labeler and wrapping machine were consecutively 83%, 64% and 76%. At present state of this processing line over the different stages total labor were 36. After the implementation of lean tools and SS methodologies it was expected that U/T could be improved and total labor could also be reduced.

6.3.2 Value chain of CSD, “X up” processing line

A value chain is a chain of activities that a firm operating in a specific industry performs in order to deliver a valuable product or service for the market. The value chain of CSD, “X up” processing line was depicted as follows-

Value chain of CSD, “X up” processing line

Raw material inventory	Syrup processing	Homogenization & pasteurization	Filing	Warming	Labeling	Wrapping
In this stage all required raw materials were gathered, but there was no value added towards the finished goods, although this stage was required for finished goods.	All regarding raw materials were mixed in this stage in order to formulate syrup towards get the finished goods i.e. CSD, “X up”. In this stage value was added by 8.59% (VD time 600sec of total 6978 sec)	In this stage the syrup was given ultra heat treatment (129° C for 15 sec) in order to increase the self life by destroying the presence microbes with adding value by 17.19% (VD time 1200 sec of total 6978sec).	In this stage the syrup was bottled at cool condition towards giving the more finished goods of CSD, “X up”. In this stage the value was added by 32.91% (VD time 2297 sec of total 6978sec)	In this stage the cooled bottles were warmed without adding any value but this stage was necessary in order to attain the finished goods.	In this stage the bottle CSD, “X up” beverage were labeled with label foil that contains the details identity of product. In this stage value was added by 23.64%. (VD time 1650 sec of total 6978 sec).	In this stage the bottle CSD, “X up” beverage were wrapped with the case. 24 bottles were wrapped in a single case. In this stage value was added by 17.64% (VD time 1231 sec of total 6978 sec)

Note: VD: Value Added; CSD, “X up”: Carbonated Soft Drink; The percentage of value added was calculated- the VD time of each processing unit is divided by the total VD time of whole processing line.

6.3.3 Present PCE of “X up” process Line

In the CSD, “X up” process Line,

Value Added time = 6978 Sec

Non Value Added time = 76889Sec

Lead time = Value Added time + Non Value Added time

= 6978 Sec + 76889Sec = 83867 Sec

$$\text{PCE} = \frac{\text{Value Added time} \times 100}{\text{Lead time}}$$

8.32 %

It seems that the present VSM of CSD, “X up” processing line is 8.32 % which is the below of internationally competitive level 25% [74]. Throughout this study it was tried to improve the present PCE of CSD, “X up” processing line with the proper implementation of lean tools and SS methodologies.

6.3.4 Present Tact time of "X up" process line

Net available time			**Customer / production Demand**		
Working shifts / day	2	Shifts	Customer demand/day	9333	cases
Hours / shift	10	Hours			
Available time / shift	600	Minutes			
Prepare time / shift	40	Minutes			
Lunch time / shift	0	Minutes	Net available time / day	67200	seconds / day
Planned downtime / shift	0	Minutes	Customer demand / day	9333	cases / day
Net working time / shift	560	Minutes			
Net working time / shift	33600	Seconds	**Tact time**	7.20	seconds / cases
Net available time / day	67200	Seconds			

Note: Tact time- is considered as the rate at which customers need products i.e. the products should be produced at least equal to Tact time to meet the customer demand.

Tact time is considered as the heart beat of any process line. The present Tact time of CSD, "X up" processing line was 7.20 sec. i.e. it takes 7.20 sec to produce a single case of CSD, "X up" production. Each case contains 24 bottle of CSD, "X up" where a single bottle contains 250 ml. CSD, "X up". One of the basic objectives of this study was to reduce this present Tact time after the proper implementation of lean tools and SS methodologies.

6.3.5 Manufacturing waste of "X up" processing line

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites, and unnecessary motion in the work place. Among these defect productions, wasted time due to different causes and unnecessary motion of labor was very common in the CSD processing line.

6.3.5.1 Down Time (D/T) calculation of “X up” processing line

The down time for different causes in the CSD, “X up” processing floor were documented in Table 6.3.3.

Table 6.3.3: Down Time (D/T) of “X up” processing line

Step	Causes for D/T	D/T (sec)	Average D/T	C/T	% D/T
Filler	Bottle short in supply	302		2760	
		308	303		17.55
		298			
	Bottle queue in warmer line	55			
		51	53		3.07
		48			
	Crock changing	34			
		32	35		2.02
		40			
	Machine (sensor) problem	83			
		96	89		5.15
		88			
Labeler	Bottle short in supply	534		2400	
		524	526		5.96
		520			
	Sensor (machine) problem	97			
		109	103		
		103			
	Label changing	93			
		102	97		5.62
		96			

	Oil time	48		
		39	43	2.49
		41		
	Over glue in label	90		
		95	91	5.27
		89		
Wrapping	Insufficient bottle supply	176		1620
		170	171	9.90
		167		
	Case cover changing	90		
		87	91	5.27
		95		
	Sensor (machine) problem	39		
		45	42	2.43
		42		
	Label torning	38		
		45	41	2.37
		41		
	Disarray of bottle	41		
		38	41	2.37
		43		
Total			**1726**	

In CSD, "X up" processing line, the most important processing stages were filing, labeling and wrapping where the most frequent D/T was observed due to different causes that were documented in Table 6.3.3

6.3.5.2 Wasted bottles calculation of "X up" processing line

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites, and unnecessary motion in the work place. In a single processing line all types of wastes could not be seen. Base on the nature of production the manufacturing wastes are varied. Among these manufacturing wastes, defect production was very common in the CSD, "X up" processing line. In this processing line defect bottle was considered as the defect production. The amount of defect bottle was documented in Table 6.3.4.

Table 6.3.4: Wasted bottle calculation of "X up" processing line

Name of stage	No of observation	Rejected bottles per batch	Average rejected bottle per batch	Average rejected bottle per day (per day 12 batch)	Rejected bottle per million opportunity	Gap at Six Sigma level	Remarks
Filling	1	14					Contains
	2	11					at three
	3	10	11	132	688	685	Sigma
	4	13					level
	5	9					
Date coding	1	260					
	2	258					
	3	269	258	3096	16125	16122	
	4	253					
	5	248					
Labeling	1	193					
	2	180					
	3	199	186	2232	11625	11622	
	4	170					
	5	189					
Wrapping	1	4					
	2	3					

	3	3	3×24=72	864	4500	4497
	4	3				
	5	3				
Total			**527**	**6324**	**32938**	

*Note: *Opportunity: a situation or a condition for attainment of a goal; here it indicates to get the chance of total number of bottle production in both case of defect and defect free [83].*

Based on central SS concept it seems that if the amount of defect product is more than 6,210 but less than 66,807 per million product of production then it is considered as the three Sigma productions. From Table 6.3.4, it seems that the total defect product of "X up" process line was 32938 per million product of production which was considered as the three Sigma productions. But the prime target of any manufacturing industry should be Six Sigma production where the amount of defect product should not be more than 3.4 per million product of production. Throughout this study it was expected that 80% of the present manufacturing waste could be reduced after the implementation of lean tools and SS methodologies.

6.3.5.3 Wasted labor of "X up" processing line

After lean tools implementation it was expected that a number of labor could be eliminated from "X up" processing line. The unnecessary motion of labor in the processing line was also considered as the manufacturing waste. The expected number of eliminated labor was documented in the Table 6.3.5.

Table 6.3.5: Present and expected Labor of "X up" processing line

Name of Stages	No of labor at present state			No of labor at future state		
	O	AO	W	O	AO	W
Syrup processing	1	1	3	1	1	3
Homogenization & pasteurization	1	1	0	1	0	0
Filing	1	1	1	1	0	1

Warming	0	0	11	0	0	4
Labeling	1	1	7	1	1	3
Wrapping	1	0	5	1	0	2
Total	5	4	27	5	2	13

At present state, from Table 6.3.5, it was seen that throughout the different processing stages of "X up" processing line, total labor were 36 where operator (O), assistant operator (AO) and worker were consecutively 5, 4 and 27. At future state, if the lean tools and SS methodologies will implement, it was expected that different types of bottlenecks and NVD activities will be reduced thus the present number of labor will also be reduced from 36 to 20 where operator (O), assistant operator (AO) and worker were consecutively 5, 2 and 13. Because of a number of unwanted labors were engaged to manage the different types of bottlenecks and NVD activities.

6.3.6 Pareto analysis

Pareto analysis was performed by drawing the Pareto chart consisting of causes for delay along the X axis and percentage and cumulative percentage of down time along the Y axis. The highest frequency of down time was found as insufficient bottle supply at the "X up" processing line, while crock changing of filer showed the lowest frequency.

Table 6.3.6: Cumulative D/T for Pareto analysis of "X up" processing line

Causes of delay times	Down Time(D/T)	Percentage of (D/T)	Cumulative of percentage
Insufficient bottle supply	1000	57.93742	57.93742
Sensor problem of machine	234	13.55735	71.49477
Label changing of labeler	97	5.61993	77.11470
Over glue in label at labeler	91	5.27230	82.38700
Case cover changing time of labeler	91	5.27230	87.65930
Bottle queue in front of filer	53	3.07068	90.72998

Oil time of labeler	43	2.49130	93.22128
Case cover stretching	41	2.37543	95.59671
Disarray of bottle at wrapping	41	2.37543	97.97214
Crock Changing of filer	35	2.02786	100.00000

Different causes of NVD activities or down time at different processing stages of “X up” processing line with their frequency in terms of percentages and cumulative percentages were documented in Table 6.3.6. The causes for NVD activities were arranged in downward movements in terms of their frequency.

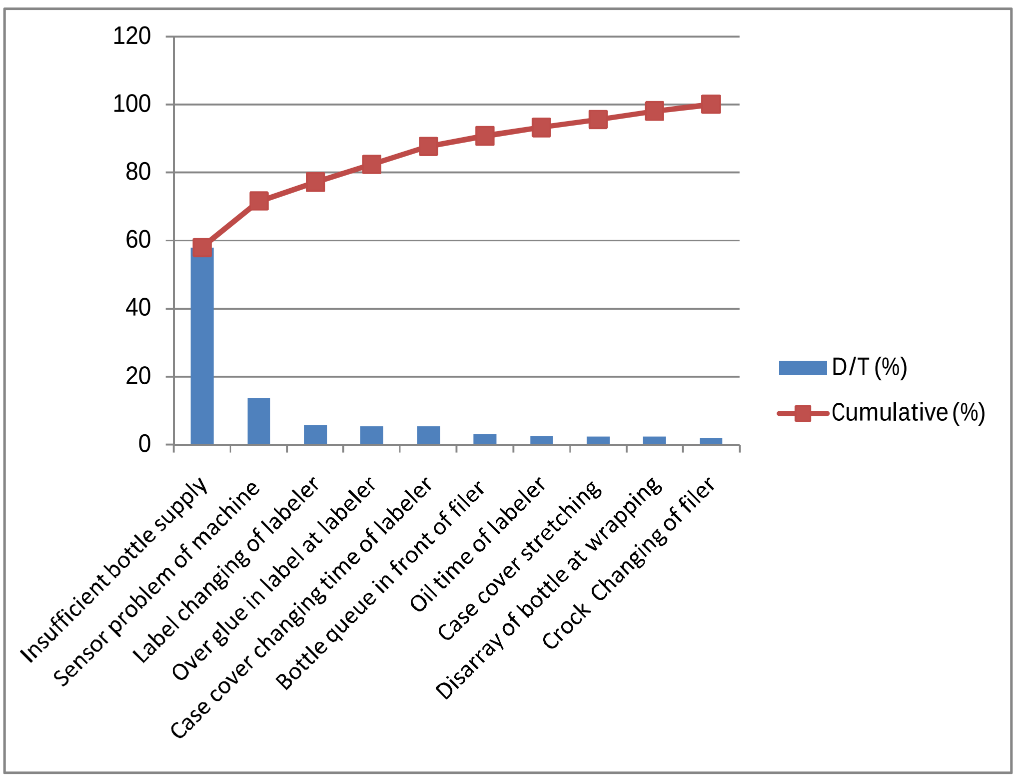


Fig 6.3.3 Pareto chart of “X up” processing line

Pareto chart (Fig 6.3.3) was depicted from Pareto table (Table 6.3.6) by aligning the different causes along with X axis; percentage and cumulative percentage of these causes for NVD activities were aligned along with the Y axis. From Fig 6.3.3, it seems that the pioneer causes beyond the different types of bottlenecks and NVD activities were insufficient bottle supply (57.93%), sensor problem of machine (13.55%), label changing of labeler (5.61%), over glue in label at labeler (5.27%), case cover changing time of labeler (5.27%), bottle queue in front of filer (3.07%), oil time of labeler (2.49%), case cover stretching (2.37%), disarray of bottle at wrapping (2.37%) and crock changing of filer (2.02%)

From Pareto chart (Fig 6.3.3) the most responsible causes could be easily observed and the effective initiatives could also be taken to remove these causes. It was expected that if the most frequent first three or 20% causes like as insufficient bottle supply (57.93%), sensor problem of machine (13.55%), label changing of labeler (5.61%), could be removed, the 80% NVD activities or down times could be removed. 5S, JIT, TPM, DMAIC and other improving strategies could be effective initiatives to remove these most frequent causes.

6.3.7 Improvement points at present VSM of CSD, “X up” process line

Throughout the observation it was seen that there were some improvement points at different stages of “X up” processing line. The nature of improving point differs from each and another stages.

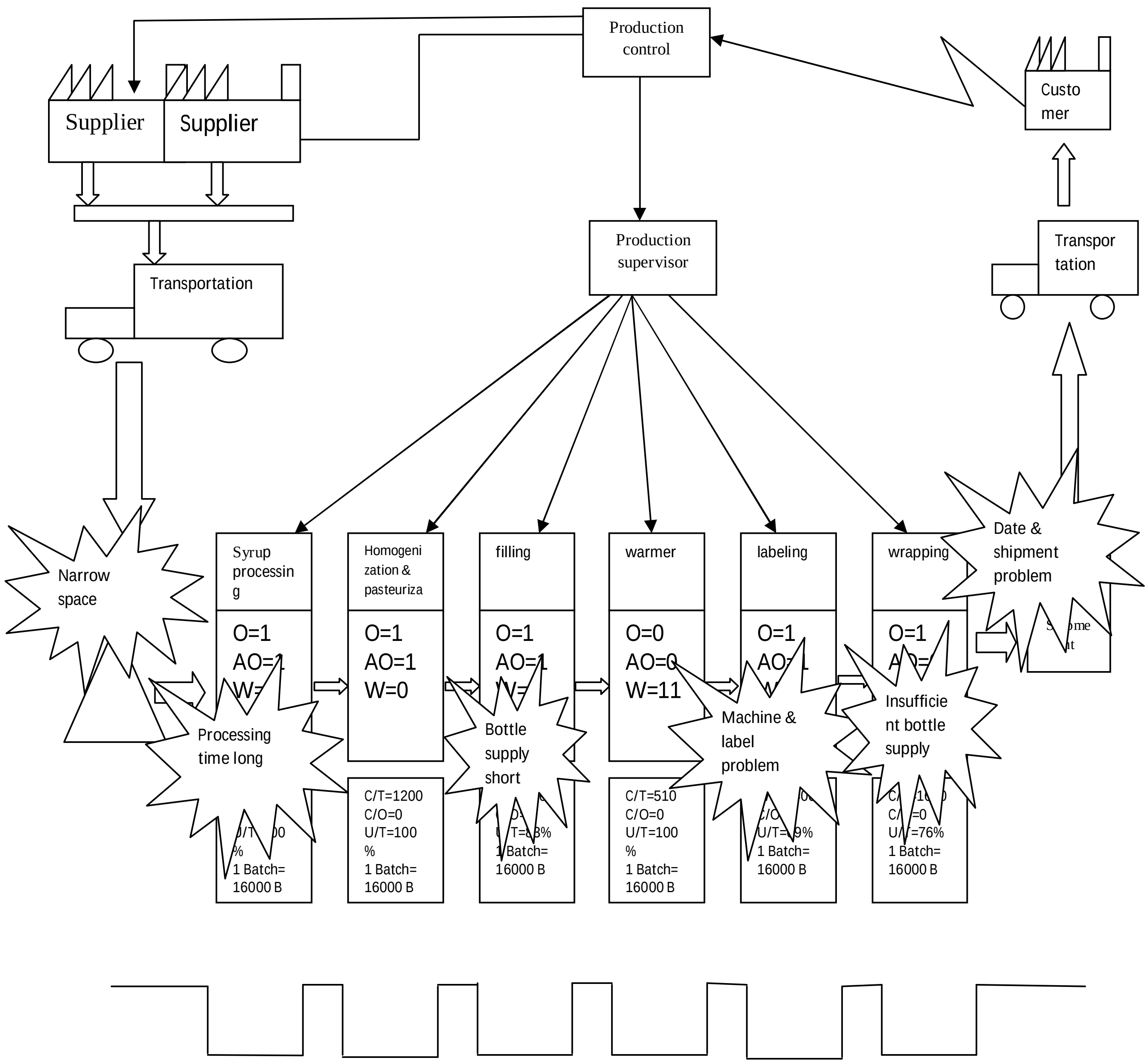


Fig 6.3.4 Present VSM of CSD, “X up” process with improvement point

The crucial improvement points were pointed in Fig 6.3.4. In the stage of raw material or receiving inventory, delay handling of raw materials towards the next stage of syrup processing was observed as the prime point that should be removed in order to reduce the lead time as well as to improve the PCE. Besides these, conventional movement of raw materials like as carry of raw materials sack by labor instead of conveyor belt movement, inventory storage room was soaked and congested, crowd movement were most common. In the syrup processing stage, the delay of syrup processing was the main hindrance beyond the NVD activities and bottlenecks. No cause was indentified that need to solve in the stage of homogenization and pasteurization, because of it was difficult to detect any barrier beyond the bottleneck due to fully pipe flow of syrup towards the next filing stage, but it was observed that this stage was smoothly running and based on previous experience of regarding personnel it was also known that there was no mentionable barrier for bottlenecks. In the filing stage the basic causes were bottle short in supply, bottle queue in warmer line, crock changing, machine (sensor) problem. In the stage of warming bottle jam was observed as the only one problem both in enters and exit of cooling chamber. In the stage of labeling the main causes for bottlenecks or breakdown of machine were bottle short in supply, sensor (machine) problem, label changing, oil time, over glue in label. In case of wrapping stage the basic problems were pointed as insufficient bottle supply, case cover changing, sensor (machine) problem, label torning, disarray of bottle. In the stage of shipment the basic barrier were irregular shipment and insufficient space for movement. In Fig 6.3.4 only the most frequent cause at different stages of CSD, “X up” processing line were pointed. These pointed causes or barriers should be removed in order to reduce the manufacturing wastes and improve the PCE.

6.3.8 Future VSM of "X up" process line

In the future VSM after a deep brainstorming and an intense observation on the CSD, "X up" processing line the VD and NVD time were calculated and documented in Table 6.3.7.

Table 6.3.7: Future State VD and NVD time analysis of "X up" processing line

Processing stage	Value Added Time (Sec)	Non Value Added Time (Sec)
Receiving Inventory	00	14400 (50%)
Syrap processing	600	600 (50%)
Homogenization & pasteurization	1200	240 (0%)
Filling	2297	140 (80%)
Cooling	0	134 (80%)
Labeling	1650	274 (80%)
Wrapping	1231	140 (80%)
Shipping Inventory	00	12960 (70%)
Total	**6978 (19.46 %)**	**28888 (80.54%)**

Note: VD time- the time that is desired which add the value to goods or service; NVD time- the time that is not desired or that does not add any value to goods or service

It was expected, after the implementation of lean tools and SS methodologies the present state NVD activities or times could be reduced at least up to 80%. In this study, based on intense observation, brainstorming and previous regarding studies, it was assumed that the NVD time of receiving stage of "X up" processing line could be reduced at least 50% (14400 sec) and the NVD time of syrup processing could be also be reduced at least 50% (600 sec). The NVD time of filing, cooling, labeling and wrapping could be reduced at least 80% from the present state and in the future state these NVD times could be consecutively 140 sec, 134 sec, 274 sec and 140 sec which were seen in Table 6.3.7.

The Fig 6.3.5 is the future VSM of “X up” processing line. The future VSM indicates the materials, information and labor flow of single batch production of “X up” processing line. Each batch contains 4000 L syrup that produce 16000 bottle (B) of CSD, “X up”.

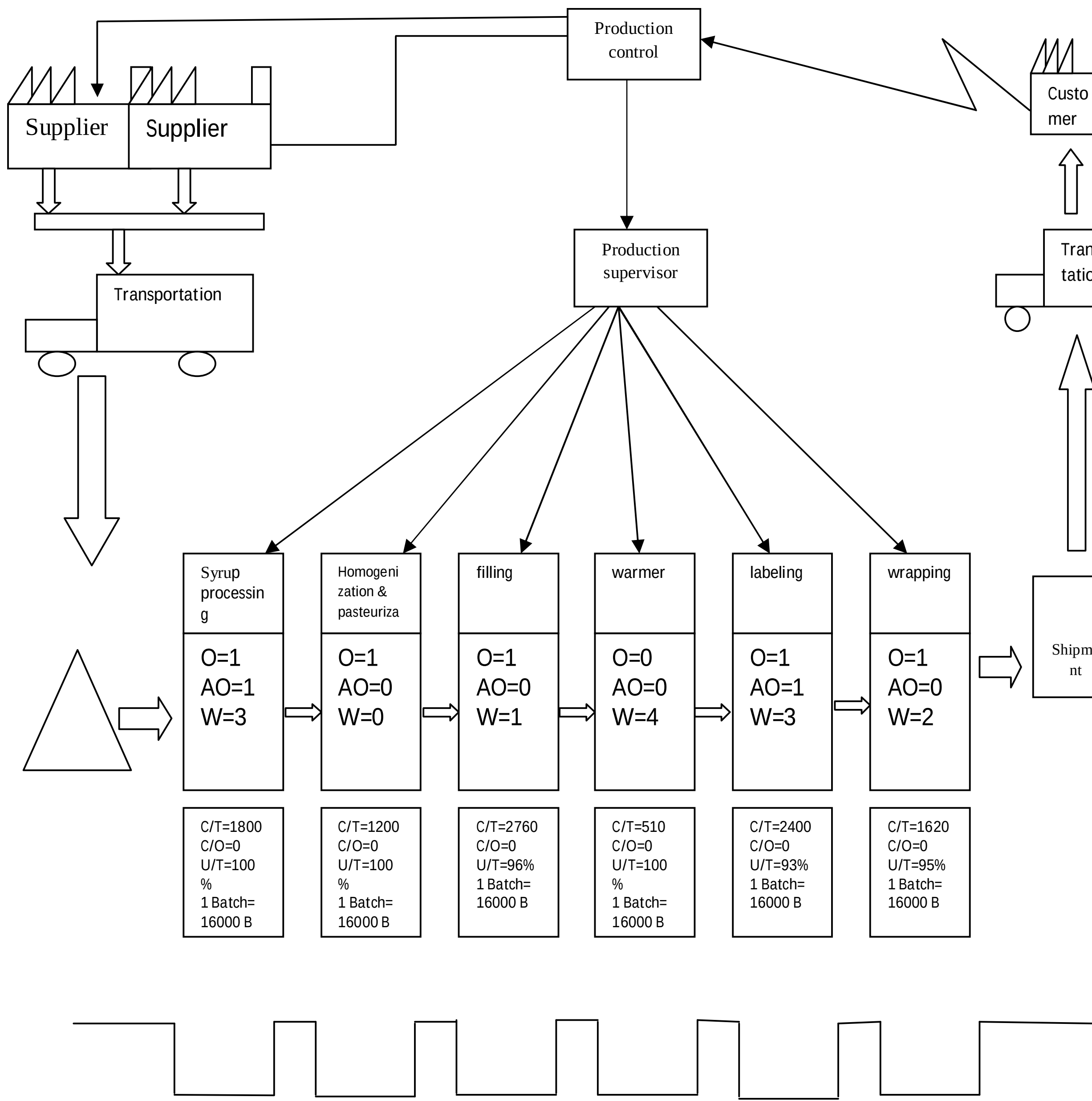


Fig 6.3.5 Future VSM of “X up” processing line

The basic components of future VSM were customers, production control, production supervisor, suppliers, transportation, different stages of processing line like as receiving inventory, syrup processing, homogenization and pasteurization, filing, warming, labeling, wrapping and shipment inventory and finally the VD and NVD times that were depicted at the bottom of future VSM.

Production control consists of one production manager and two assistant production managers. The production starts with taking the order from customer by electric signal like as over telephone or email. Later required raw materials were collected from the suppliers. Finally raw materials were transformed into finished CSD, “X up” throughout the receiving inventory stage to shipment stage.

In this future VSM the basic promising changes were the reduction of total number of labor which was observed at every processing stage, reduction of NVD time which was indicated at the bottom level of future VSM, improved Up time (U/T) which was also seen at every processing stage of “X up” processing line.

In future VSM the total labor including operator, assistant operator and worker could be 20 which was 36 at present VSM i.e. after the implementation of lean tools and SS methodologies it was expected at least 16 labors could be reduced. The U/T of filer, labeler and wrapping machine could be consecutively 96%, 93% and 95% but at present state the U/T of filer, labeler and wrapping machine were consecutively 83%, 64% and 76%.

6.3.9 Expected PCE of "X up" processing line

In the "X up" processing Line,

Value Added time	= 6978 Sec
Non Value Added time	= 28,888 Sec
Expected Lead time	= Value Added time + Non Value Added time
	= 6978 Sec + 28888 Sec = 35866 Sec

$$PCE = \frac{\text{Value Added time} \times 100}{\text{Lead time}}$$

19.46 %

After the proper implementation of lean tools and SS methodologies it was expected the PCE of CSD, "X up" processing line could be 19.46 % while the present PCE was 8.32 %, the NVD time could be reduced from 76889 sec to 28,888 sec and lead time could be reduced from 83867 sec to 35866 sec.

6.3.10 Expected Tact time of "X up" process line

Net available time			**Customer / production Demand**		
Working shifts / day	2	Shifts	Customer demand/day	9333	cases
Hours / shift	10	Hours			
Available time / shift	600	Minutes			
Prepare time / shift	40	Minutes			
Lunch time / shift	0	Minutes	Net available time / day	67200	seconds / day
Planned downtime / shift	0	Minutes	Customer demand / day	9597	cases / day
Net working time / shift	560	Minutes			
Net working time / shift	33600	Seconds	**Tact time**	7.002	seconds / cases
Net available time / day	67200	Seconds			

Note: Tact time- is considered as the rate at which customers need products i.e. the products should be produced at least equal to Tact time to meet the customer demand.

As earlier, it was mentioned that Tact time is the heart beat of production of any manufacturing industry. As it is lower indicates the faster of production. Throughout this study it was tried to reduce the Tact time. The present Tact time of "X up" processing line was 7.20 sec per case production and it was expected that after the adoption of lean tools and SS methodologies this could be reduced to 7.002 sec per case production. So, it seems that the lean tools and SS methodologies could bring the revolution beyond the speed of production of any processing line.

6.4 X Energy Drinks Processing Line

It was also Carbonated Soft Drinks (CSD), as like as “X up”. All regarding processing steps were also same as to “X up”, but contains the different unique ingredients. The basic stages of X energy drinks processing line were as follows-

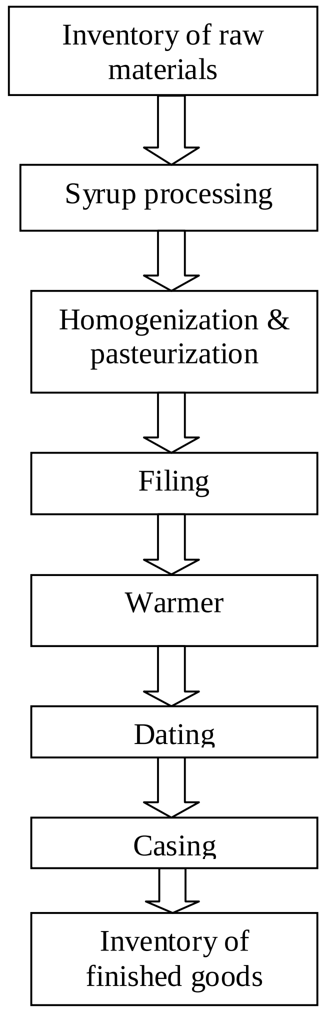


Fig 6.4.1 Basic stages of X energy drink processing line

6.4.1 Present VSM of X energy drink

To draw the present VSM relevant data, like as VD and NVD time, Cycle time, Change Over time, Uptime, Lot size, quantity to deliver, delivery time were observed and information related to assembly line such as processing time, inventory storages, inspections, rework loops, number of workers and operational hours per day were collected and documented in Table 6.4.1 and Table 6.4.2. Other relevant data such as number of operators (O), assistant operator (AO) and worker (W) were shown in current VSM. To draw the completion of present VSM of X energy drinks processing line, a timeline was added at the bottom of the map recording the VD and NVD time.

Table 6.4.1: Present state Down Time (D/T), Cycle Time (C/T) and Up Time (U/T) data of X energy drinks processing line

Times	Filler			Labeler			Wrapping machine		
	D/T (sec)	C/T (sec)	U/T (%)	D/T (sec)	C/T (sec)	U/T (%)	D/T (sec)	C/T (sec)	U/T (%)
1st	503	2700	82	651	2400	73	501	1620	69
2nd	512	2700	81	646	2400	73	462	1620	71
3rd	515	2700	81	621	2400	74	492	1620	70

Note: Filler speed: 350 BPM; Labeler speed: 400 BPM; Wrapping machine speed: 27 case per min. Batch-4000; BPM: Bottle Per Minutes; ; D/T- the time that is wasted due to breakdown of machine; C/T- the time that is required to produce a single batch production; U/T- the time that is available for machine work or production.

The D/T, C/T, and U/T of X energy drinks processing line were documented in Table 6.4.1. In this processing line the stage of filer, labeler and wrapping machine were mainly responsible for D/T. In the stage of filer, average U/T was 81% and C/T was 2760 sec. In the stage of labeler average U/T was 73% and C/T was 2400 sec. In the stage of wrapping, C/T was 1620 sec and U/T was 70%. The percentage of available time for machine work or processing of desire product was known as the U/T. By observing the U/T of different unit stage of production line, it can be assumed the efficiency of the whole production line. At present state, the U/T of X energy drinks process line varies from 70% (wrapping stage) to 81% (filing stage). By this study it was attempted to increase the U/T in the future state as well as to reduce the D/T and to reduce the ultimate lead time.

Table 6.4.2: Present state VD and Non NVD time for X energy drinks processing line

Processing stage	VD time (Sec)	NVD time (Sec)
Receiving Inventory	00	28800
Syrup processing	600	1200
Homogenization & pasteurization	1200	240
Filling	2035	905
Warmer	00	648
Labeling	1745	1205
Wrapping	1132	790
Shipping Inventory	00	43200
Total	**6712 (8.01%)**	**76988 (91.99 %)**

Note: VD time- the time that is desired which add the value to goods or service; NVD time- the time that is not desired or that does not add any value to goods or service.

The VD and NVD time of different processing stages of X energy drinks processing line were documented in Table 6.4.2. At present state, there were no VD time except NVD time in the stages of receiving inventory, warming and shipping inventory, but in this process line, this NVD time or these stages were required for the CSD, X energy drinks processing.

In this processing line, the total VD time were 6712 sec (8.01%) and the total NVD time were 76988 sec (91.99 %). By this study, it was tried to increase the percentage of VD time by reducing the NVD time with the proper implementation of lean tools and SS methodologies.

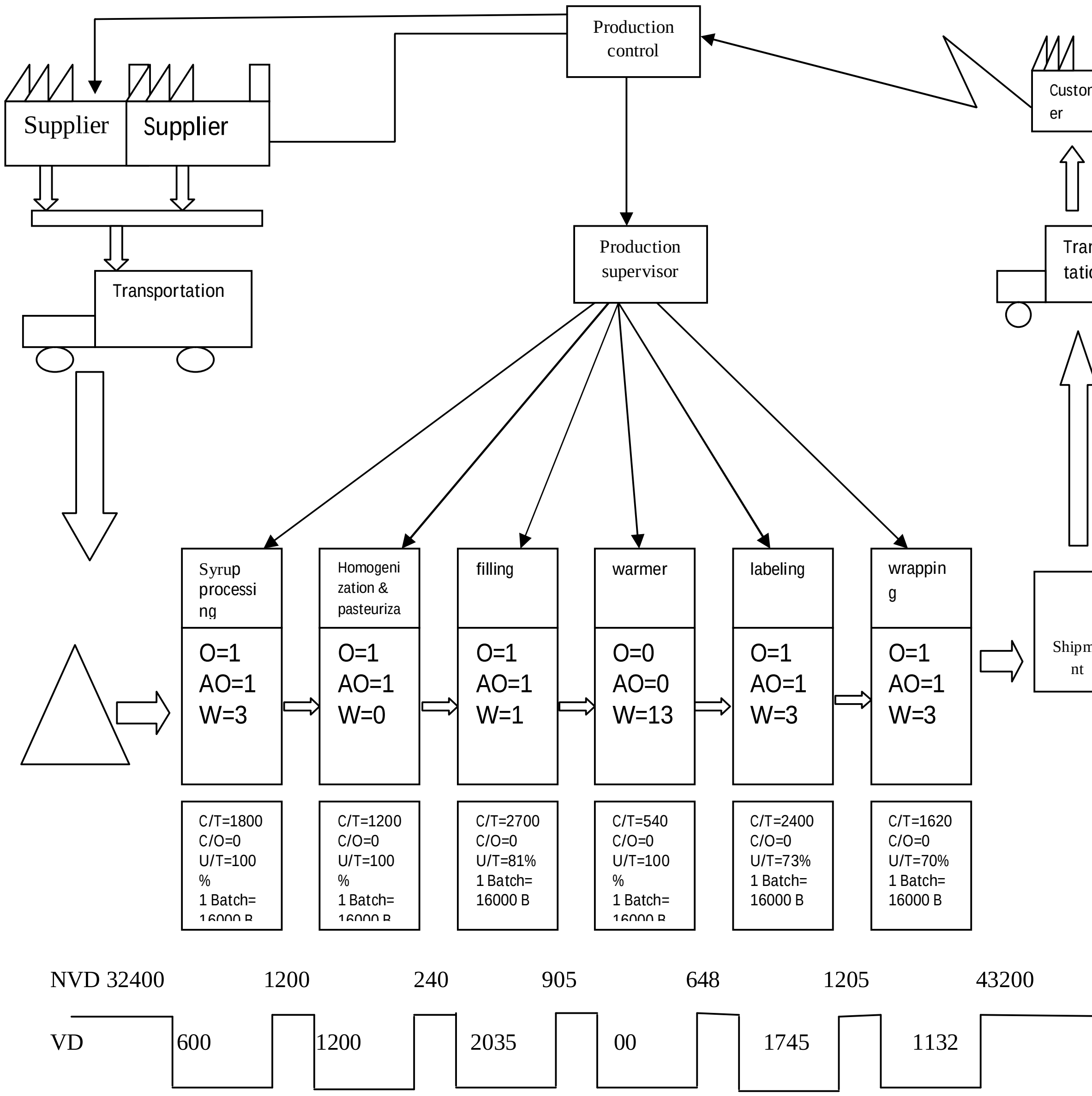


Fig 6.4.2 Current VSM of X energy drinks process

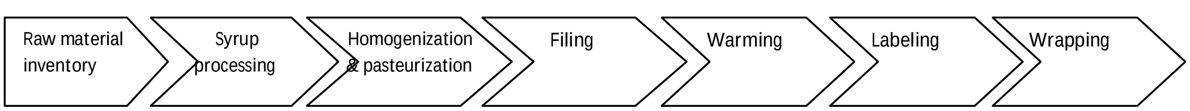
Note: Throughout the present VSM the whole processing system of X energy drinks process line were depicted with the flow of order, raw materials, labor, information, VD & NVD times. It helps to draw the required processing stage like syrup processing, homogenization & pasteurization, filing, cooling, labeling and wrapping with mentioning required labor, C/T, U/T, C/O and batch size. By observing the present scenario of regarding processing line, it can be known like as what number of labor is *needed at different processing unit? How much VD & NVD time is present? Where & what kind of improvement should be done? It helps to calculate the PCE, lead time and Tact time.*

Fig 6.4.2 represents the present VSM of X energy drinks process line. At present VSM, the production of X energy drinks was controlled by production manager, assistant manager and supervisor. In this processing line, the production starts by taking the order of production from the customers. In order to fulfill the customer demand the required raw materials were collected from the different regarding suppliers. These required raw materials were brought in the raw materials inventory which was considered as the first stage of X energy drinks production that followed by syrup processing, homogenization & pasteurization, filing, warming, labeling, wrapping and shipment of finished goods. As observed from the present VSM of X energy drinks process line, different types of NVD activities were present in the flow of process line at different stages. The different types of bottlenecks at different processing stages were identified and quantified in terms of time as shown in the Fig 6.4.2. The Up time (U/T) of filer, labeler and wrapping machine were consecutively 81%, 73% and 70%. At present state of this processing line over the different stages total labor was 33. After the implementation of lean tools and SS methodologies it was expected that U/T could be improved and total labor could be reduced.

6.4.2 Value chain of X energy drinks processing line

A value chain is a chain of activities that a firm operating in a specific industry performs in order to deliver a valuable product or service for the market. The value chain of X energy drinks processing line was depicted as follows-

Value chain of X energy drinks processing line



In this stage all required	All regarding raw	In this stage the syrup was	In this stage the syrup was	In this stage the cooled	In this stage the bottles	In this stage the bottles

raw materials were gathered, but there was no value added towards the finished goods, although this stage was required for finished goods.	materials were mixed in this stage in order to formulate syrup towards get the finished goods i.e. X energy drinks. In this stage value was added by 8.93% (VD time 600sec of total 6712 sec)	given ultra heat treatment (129º C for 15 sec) in order to increase the self life by destroying the presence microbes with adding value by 17.87% (VD time 1200 sec of total 6712 sec).	bottled at cool condition towards giving the more finished goods of X energy drinks. In this stage the value was added by 30.31% (VD time 2035 sec of total 6712 sec)	bottle were warmed without adding any value but this stage was necessary in order to attain the finished goods.	were labeled with label foil that contains the details identity of product. In this stage value was added by 25.99%. (VD time 1745 sec of total 6712 sec).	were wrapped with the case. 24 bottles were wrapped in a single case. In this stage value was added by 16.86% (VD time 1132 sec of total 6712 sec)

Note: VD: Value Added; CSD, "X up"*: Carbonated Soft Drink; The percentage of value added was calculated- the VD time of each processing unit is divided by the total VD time of whole processing line.*

6.4.3 Present PCE of X energy drinks processing line

In the X energy drinks process line,

Value Added time = 6712 Sec

Non Value Added time = 76988Sec

Lead time = Value Added time + Non Value Added time

= 6712 Sec + 76988Sec = 83700 Sec

$$\text{PCE} = \frac{\text{Value Added time} \times 100}{\text{Lead time}}$$

8.01 %

It seems that the present PCE of X energy drinks processing line was 8.01 % which was the below of internationally competitive level 25% [74]. Throughout this study it was tried to improve the present PCE of X energy drinks processing line with the proper implementation of lean tools and SS methodologies.

6.4.4 Present Tact time of X energy drinks process line

Net available time			**Customer / production Demand**		
Working shifts / day	2	Shifts	Customer demand/day	9566	cases
Hours / shift	10	Hours			
Available time / shift	600	Minutes			
Prepare time / shift	40	Minutes			
Lunch time / shift	0	Minutes	Net available time / day	67200	seconds / day
Planned downtime / shift	0	Minutes	Customer demand / day	9566	cases / day
Net working time / shift	560	Minutes			
Net working time / shift	33600	seconds	**Tact time**	7.03	seconds / cases
Net available time / day	67200	seconds			

Note: Tact time- is considered as the rate at which customers need products i.e. the products should be produced at least equal to Tact time to meet the customer demand.

Tact time is considered as the heart beat of any process line. The present Tact time of “X up” processing line was 7.03 sec. i.e. it takes 7.03 sec to produce a single case of X energy drinks production. Each case contains 24 bottle of X energy drinks where a single bottle contains 250 ml. X energy drinks. One of the basic objectives of this study was to reduce this present Tact time after the proper implementation of lean tools and SS methodologies.

6.4.5 Manufacturing waste of X energy drinks processing line

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites, and unnecessary motion of labor in the work place. Among these manufacturing wastes defect productions, wasted time due to different causes and unnecessary motion of labor were very common in the X energy drinks processing line.

6.4.5.1 Down time (D/T) calculation for X energy drinks processing line

The down time of different machines of the processing line were observed and documented in Table 6.4.3.

Table 6.4.3: Down time (D/T) of X energy drinks processing line

Step	Causes for D/T	D/T (sec)	Average D/T	C/T	% D/T
Filler	Bottle short in supply	314		2760	
		310	311		19.09
		308			
	Bottle queue in warmer line	73			
		82	78		4.78
		80			
	Crock changing	29			
		31	32		1.96
		37			
	Machine (sensor) problem	87			
		89	87		5.34
		90			
Labeler	Bottle short in supply	312		2400	
		318	313		19.21
		310			
	Sensor (machine) problem	112			
		104	103		6.32
		93			
	Label changing	93			
		96	92		5.64
		88			
	Machine cutter problem	84			
		81	81		4.97
		78			
	Bottle queue in front	50			

	stage				
		47	49		3.01
		52			
Wrapping	Insufficient bottle supply	293		1620	
		281	286		17.55
		284			
	Case cover changing	83			
		78	83		5.09
		87			
	Case queue in front	46			
		41	41		2.51
		37			
	Label torning	41			
		32	37		2.27
		43			
	Disarray of bottle	38			
		30	36		2.20
		41			
Total			**1629**		

In X energy drinks processing line, the most important processing stages were filing, labeling and wrapping where the most frequent D/T was observed due to different causes that were documented in Table 6.4.3.

6.4.5.2 Wasted bottles calculation of X energy drinks processing line

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites, and unnecessary motion in the work place. In a single processing line all types of wastes could not be seen. Based on the nature of production the manufacturing wastes are varied. Among these manufacturing wastes, defect production was very common in the X energy drinks processing line. In this processing line defect bottle was considered as the defect production. The amount of defect bottle was documented in Table 6.4.4.

Table 6.4.4: Wasted bottles of X energy drinks processing line

Name of stage	No of observation	Rejected bottles per batch	Average of rejected bottle per batch	Average of rejected bottle per day (12 batch per day)	Rejected bottle per million opportunity	Gap at Six Sigma level	Remarks
Filling	1	10					Contains at three Sigma level
	2	11					
	3	9	11	132	688	685	
	4	13					
	5	12					
Date coding	1	266					
	2	253					
	3	260	257	3084	16063	16060	
	4	254					
	5	250					
Labeling	1	186					
	2	180					
	3	192	185	2220	11563	11560	
	4	176					
	5	189					
Wrapping	1	3					
	2	3					
	3	2	3×24=72	864	4500	4497	

	4	3			
	5	3			
Total			525	6300	32814

*Note: *Opportunity: a situation or a condition for attainment of a goal; here it indicates to get the chance of total number of bottle production in both case of defect and defect free [83].*

Based on central SS concept it seems that if the amount of defect product is more than 6,210 but less than 66,807 per million product of production then it is considered as the three Sigma productions. From Table 6.4.4, it seems that the total defect product of X energy drinks process line was 32814 per million product of production which was considered as the three Sigma productions. But the prime target of any manufacturing industry should be Six Sigma production where the amount of defect product should not be more than 3.4 per million product of production. Throughout this study it was expected that 80% of the present manufacturing waste could be reduced after the implementation of lean tools and SS methodologies.

6.4.5.3 Wasted labor of X energy drinks processing line

After lean tools implementation it was expected that a number of labor could be eliminated from X energy drinks processing line. The unnecessary motion of labor in the processing line was also considered as the manufacturing waste. The expected number of eliminated labor was documented in the Table 6.4.5.

Table 6.4.5: Present and expected labor of X energy drinks processing line

Name of Stages	No of labor at present state			No of labor at future state		
	O	AO	W	O	AO	W
Syrup processing	1	1	3	1	1	3
Homogenization & pasteurization	1	1	0	1	0	0

Filing	1	1	1	1	0	1
Warming	0	0	13	0	0	5
Labeling	1	1	3	1	1	1
Wrapping	1	1	3	1	0	2
Total	5	5	23	5	2	12

At present state, from Table 6.4.5, it was seen that throughout the different processing stages of X energy drinks processing line, total labor were 33 where operator (O), assistant operator (AO) and worker (W) were consecutively 5, 5 and 23. At future state, if the lean tools and SS methodologies could be implemented, it was expected that different types of bottlenecks and NVD activities could be reduced thus the present number of labor will also be reduced from 33 to 19 where operator (O), assistant operator (AO) and worker were (W) consecutively 5, 2 and 12. Because of a number of unwanted labors were engaged to manage the different types of bottlenecks and NVD activities.

6.4.6 Pareto analysis for X energy drinks processing line

Pareto Analysis was performed by drawing the Pareto chart consisting of causes for delay along the X axis and percentage and cumulative percentage of down time along the Y axis. The highest frequency of down time was found for bottle short in supply at the X energy drinks processing line, while crock change of filer machine showed the lowest frequency. Different causes of down time with their frequency in terms of percentages and cumulative percentages were documented in Table 6.4.5.

Table 6.4.6: Cumulative percentage of D/T for Pareto analysis of X energy drinks processing line

Causes of delay times	Down Time(D/T)	Percentage of (D/T)	Cumulative of percentage
Insufficient bottle supply	910	55.86249	55.86249
Sensor problem of machine	190	11.66359	67.52608
Label changing at labeler	92	5.64763	73.17371
Cover case changing of	83	5.09515	78.26886

wrapping machine			
Problem in cutter of labeler	81	4.97237	83.24123
Bottle queue in front of filler (warmer line)	78	4.78821	88.2944
Bottle queue in front of labeler	49	3.00798	91.03742
Case queue in front of wrapping machine	41	2.51688	93.5543
Case cover splitting of wrapping machine	37	2.27133	95.82563
Disarray of bottle at wrapping machine	36	2.20994	98.03557
Crock change of filer	32	1.96443	100.00000

Different causes of NVD activities or down time at different processing stages of X energy drinks processing line with their frequency in terms of percentages and cumulative percentages were documented in Table 6.4.6. The causes for NVD activities were arranged in downward movements in terms of their frequency.

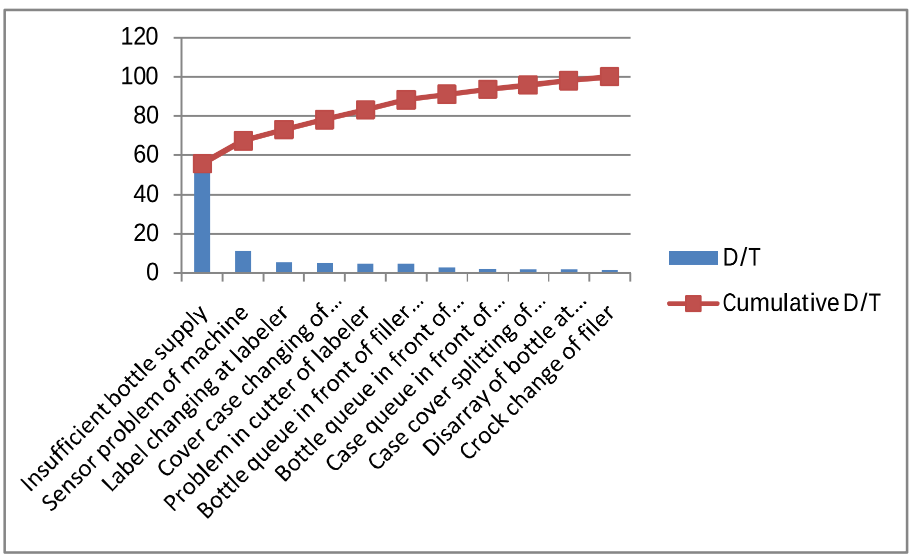


Fig 6.4.3 Pareto chart of X energy drinks processing line

Pareto chart (Fig 6.4.3) was depicted from Pareto table (Table 6.4.6) by aligning the different causes along with X axis; percentage and cumulative percentage of these causes for NVD activities were aligned along with the Y axis. From Fig 6.4.3, it seems that the pioneer causes beyond the different types of bottlenecks and NVD activities were insufficient bottle supply (55.86%), sensor problem of machine (11.66%), label changing at labeler (5.64%), cover case changing of wrapping machine (5.09%), problem in cutter of labeler (4.97%), bottle queue in front of filler (warmer line) (4.78%), bottle queue in front of labeler (3.00%), case queue in front of wrapping machine (2.51%), case cover splitting of wrapping machine (2.27%), disarray of bottle at wrapping machine (2.20%), and crock change of filer (1.96%).

From Pareto chart (Fig 6.4.3) the most responsible causes were easily observed and the effective initiatives can be taken to remove these causes. It was expected that if the most frequent first three or 20% causes like as insufficient bottle supply (55.86%), sensor problem of machine (11.66%), label changing at labeler (5.64%), could be removed, the 80% NVD activities or down times could be removed. 5S, JIT, TPM, DMAIC and other improving strategies could be effective initiatives to remove these most frequent causes.

6.4.7 Improvement points at present VSM of X energy drinks processing line

Throughout the observation it was seen that there were some improvement points at different stages of X energy drinks processing line. The nature of improving point differs from each and another stages.

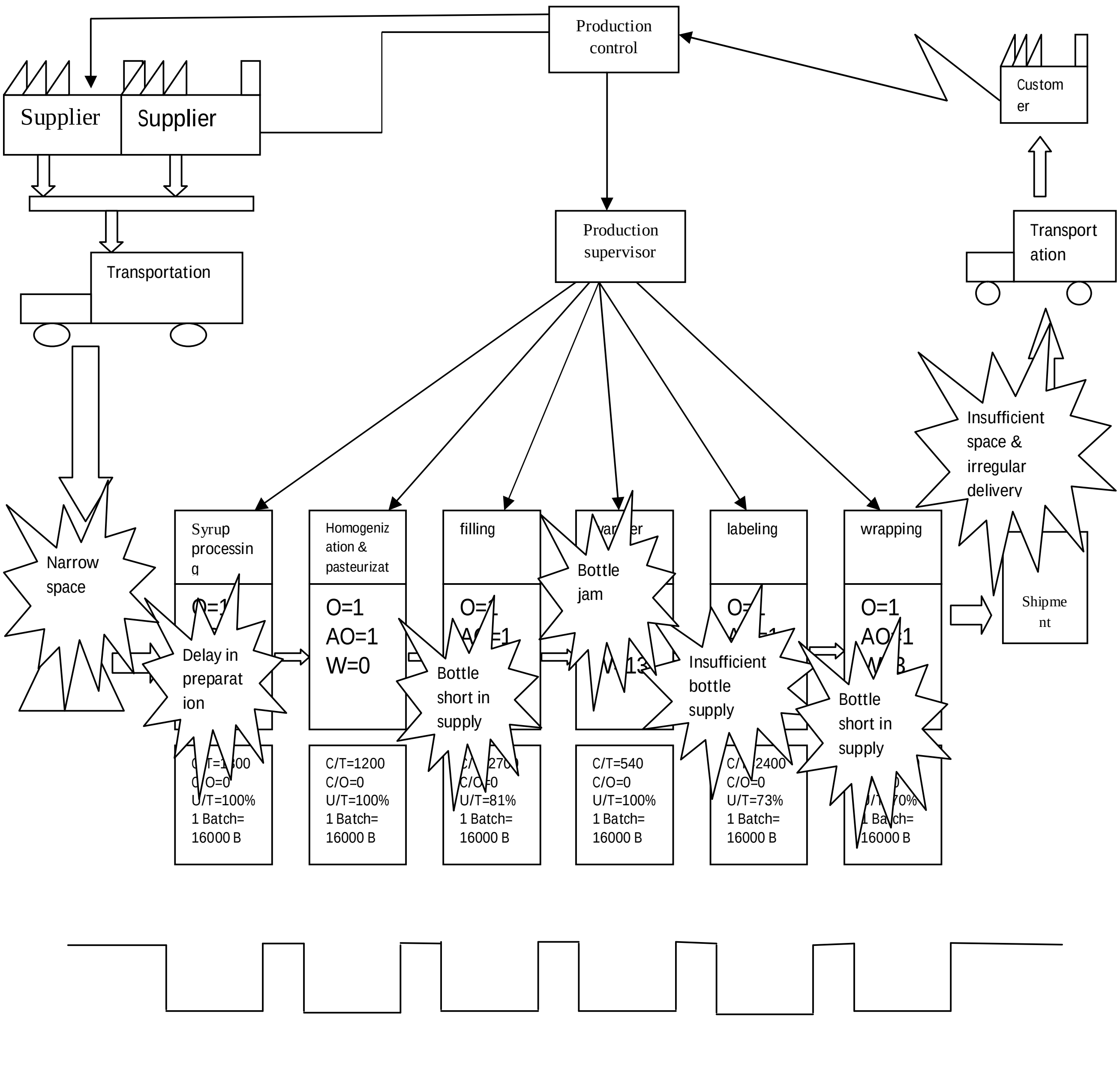


Fig 6.4.4 Current VSM of X energy drinks process with improvement points

The crucial improvement points were pointed in Fig 6.4.4. In the stage of raw material or receiving inventory, delay handling of raw materials towards the next stage of syrup processing was observed as the prime point that should be removed in order to reduce the lead time as well as to improve the PCE. Besides these, conventional movement of raw materials like as carry of raw materials sack by labor instead of conveyor belt movement, inventory storage room was soaked and congested, crowd movement were most common. In the syrup processing stage, the delay of syrup processing was the main hindrance beyond the NVD activities and bottlenecks. No cause was indentified that need to solve in the stage of homogenization and pasteurization, because of it was difficult to detect any barrier beyond the bottleneck due to fully pipe flow of syrup towards the next filing stage, but it was observed that this stage was smoothly running and based on previous experience of regarding personnel it was also known that there was no mentionable barrier for bottlenecks. In the filing stage the basic causes were bottle short in supply, bottle queue in warmer line, crock changing, and machine (sensor) problem. In the stage of warming bottle jam was observed as the only one problem both in enters and exit of cooling chamber. In the stage of labeling the main causes for bottlenecks or breakdown of machine were bottle short in supply, sensor (machine) problem, label changing, machine cutter problem and bottle queue in front stage. In case of wrapping stage the basic problems were pointed as insufficient bottle supply, case cover changing, case queue in front, label torning, disarray of bottles. In the stage of shipment the basic barrier were irregular shipment and insufficient space for movement. In Fig 6.4.4 only the most frequent cause at different stages of X energy drinks processing line were pointed. These pointed causes or barriers should be removed in order to reduce the manufacturing wastes and improve the PCE.

6.4.8 Expected future VSM of X energy drinks processing line

In the future VSM after a deep brainstorming and an intense observation in X energy drinks processing line the VD and NVD time were calculated and documented in Table 6.4.7.

Table 6.4.7: Future state VD and NVD time analysis of X energy drinks processing line

Processing stage	Value Added Time (Sec)	Non Value Added Time (Sec)
Receiving Inventory	00	14400 (50%)
Syrap processing	600	600 (50%)
Homogenization & pasteurization	1200	240 (0%)
Filling	2035	181 (80%)
Cooling	00	130 (80%)
Labeling	1745	241 (80%)
Wrapping	1132	158 (80%)
Shipping Inventory	00	12960 (70%)
Total	**6712 (18.84%)**	**28910 (81.16%)**

Note: VD time- the time that is desired which add the value to goods or service; NVD time- the time that is not desired or that does not add any value to goods or service

It was expected, after the implementation of lean tools and SS methodologies the present state NVD activities or times could be reduced at least up to 80%. In this study, based on intense observation, brainstorming and previous regarding studies it was assumed that the NVD time of receiving stage of X energy drinks processing line could be reduced at least 50% (14400 sec) and the NVD time of syrup processing could be also be reduced at least 50% (600 sec). The NVD time of filing, cooling, labeling and wrapping could be reduced at least 80% from the present state and in the future state these NVD times could be consecutively 181 sec, 130 sec, 241 sec and 158 sec which could be seen in Table 6.4.7.

The Fig 6.4.5 was the future VSM of X energy drinks processing line. The future VSM indicates the materials, information and labor flow of single batch production of X energy drinks processing line. Each batch contains 4000 L syrup that produce 16000 bottle (B) of X energy drinks.

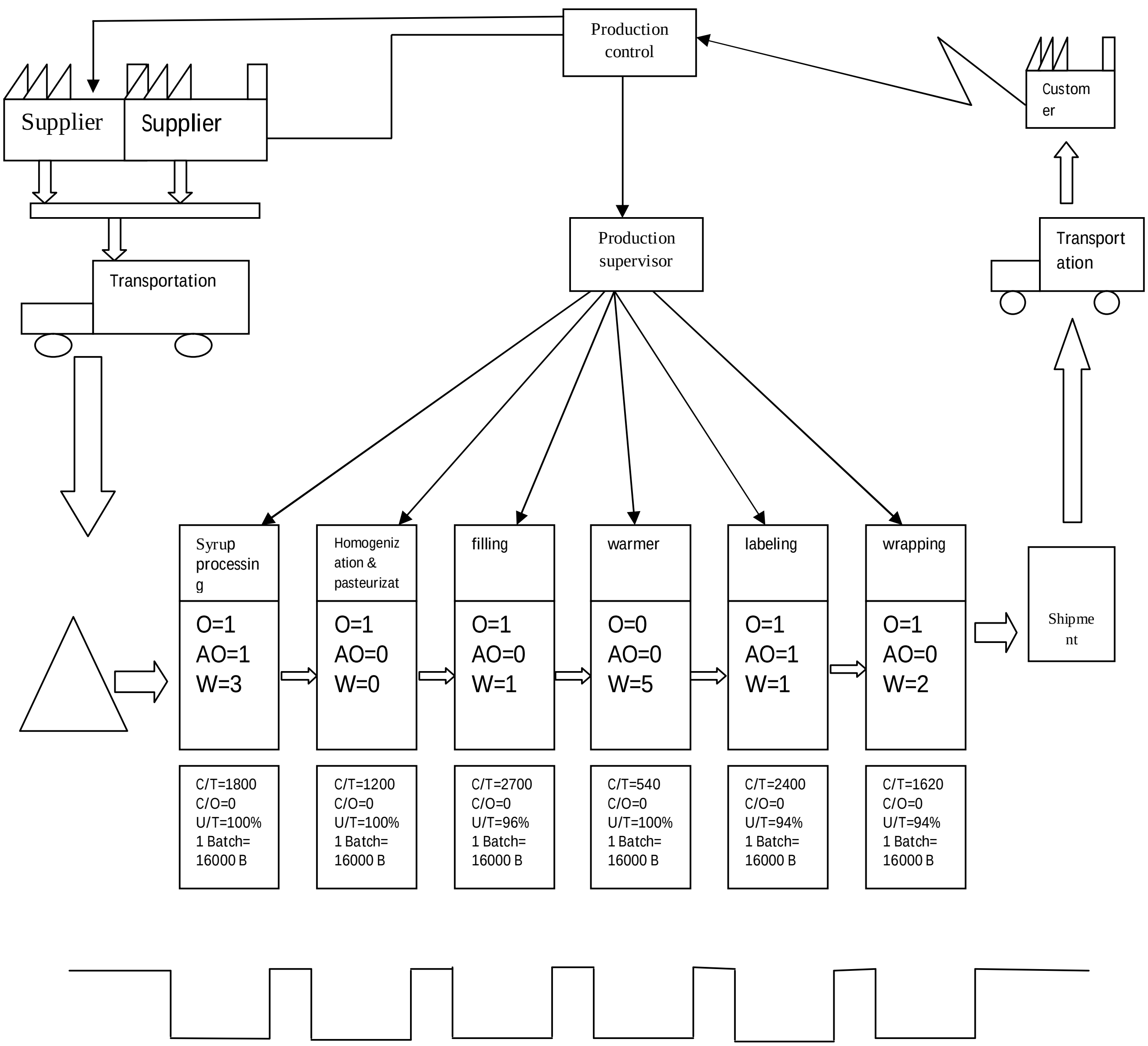


Fig 6.4.5 Future VSM of X energy drinks process

The basic components of future VSM were customers, production control, production supervisor, suppliers, transportation, different stages of processing line like as receiving inventory, syrup processing, homogenization and pasteurization, filing, warming, labeling, wrapping and shipment inventory and finally the VD and NVD times that were depicted at the bottom of future VSM.

Production control consists of one production manager and two assistant production managers and four supervisors. The production starts with taking the order from customer by electric signal like as over telephone or email. Later required raw materials were collected from the suppliers. Finally raw materials were transformed into finished X energy drinks throughout the receiving inventory stage to shipment stage.

In this future VSM the basic promising changes were the reduction of total number of labor which was seen at every processing stage, reduction of NVD time which was indicated at the bottom level of future VSM, improved Up time (U/T) which was also seen at every processing stage of X energy drinks processing line.

In future VSM the total labor including operator, assistant operator and worker could be 19 which was 33 at present VSM i.e. after the implementation of lean tools and SS methodologies it was expected at least 14 labors could be reduced. The U/T of filer, labeler and wrapping machine could be consecutively 96%, 94% and 94% but at present state the U/T of filer, labeler and wrapping machine were consecutively 81%, 73% and 70%.

6.4.9 Expected PCE of X energy drinks processing line

In the X energy drinks Processing Line,

Value Added time = 6712 Sec

Non Value Added time = 28910 Sec

Expected Lead time = Value Added time + Non Value Added time

= 6712 Sec + 28910 Sec = 35622 Sec

$$\text{PCE} \quad \frac{\text{Value Added time} \times 100}{\text{Lead time}}$$

18.84 %

After the proper implementation of lean tools and SS methodologies it was expected the PCE of X energy drinks processing line could be 18.84 % while the present PCE was

8.01 %, the NVD time could be reduced from 76988 sec to 28910 sec and lead time could be reduced from 83700 sec to 35622 sec.

6.4.10 Tact time of X energy drinks process line

Net available time			**Customer / production Demand**		
Working shifts / day	2	Shifts	Customer demand/day	9566	Cases
Hours / shift	10	Hours			
Available time / shift	600	minutes			
Prepare time / shift	40	minutes			
Lunch time / shift	0	minutes	Net available time / day	67200	seconds / day
Planned downtime / shift	0	minutes	Customer demand / day	9829	cases / day
Net working time / shift	560	minutes			
Net working time / shift	33600	seconds	**Tact time**	6.84	seconds / cases
Net available time / day	67200	seconds			

Note: Tact time- is considered as the rate at which customers need products i.e. the products should be produced at least equal to Tact time to meet the customer demand.

As earlier it was mentioned that Tact time is the heart beat of production of any manufacturing industry. As it is lower indicates the faster of production. Throughout this study it was tried to reduce the Tact time. The present Tact time of X energy drinks processing line was 7.03 sec per case production and it was expected that after the adoption of lean tools and SS methodologies this could be reduced to 6.84 sec per case production. So, it seems that the lean tools and SS methodologies could bring the revolution beyond the speed of production of any processing line.

6.5 X Banana Flavored Juice Processing Line

This was a unique beverage of X food industry. It was specialized with the banana flavor. Milk powder, pectin, citric acid, potassium sorbet, lactic acid, aspartame and sugar were the principle ingredients in the formulation of X Banana flavored juice. The principal stages of X Banana flavored juice processing line were as follows-

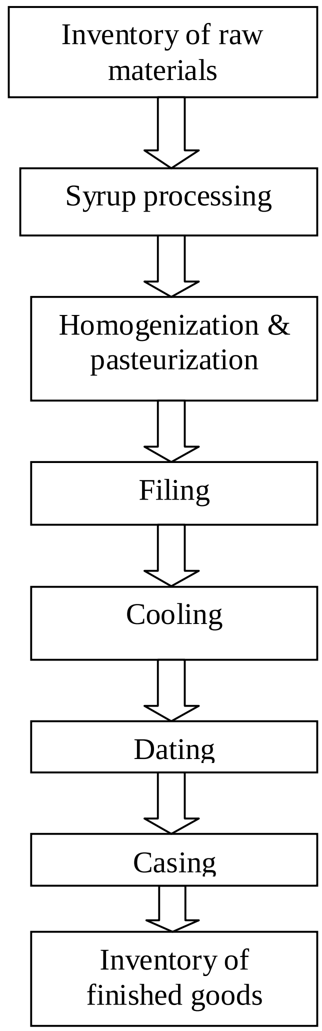


Fig 6.5.1 Principal stages of X Banana flavored juice processing line

6.5.1 Present VSM of X Banana flavored juice

The present VSM of X Banana flavored juice processing line point out the different stages in processing line which bring the value in taste, energy, flavor and appearance.

These values were brought by different stages like blending, pasteurization and homogenization, filling, cooling, labeling and wrapping which were points out in present VSM. All regarding data to build the present VSM were documented in Table 6.5.1 and Table 6.5.2. Other relevant data such as number of operators (O), assistant operator (AO) and worker (W) were shown in current VSM. To draw the completion of present VSM of X energy drinks processing line, a timeline was added at the bottom of the map recording the VD and NVD time.

Table 6.5.1: Present state Down Time (D/T), Cycle Time (C/T) and Up Time (U/T) data of X Banana flavored juice processing line

Times	Filler			Labeler			Wrapping machine A			Wrapping machine B		
	D/T (sec)	C/T (sec)	U/T (%)	D/T (sec)	C/T (sec)	U/T (%)	D/T (sec)	C/T (sec)	U/T (%)	D/T (sec)	C/T (sec)	U/T (%)
1st	630	2880	78	816	2880	72	1334	4680	71	1116	2880	76
2nd	626	2880	78	833	2880	71	1378	4680	70	1098	2880	77
3rd	639	2880	77	817	2880	72	1371	4680	71	1108	2880	76

Note: Filler speed: 245 BPM; Labeler speed: 245 BPM; Wrapping machine (A) speed: 25 case per min. Wrapping machine (A) speed: 25 case per min. Batch-2000 L; BPM: Bottle Per Minutes; D/T- the time that is wasted due to breakdown of machine; C/T- the time that is required to produce a single batch production; U/T- the time that is available for machine work or production.

The D/T, C/T, and U/T of X Banana flavored juice processing line were documented in Table 6.5.1. In this processing line the stage of filer, labeler and wrapping machine were mainly responsible for D/T. In the stage of filer, average U/T was 78% and C/T was 2880 sec. In the stage of labeler average U/T was 72% and C/T was 2880 sec. In the stage of wrapping, C/T of wrapping machine-A was 4680 sec and U/T was 71% and C/T of wrapping machine-B was 2880 sec and U/T was 76%. The percentage of available time for machine work or processing of desire product was known as the U/T. By observing the U/T of different unit stage of production line, it can be assumed the efficiency of the whole production line. At present state, the U/T of X Banana flavored juice line varies from 71% (labeling stage) to 78% (filing stage). By this study it was attempted to increase the U/T in the future state as well as to reduce the D/T and to reduce the ultimate lead time.

Table 6.5.2: Present state VD and NVD time for X Banana flavored juice processing line

Processing stage	Average Value Added Time (Sec)	Average Non Value Added Time (Sec)
Receiving Inventory	00	27000
Syrup processing	600	1800
Homogenization & pasteurization	1680	240
Filling	2200	920
Cooling	00	750
Labeling	1973	1207
Wrapping	3371	1819
Shipping Inventory	00	43200
Total	**9824 (11.32%)**	**76936 (88.68%)**

Note: VD time- the time that is desired which add the value to goods or service; NVD time- the time that is not desired or that does not add any value to goods or service

The VD and NVD time of different processing stages of X Banana flavored juice processing line were documented in Table 6.5.2. At present state, there were no VD time except NVD time in the stages of receiving inventory, cooling and shipping inventory, but in this process line, this NVD time or these stages were required for the X Banana flavored juice processing.

In this X Banana flavored juice processing line, the total VD time were 9824 sec (11.32%) and the total NVD time were 76936 sec (88.68%). By this study, it was tried to increase the percentage of VD time by reducing the NVD time with the proper implementation of lean tools and SS methodologies.

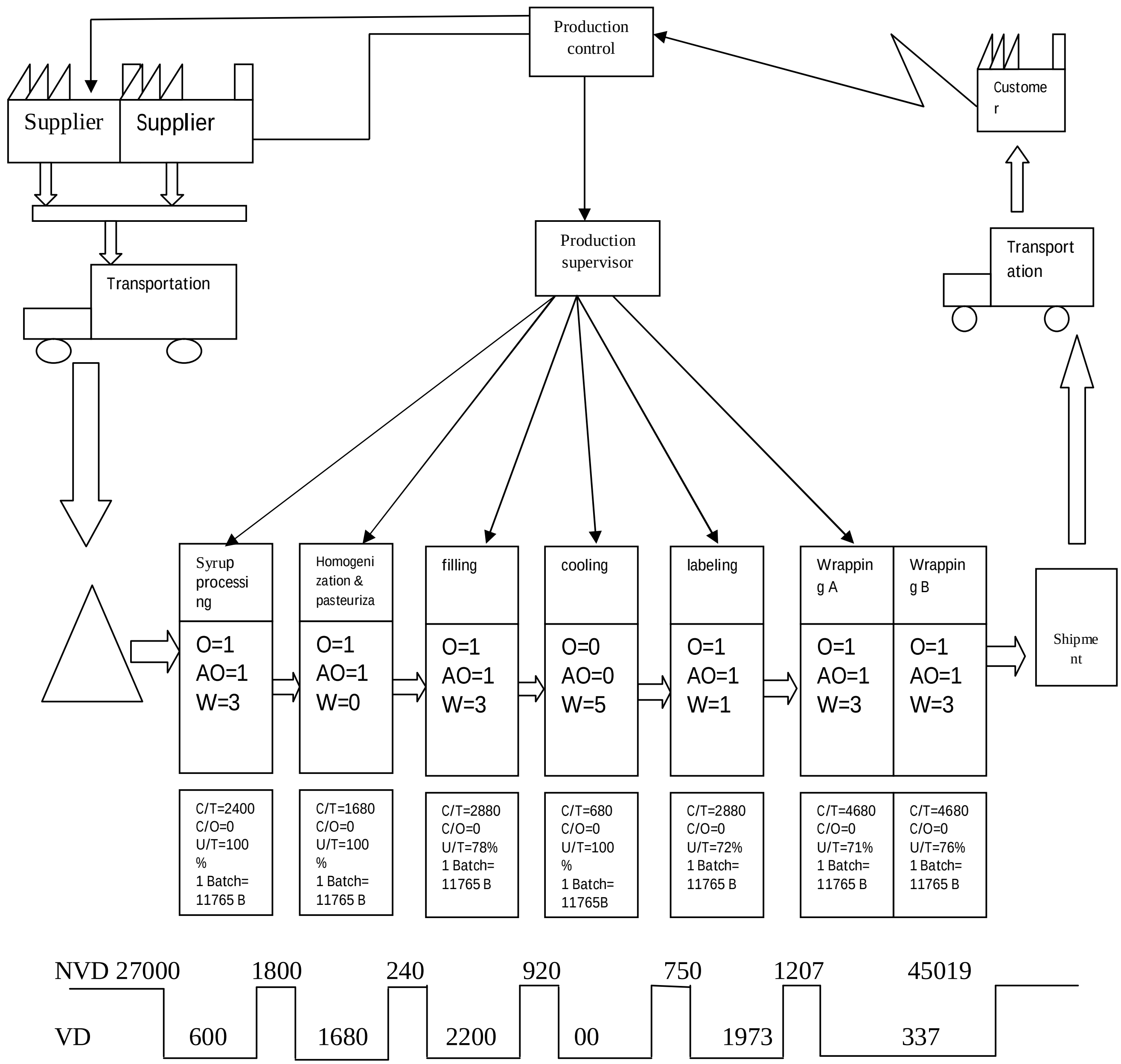


Fig 6.5.2 Present VSM of X Banana flavored juice process

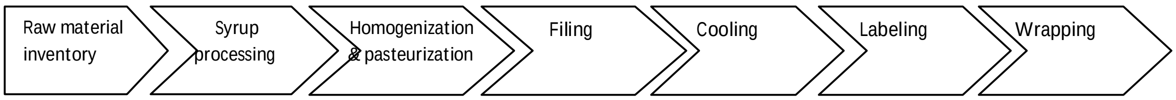
Note: Throughout the present VSM the whole processing system of X Banana flavored juice process line were depicted with the flow of order, raw materials, labor, information, VD & NVD times. It helps to draw the required processing stage like syrup processing, homogenization & pasteurization, filing, cooling, labeling and wrapping with mentioning required labor, C/T, U/T, C/O and batch size. By observing the present scenario of regarding processing line, it can be known like as what number of labor is needed at different processing unit? How much VD & NVD time is present? Where & what kind of improvement should be done? It helps to calculate the PCE, lead time and Tact time.

Fig 6.5.2 represents the present VSM of X Banana flavored juice line. At present VSM, the production of X Banana flavored juice was controlled by production manager, assistant manager and supervisor. In this processing line, the production starts by taking the order of production from the customers. In order to fulfill the customer demand the required raw materials were collected from the different regarding suppliers. These required raw materials were brought in the raw materials inventory which was the first stage of X Banana flavored juice production that followed by syrup processing, homogenization & pasteurization, filing, cooling, labeling, wrapping and shipment of finished goods. As observed from the present VSM of X Banana flavored juice process line, different types of NVD activities were present in the flow of process line at different stages. The different types of bottlenecks at different processing stages were identified and quantified in terms of time as shown in the Fig 6.5.2. The Up time (U/T) of filer, labeler and wrapping machine-A and wrapping machine-B were consecutively 78%, 72%, 71% and 70%. At present state of this processing line over the different stages total labor was 30. After the implementation of lean tools and SS methodologies it was expected that U/T could be improved and total labor could be reduced.

6.5.2 Value chain of X Banana flavored juice processing line

The value chain is a systematic approach to examining the development of competitive advantage. The value chain of X Banana flavored juice processing line was depicted as follows-

Value chain of X Banana flavored juice processing line



In this stage all required raw materials were gathered, but there was no value added towards the finished goods, although this stage was required for finished goods.	All regarding raw materials were mixed in this stage in order to formulate syrup towards get the finished goods i.e. X Banana flavored juice. In this stage value was added by 6.10% (VD time 600sec of	In this stage the syrup was given ultra heat treatment (129° C for 15 sec) in order to increase the self life by destroying the presence microbes with adding value by 17.10% (VD time 1680 sec of total	In this stage the syrup was bottled at cool condition towards giving the more finished goods of X Banana flavored juice. In this stage the value was added by 22.39% (VD time 2200 sec of total 9824 sec)	In this stage the hot bottle were cooled without adding any value but this stage was necessary in order to attain the finished goods.	In this stage the bottle juice were labeled with label foil that contains the details identity of product. In this stage value was added by 25.99%. (VD time 1973 sec of total 9824 sec).	In this stage the bottle juice were wrapped with the case. 24 bottles were wrapped in a single case. In this stage value was added by 34.31% (VD time 3371 sec of total 9824 sec)

total 9824 sec)

9824 sec).

Note: VD: Value Added; The percentage of value added was calculated- the VD time of each processing unit is divided by the total VD time of whole processing line.

6.5.3 Present PCE of X Banana flavored juice processing line

In the X Banana flavored process line,

Value Added time = 9824 Sec

Non Value Added time = 76936Sec

Lead time = Value Added time + Non Value Added time

= 9824 Sec + 76936 Sec = 86760 Sec

$$PCE = \frac{\text{Value Added time} \times 100}{\text{Lead time}}$$

11.32 %

It seems that the present PCE of X Banana flavored juice processing line was 11.32 % which was the below of internationally competitive level 25% [74]. Throughout this study it was tried to improve the present PCE of X Banana flavored juice processing line with the proper implementation of lean tools and SS methodologies.

6.5.4 Present Tact time calculation of X Banana flavored juice process line

Net available time			**Customer / production Demand**		
Working shifts / day	2	Shifts	Customer demand/day	26781	cases
Hours / shift	10	Hours			
Available time / shift	600	minutes			
Prepare time / shift	40	minutes			
Lunch time / shift	0	minutes	Net available time / day	67200	seconds / day
Planned downtime / shift	0	minutes	Customer demand / day	26781	cases / day
Net working time / shift	560	minutes			
Net working time / shift	33600	seconds	**Tact time**	2.51	seconds / cases
Net available time / day	67200	seconds			

Note: Tact time- is considered as the rate at which customers need products i.e. the products should be produced at least equal to Tact time to meet the customer demand.

Tact time is considered as the heart beat of any process line. The present Tact time of X Banana flavored juice processing line was 2.51 sec. i.e. it takes 2.51 sec to produce a single case of X Banana flavored juice production. Each case contains 6 bottle of X Banana flavored juice where a single bottle contains 170 ml X Banana flavored juice. One of the basic objectives of this study was to reduce this present Tact time after the proper implementation of lean tools and SS methodologies.

6.5.5 Manufacturing waste of X Banana flavored juice processing line

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites, and unnecessary motion of labor in the work place. Among these manufacturing wastes defect productions, wasted time due to different causes and unnecessary motion of labor were very common in the X Banana flavored juice processing line.

6.5.5.1 Down Time (D/T) calculation for X Banana flavored juice processing line

The down time at different machines and stages of this processing line were observed and documented in Table 6.5.3.

Table 6.5.3: Down Time (D/T) of X Banana flavored juice processing line

Step	Causes for D/T	D/T (sec)	Average D/T	C/T	% D/T
Filler	Bottle short in supply	316		2880	
		312	316		9.09
		320			
	Bottle queue in warmer line	38			
		41	41		1.18
		45			
	Bottle queue in front of cooler	75			
		71	75		2.15
		79			
	Crock changing	67			
		60	62		1.78
		59			
	Machine (sensor)	134			

	problem				
		142	137		3.94
		136			
Labeler	Bottle short in supply	456		2880	
		446	447		12.86
		441			
	Label changing	142			
		150	146		4.20
		145			
	Machine cutter problem	132			
		145	138		3.97
		136			
	Bottle queue in front stage	86			
		92	91		2.62
		95			
Wrapping A	Insufficient bottle supply	1022		4680	
		1050	1036		29.82
		1035			
	Case cover changing	60			
		55	59		1.69
		63			
	Label defect slim	201			
		215	209		6.01
		210			
	Disarray of bottle	51			
		58	57		1.06
		63			
Wrapping B	Insufficient bottle supply	767		4680	

		759	759	21.84
		751		
	Label defect slim	215		
		208	214	6.16
		220		
	Sensor problem	68		
		71	68	1.95
		65		
	Machine problem	66		
		60	66	1.89
		72		
Total			**3474**	

In X Banana flavored juice processing line, the most important processing stages were filing, labeling and wrapping where the most frequent D/T was observed due to different causes that were documented in Table 6.5.3.

6.5.5.2 Wasted bottles calculation of X Banana flavored juice processing line

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites, and unnecessary motion in the work place. In a single processing line all types of wastes could not be seen. Based on the nature of production the manufacturing wastes are varied, among these manufacturing wastes, defect production was very common in the X Banana flavored juice processing line. In this processing line defect bottle was considered as the defect production. The amount of defect bottle was documented in Table 6.5.4.

Table 6.5.4: Wasted bottle calculation of X Banana flavored juice processing line

Name of stage	No of observation	Rejected Bottles per Batch	Average rejected bottle per Batch	Average rejected bottle per day (12 batch per day)	Rejected bottle per million opportunity	Gap at Six Sigma level	Remarks
Filling	1	23					Contains at three Sigma level
	2	25					
	3	21	22	264	1870	1867	
	4	20					
	5	20					
Date coding	1	37					
	2	40					
	3	43	38	456	3230	3227	
	4	39					
	5	33					
Labeling	1	103					
	2	99					
	3	94	95	1140	8075	8072	
	4	88					
	5	89					
Wrapping A	1	10					
	2	9					
	3	11	11×6=66	792	5610	5607	
	4	11					
	5	13					
Wrapping B	1	14					
	2	16					
	3	15	15×6=90	1080	7650	7647	
	4	14					
	5	16					
Total			311	3732	26435		

*Note: *Opportunity: a situation or a condition for attainment of a goal; here it indicates to get the chance of total number of bottle production in both case of defect and defect free [83].*

Based on central SS concept it seems that if the amount of defect product was more than 6,210 but less than 66,807 per million product of production then it was considered as the three Sigma productions. From Table 6.5.4, it seems that the total defect product of X Banana flavored juice process line was 26435 per million product of production which was considered as the three Sigma productions. But the prime target of any manufacturing industry should be Six Sigma production where the amount of defect product should not be more than 3.4 per million product of production. Throughout this study it was expected that 80% of the present manufacturing waste could be reduced after the implementation of lean tools and SS methodologies.

6.5.5.3 Present and expected labor of X Banana flavored juice processing line

With the involvement of lean tools and Six Sigma methodology, it was expected that a number of labor could be eliminated from X Banana flavored juice processing line. The unnecessary motion of labor in the processing line was also considered as the manufacturing waste. The expected numbers of eliminated labor were documented in the Table 6.5.5.

Table 6.5.5: Present and expected labor of X Banana flavored juice processing line

Name of Stages	No of labor at present state			No of labor at future state		
	O	AO	W	O	AO	W
Syrup processing	1	1	3	1	1	3
Homogenization & pasteurization	1	1	0	1	0	0
Filing	1	1	3	1	1	1
Warming	0	0	5	0	0	2
Labeling	1	1	1	1	1	1
Wrapping A	1	1	3	1	1	1
Wrapping B	1	1	3	1	1	1
Total	6	6	18	6	5	9

At present state, from Table 6.5.5, it was seen that throughout the different processing stages of X Banana flavored juice processing line, total labor were 30 where operator

(O), assistant operator (AO) and worker (W) were consecutively 6, 6 and 18. At future state, if the lean tools and SS methodologies will implement, it was expected that different types of bottlenecks and NVD activities will be reduced thus the present number of labor will also be reduced from 30 to 20 where operator (O), assistant operator (AO) and worker (W) were consecutively 6, 5 and 9. Because of a number of unwanted labors were engaged to manage the different types of bottlenecks and NVD activities.

6.5.6 Pareto analysis of X Banana flavored juice processing line

Pareto Analysis was performed by drawing the Pareto chart consisting of causes for delay along the Y axis and percentage and cumulative percentage of down time along the X axis. The highest frequency of down time was found for bottle short in supply at the X Banana flavored juice processing line, while Bottle queue in front of filer showed the lowest frequency. Different causes of down time with their frequency in terms of percentages and cumulative percentages were documented in Table 6.5.5.

Table 6.5.6: Cumulative percentages D/T of X Banana flavored juice processing line for Pareto Analysis

Causes of delay times	Down Time(D/T)	Percentage of (D/T)	Cumulative of percentage
Insufficient bottle supply	2558	65.23845	65.23845
Label defect (slim) at wrapping machine	423	10.78806	76.02651
Sensor problem of machine	205	5.22825	81.25476
Label changing at labeler	146	3.72353	84.97829
Machine cutter problem at labeler	138	3.51951	88.49780
Disarray of bottle	123	3.13695	91.63475
Bottle queue in front of labeler	91	2.32083	93.95558
Bottle queue in front of cooler	75	1.91277	95.86835
Crock changing of filer	62	1.58122	97.44957
Case cover changing at wrapping machine	59	1.50471	98.95428
Bottle queue in front of filer	41	1.04572	100.00000

Different causes of NVD activities or down time at different processing stages of X Banana flavored juice processing line with their frequency in terms of percentages and cumulative percentages were documented in Table 6.5.6. The causes for NVD activities were arranged in downward movements in terms of their frequency.

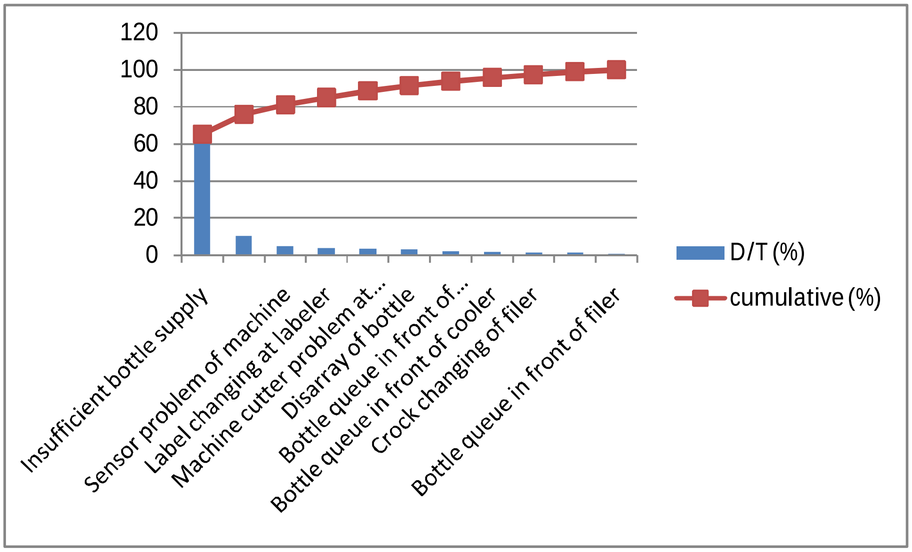


Fig 6.5.3 Pareto chart of X Banana flavored juice processing line

Pareto chart (Fig 6.5.3) was depicted from Pareto table (Table 6.5.6) by aligning the different causes along with X axis; percentage and cumulative percentage of these causes for NVD activities were aligned along with the Y axis. From Fig 6.5.3, it seems that the pioneer causes beyond the different types of bottlenecks and NVD activities were insufficient bottle supply (65.23%), label defect (slim) at wrapping machine (10.78%), sensor problem of machine (5.22%), label changing at labeler (3.72%), machine cutter problem at labeler (3.51%), disarray of bottle (3.13%), bottle queue in front of labeler (2.32%), bottle queue in front of cooler (1.91%), crock changing of filer (1.58%), case cover changing at wrapping machine (1.50%), and bottle queue in front of filer (1.04%).

From Pareto chart (Fig 6.5.3) the most responsible causes were easily observed and the effective initiatives can be taken to remove these causes. It was expected that if the most frequent first three or 20% causes like as insufficient bottle supply (65.23%), label defect (slim) at wrapping machine (10.78%), sensor problem of machine (5.22%), could be removed, the 80% NVD activities or down times could be removed. 5S, JIT, TPM, DMAIC and other improving strategies could be effective initiatives to remove these most frequent causes.

6.5.7 Improvement points at present VSM of X Banana flavored juice processing line

Throughout the observation it was seen that there were some improvement points at different stages of X Banana flavored juice processing line. The nature of improving point differs from each and another stages.

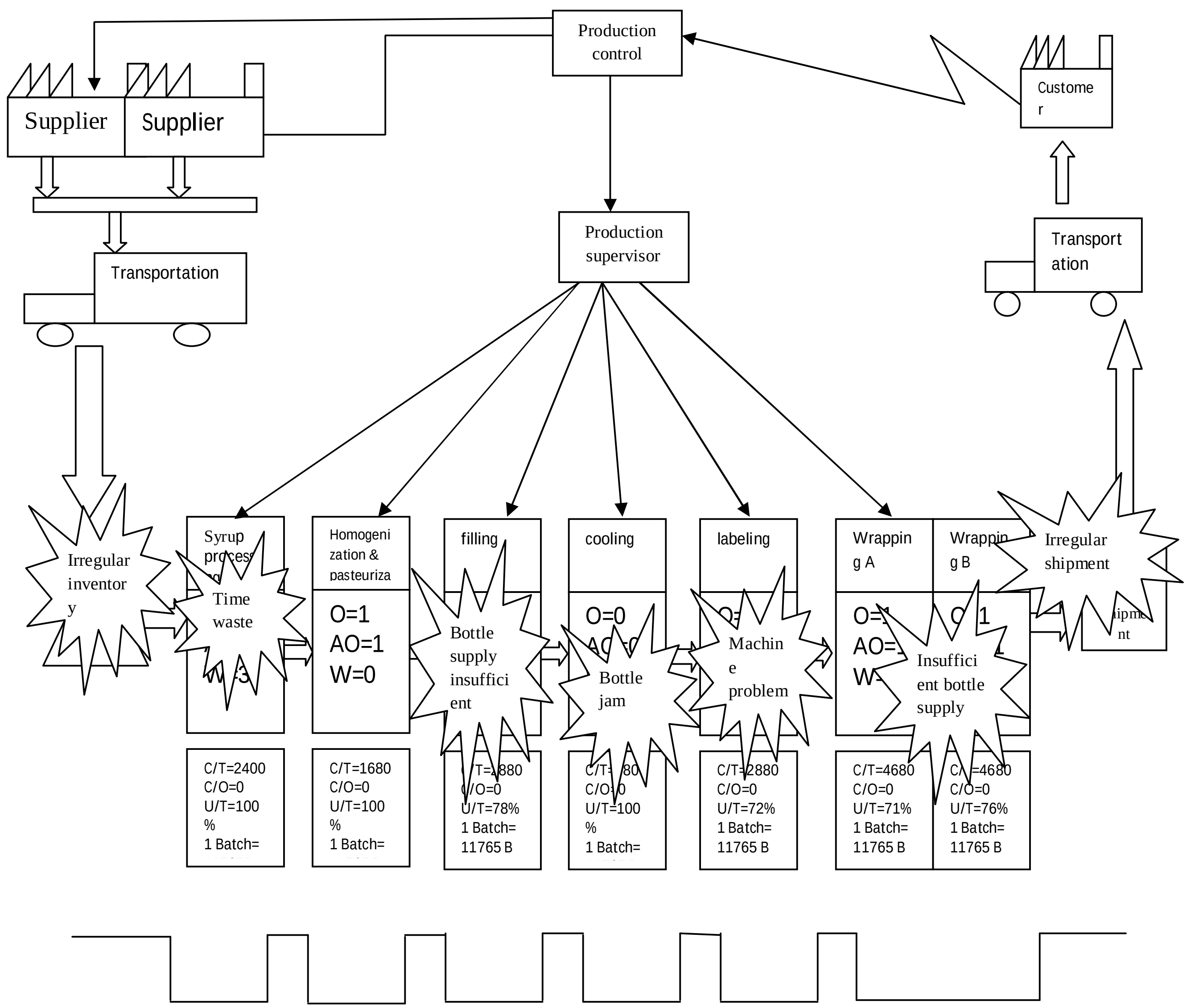


Fig 6.5.4 Present VSM of X Banana flavored juice process with improvement points

The crucial improvement points were pointed in Fig 6.5.4. In the stage of raw material or receiving inventory, delay handling of raw materials towards the next stage of syrup processing was observed as the prime point that should be removed in order to reduce the lead time as well as to improve the PCE. Besides these, conventional movement of raw materials like as carry of raw materials sack by labor instead of conveyor belt movement, inventory storage room was soaked and congested, crowd movement were most common. In the syrup processing stage, the delay of syrup processing was the main hindrance beyond the NVD activities and bottlenecks. No cause was indentified that need to solve in the stage of homogenization and pasteurization, because of it was difficult to detect any barrier beyond the bottleneck due to fully pipe flow of syrup towards the next filing stage, but it was observed that this stage was smoothly running and based on previous experience of regarding personnel it was also known that there was no mentionable barrier for bottlenecks.

In the filing stage the basic causes were bottle short in supply, bottle queue in warmer line, bottle queue in front of cooler, crock changing, and machine (sensor) problem.

In the stage of cooling bottle jam was observed as the only one problem both in enters and exit of cooling chamber. In the stage of labeling the main causes for bottlenecks or breakdown of machine were bottle short in supply, label changing, machine cutter problem, and bottle queue in front stage. In case of wrapping-A stage the basic problems were pointed as insufficient bottle supply, case cover changing, label defect slim, and disarray of bottle. In case of wrapping-B insufficient bottle supply, label defect slim, sensor problem, and machine problem. In the stage of shipment the basic barrier were irregular shipment and insufficient space for movement. In Fig 6.5.4 only the most frequent cause at different stages of X Banana flavored juice processing line were pointed. These pointed causes or barriers should be removed in order to reduce the manufacturing wastes and improve the PCE.

6.5.8 Future VSM of X Banana flavored juice processing line

In the future VSM, after a deep brainstorming and an intense observation in X Banana flavored processing line the VD and NVD time were calculated and documented in Table 6.5.7.

Table 6.5.7: Future state VD and NVD time analysis of X Banana flavored juice processing line

Processing stage	Value Added Time (Sec)	Non Value Added Time (Sec)
Receiving Inventory	00	13500 (50%)
Syrap processing	600	900 (50%)
Homogenization & pasteurization	1680	240 (0%)
Filling	2200	184 (80%)
Cooling	00	150 (80%)
Labeling	1973	241 (80%)
Wrapping	3371	364 (80%)
Shipping Inventory	00	12960 (70%)
Total	**9824 (25.61%)**	**28539 (74.39%)**

Note: VD time- the time that is desired which add the value to goods or service; NVD time- the time that is not desired or that does not add any value to goods or service

It was expected, after the implementation of lean tools and SS methodologies the present state NVD activities or times could be reduced at least up to 80%. In this study, based on intense observation, brainstorming and previous regarding studies it was assumed that the NVD time of receiving stage of X Banana flavored juice line could be reduced at least 50% (13500 sec) and the NVD time of syrup processing could be also be reduced at least 50% (900 sec). The NVD time of filing, cooling, labeling and wrapping could be reduced at least 80% from the present state and in the future state these NVD times could be consecutively 184 sec, 150 sec, 241 sec and 364 sec which could be seen in Table 6.5.7.

The Fig 6.5.5 was the future VSM of X Banana flavored juice processing line. The future VSM indicates the materials, information and labor flow of single batch production of X Banana flavored juice processing line. Each batch contains 2000 L syrup that produce 11765 bottle (B) of X Banana flavored juice.

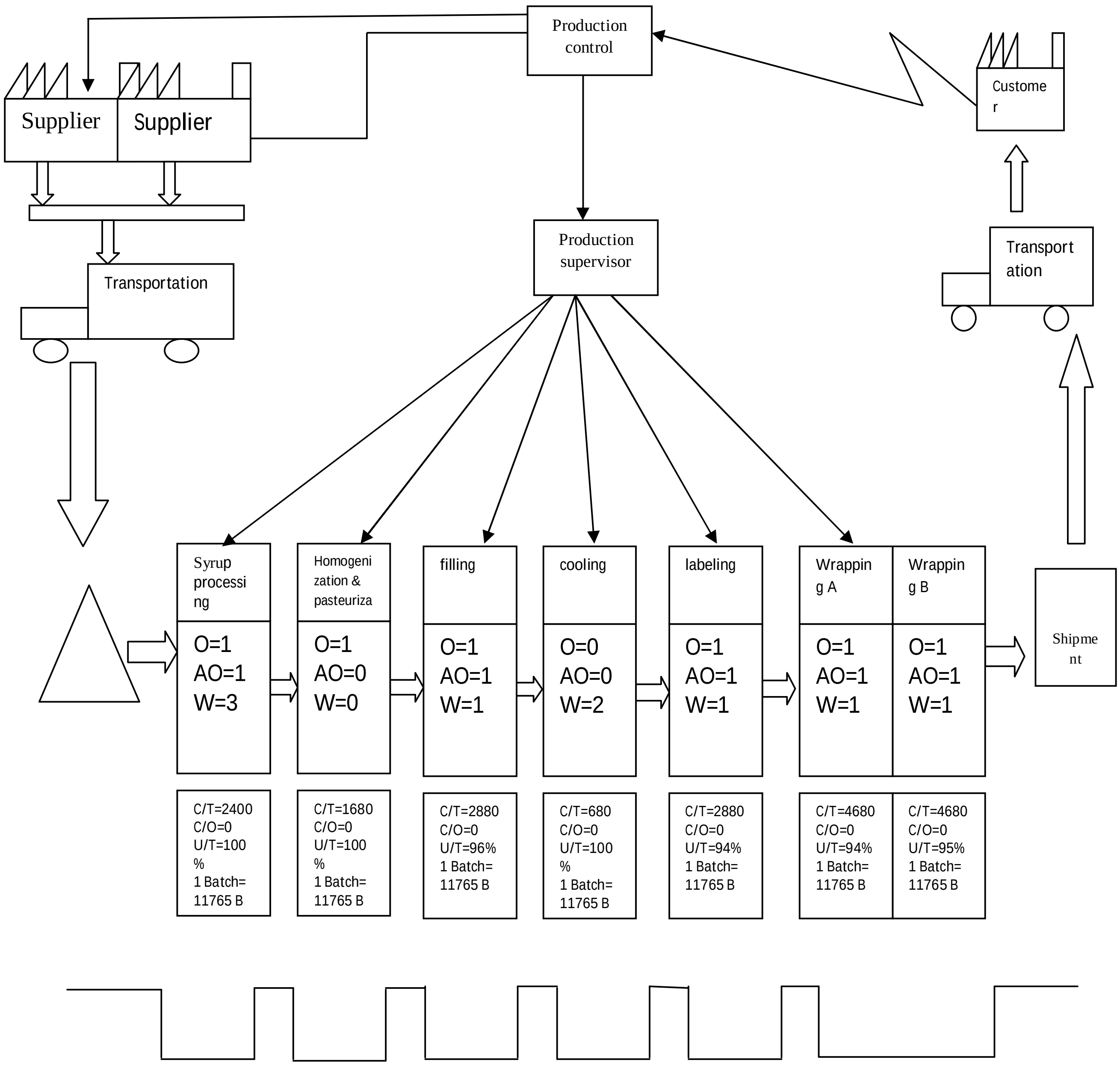


Fig 6.5.5 Future VSM of X Banana flavored juice process

The basic components of future VSM were customers, production control, production supervisor, suppliers, transportation, different stages of processing line like as receiving inventory, syrup processing, homogenization and pasteurization, filing, cooling, labeling, wrapping and shipment inventory and finally the VD and NVD times that were depicted at the bottom of future VSM.

Production control consists of one production manager and two assistant production managers and four supervisors. The production starts with taking the order from customer by electric signal like as over telephone or email. Later required raw materials were collected from the suppliers. Finally raw materials were transformed into finished X Banana flavored juice throughout the receiving inventory stage to shipment stage.

In this future VSM the basic promising changes were the reduction of total number of labor which was observed at every processing stage, reduction of NVD time which was indicated at the bottom level of future VSM, improved Up time (U/T) which was also seen at every processing stage of X Banana flavored juice processing line.

In future VSM the total labor including operator, assistant operator and worker could be 20 which was 30 at present VSM i.e. after the implementation of lean tools and SS methodologies it was expected at least 14 labors could be reduced. The U/T of filer, labeler, wrapping machine-A and wrapping machine-B could be consecutively 96%, 94%, 94% and 95% but at present state the U/T of filer, labeler, wrapping machine-A and wrapping machine-B were consecutively 78%, 72%, 71% and 76%.

6.5.9 Expected PCE of X Banana flavored processing line

In the X Banana flavored processing line,

Value Added time = 9824 Sec

Non Value Added time = 28539 Sec

Lead time = Value Added time + Non Value Added time

= 9824 Sec + 28539 Sec = 38363 Sec

$$\text{PCE} = \frac{\text{Value Added time} \times 100}{\text{Lead time}}$$

25.60 %

After the proper implementation of lean tools and SS methodologies it was expected the PCE of X Banana flavored juice processing line could be 25.60 % while the present PCE was 11.32 %, the NVD time could be reduced from 76936 sec to 28539 sec and lead time could be reduced from 86728 sec to 38363 sec.

6.5.10 Expected Tact Time calculation X Banana flavored juice process line

Net available time			**Customer / production Demand**		
Working shifts / day	2	Shifts	Customer demand/day	26781	cases
Hours / shift	10	Hours			
Available time / shift	600	minutes			
Prepare time / shift	40	minutes			
Lunch time / shift	0	minutes	Net available time / day	67200	seconds / day
Planned downtime / shift	0	minutes	Customer demand / day	27403	cases / day
Net working time / shift	560	minutes			
Net working time / shift	33600	seconds	**Tact time**	2.45	seconds / cases
Net available time / day	67200	seconds			

Note: Tact time- is considered as the rate at which customers need products i.e. the products should be produced at least equal to Tact time to meet the customer demand.

As earlier it was mentioned that Tact time is the heart beat of production of any manufacturing industry. As it is lower indicates the faster of production. Throughout this study it was tried to reduce the Tact time. The present Tact time of X Banana flavored juice processing line was 2.51sec per case production and it was expected that after the adoption of lean tools and SS methodologies this could be reduced to 2.45 sec per case production. So, it seems that the lean tools and SS methodologies could bring the revolution beyond the speed of production of any processing line.

6.6 X Litchi Flavored Juice Processing Line

X Litchi flavored juice was unified with the fresh flavor of Litchi fruit. This process line was arranged with the syrup processing or blending, pasteurization and homogenization, filling, cooling, labeling, wrapping and finally the cases products were send for shipment. The pivotal stages of X Litchi flavored juice processing line were as follows-

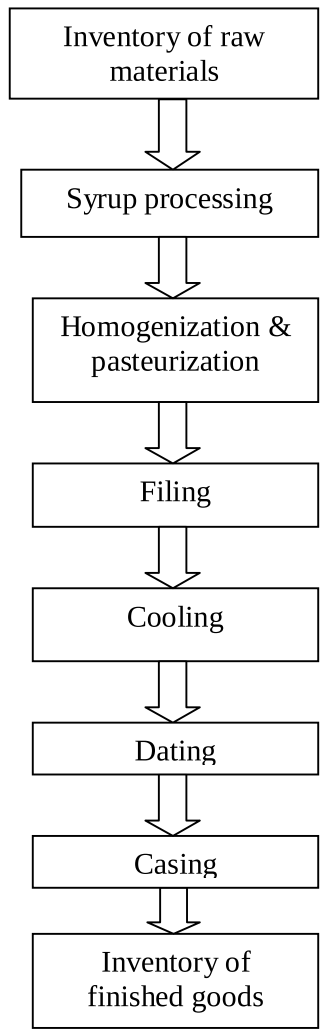


Fig 6.6.1 Pivotal stages of X Litchi flavored juice processing line

In blending step all required and formulated ingredients for X Litchi flavored juice preparation were mixed and blended in Blending tank. After blending the syrup was pasteurized with 96º C and just after pasteurization homogenization was performed. Pasteurization and homogenization was terminated by filling where each bottle was filled with 170 ml of X Litchi flavored juice. After filling the filled bottles were sending to label step for labeling and the labeling was terminated by the wrapping. Wrapping was performed by case production and each case contains six bottles of X Litchi flavored juice. Wrapping was the end stage of X Litchi flavored juice processing and after wrapping the case juice were send for shipment.

6.6.1 Present VSM of X Litchi flavored juice processing line

The final product of X Litchi flavored juice was derived throughout a series of stages by which the X Litchi flavored juice was gained its unique value in taste, energy, flavor and appearance. In processing line, the value adding stages were blending, pasteurization and homogenization, filling, cooling, labeling and wrapping which were drawn in VSM. The VD and NVD time were documented in Table 6.6.1 and other required data like as D/T, C/T and U/T were documented in Table 6.6.2 in order to draw the current VSM of X Litchi flavored juice process line.

Table 6.6.1: Down Time (D/T), Cycle Time (C/T) and Up Time (U/T) data of X Litchi flavored juice processing line

Times	Filler			Labeler			Wrapping machine		
	D/T (sec)	C/T (sec)	U/T (%)	D/T (sec)	C/T (sec)	U/T (%)	D/T (sec)	C/T (sec)	U/T (%)
1st	642	2880	78	649	2940	78	1058	3900	73
2nd	661	2880	77	672	2940	77	1083	3900	72
3rd	668	2880	77	675	2940	77	1083	3900	74

Note: Filler speed: 245 BPM; Labeler speed: 240 BPM; Wrapping machine speed: 30 case per min. Batch-2000 L; BPM: Bottle Per Minutes; D/T- the time that is wasted due to breakdown of machine; C/T- the time that is required to produce a single batch production; U/T- the time that is available for machine work or production.

The D/T, C/T, and U/T of X Litchi flavored juice processing line were documented in Table 6.6.1. In this processing line the stage of filer, labeler and wrapping machine were mainly responsible for D/T. In the stage of filer, average U/T was 77% and C/T was 2880 sec. In the stage of labeler average U/T was 77% and C/T was 2940 sec. In the stage of wrapping, C/T of wrapping machine was 3900 sec and U/T was 73%. The percentage of available time for machine work or processing of desire product was known as U/T. By observing the U/T of different unit stage of production line, it can be assumed the efficiency of the whole production line. At present state, the U/T of X Litchi flavored juice processing line varies from 73% (wrapping stage) to 77% (filing and labeling stage). By this study it was attempted to increase the U/T in the future state as well as to reduce the D/T and to reduce the ultimate lead time.

Table 6.6.2: Present state VD and NVD time for X Litchi flavored juice processing line

Processing stage	Average VD time (Sec)	Average NVD time (Sec)
Receiving Inventory	00	27000
Syrap processing	600	1800
Homogenization & pasteurization	1680	240
Filling	2113	1007
Cooling	00	1046
Labeling	2028	1362
Wrapping	2849	1803
Shipping Inventory	00	43200
Total	**9270 (10.68%)**	**77458 (89.32%)**

Note: VD time- the time that is desired which add the value to goods or service; NVD time- the time that is not desired or that does not add any value to goods or service

The VD and NVD time of different processing stages of X Litchi flavored juice processing line were documented in Table 6.6.2. At present state, there were no VD time rather than NVD time in the stages of receiving inventory, cooling and shipping inventory, but in this process line, this NVD activities were required for the X Litchi flavored juice processing.

In this X Litchi flavored juice processing line, the total VD time were 9270 sec (10.68%) and the total NVD time were 77458 sec (89.32%). By this study, it was tried to increase the percentage of VD time by reducing the NVD time with the proper implementation of lean tools and SS methodologies.

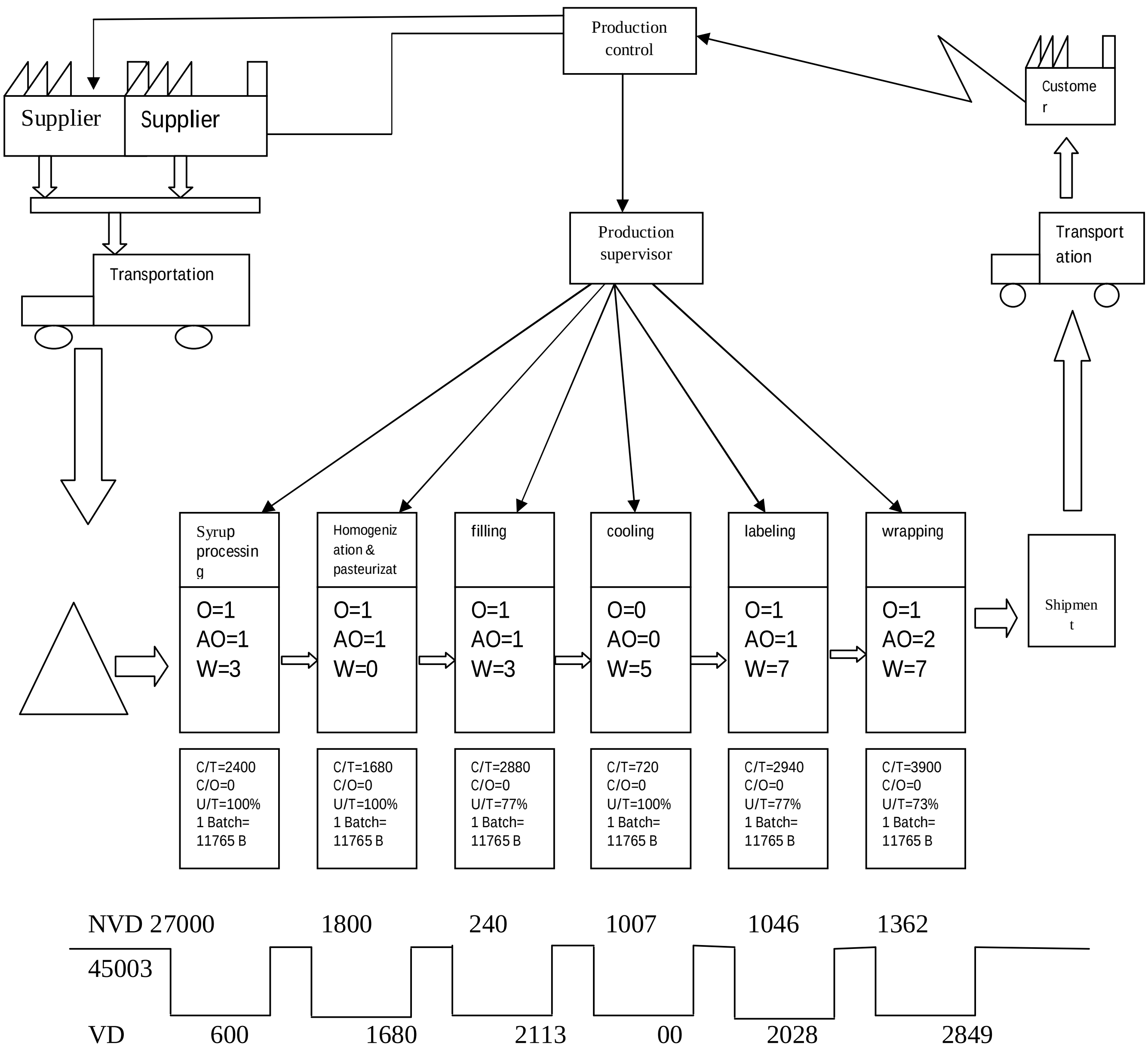


Fig 6.6.2 Present VSM of X Litchi flavored juice process line

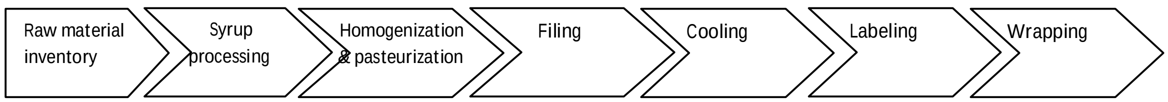
Note: Throughout the present VSM the whole processing system of X Litchi flavored juice process line were depicted with the flow of order, raw materials, labor, information, VD & NVD times. It helps to draw the required processing stage like syrup processing, homogenization & pasteurization, filing, cooling, labeling and wrapping with mentioning required labor, C/T, U/T, C/O and batch size. By observing the present scenario of regarding processing line, it can be known like as what number of labor is needed at different processing unit? How much VD & NVD time is present? Where & what kind of improvement should be done? It helps to calculate the PCE, lead time and Tact time.

Fig 6.6.2 represents the present VSM of X Litchi flavored juice line. At present VSM, the production of X Litchi flavored juice was controlled by production manager, assistant manager and supervisor. In this processing line, the production starts by taking the order of production from the customers. In order to fulfill the customer demand the required raw materials were collected from the different regarding suppliers. These required raw materials were brought in the raw materials inventory which was considered as the first stage of X Litchi flavored juice production that followed by syrup processing, homogenization & pasteurization, filing, cooling, labeling, wrapping and shipment of finished goods. As observed from the present VSM of X Litchi flavored juice process line, different types of NVD activities were present in the flow of process line at different stages. The different types of bottlenecks at different processing stages were identified and quantified in terms of time as shown in the Fig 6.6.2. The Up time (U/T) of filer, labeler and wrapping machine were consecutively 77%, 77%, 73% and 70%. At present state of this processing line over the different stages total labor was 36. After the implementation of lean tools and SS methodologies it was expected that U/T could be improved and total labor could be reduced.

6.6.2 Value chain of X Litchi flavored juice processing line

A value chain is a chain of activities that a firm operating in a specific industry performs in order to deliver a valuable product or service for the market. The value chain of X Litchi flavored juice processing line was depicted as follows-

Value chain of X Litchi flavored juice processing line



In this stage all required raw materials were gathered, but there was no value added towards the finished goods, although this stage was required for finished	All regarding raw materials were mixed in this stage in order to formulate syrup towards get the finished goods i.e. X Litchi flavored juice. In this stage value was added by 6.47%	In this stage the syrup was given ultra heat treatment (129^{o} C for 15 sec) in order to increase the self life by destroying the presence microbes with adding value by 17.10% (VD time	In this stage the syrup was bottled at cool condition towards giving the more finished goods of X Litchi flavored juice. In this stage the value was added by 22.79% (VD time 2113 sec of total	In this stage the hot bottle were cooled without adding any value but this stage was necessary in order to attain the finished goods.	In this stage the bottled juice were labeled with label foil that contains the details identity of product. In this stage value was added by 21.87%. (VD time 2028 sec of total 9270 sec).	In this stage the bottled juice were wrapped with the case. 24 bottles were wrapped in a single case. In this stage value was added by 30.73% (VD time 2849 sec of total 9270

goods.	(VD time 600sec of total 9270 sec).	1680 sec of total 9270 sec).	9270 sec).		sec).

Note: VD: Value Added; The percentage of value added was calculated- the VD time of each processing unit is divided by the total VD time of whole processing line.

6.6.3 Present PCE of X Litchi flavored juice processing line

In the X Litchi flavored juice process line,

Value Added time = 9270 Sec

Non Value Added time = 77458 Sec

Lead time = Value Added time + Non Value Added time

= 9270 Sec + 77458 Sec = 86728 Sec

PCE = (Value Added time/Lead time) × 100%

= 10.8%

It seems that the present VSM of X Litchi flavored juice processing line was 10.68 % which was the below of internationally competitive level 25% [74]. Throughout this study it was tried to improve the present PCE of X Litchi flavored juice processing line with the proper implementation of lean tools and SS methodologies.

6.6.4 Present Tact time calculation of X Litchi flavored juice process line

Net available time			**Customer / production Demand**		
Working shifts / day	2	Shifts	Customer demand/day	27450	Cases
Hours / shift	10	Hours			
Available time / shift	600	Minutes			
Prepare time / shift	40	Minutes			
Lunch time / shift	0	Minutes	Net available time / day	67200	seconds / day
Planned downtime / shift	0	Minutes	Customer demand / day	27450	cases / day
Net working time / shift	560	Minutes			
Net working time / shift	33600	Seconds	**Tact time**	2.45	seconds / cases
Net available time / day	67200	Seconds			

Note: Tact time- is considered as the rate at which customers need products i.e. the products should be produced at least equal to Tact time to meet the customer demand.

Tact time is considered as the heart beat of any process line. The present Tact time of X Litchi flavored juice processing line was 2.45 sec. i.e. it was taken 2.45 sec to produce a single case of X Litchi flavored juice production. Each case contains 6 bottle of X Litchi flavored juice where a single bottle contains 170 ml X Litchi flavored juice. One of the basic objectives of this study was to reduce this present Tact time after the proper implementation of lean tools and SS methodologies.

6.6.5 Manufacturing waste of X Litchi flavored juice processing line

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites, and unnecessary motion of labor in the work place. Among these manufacturing wastes, defect productions, wasted time due to different causes and unnecessary motion of labor were very common in the X Litchi flavored juice processing line.

6.6.5.1 Down Time (D/T) calculation of X Litchi flavored juice Processing Line

The down time for different causes at different processing stages was observed and calculated in Table 6.6.3.

Table 6.6.3:Down Time (D/T) calculation of X Litchi flavored juice processing line

Step	Causes for D/T	D/T (sec)	Average D/T	C/T	% D/T
Filler	Bottle short in supply	310			
		305	312	2880	13.11
		320			
	Bottle queue in warmer line	99			
		105	105		4.41
		112			
	Crock changing	63			
		71	67		2.82
		68			
	Caper sensor problem	170			
		180	173		7.27
		168			
Labeler	Bottle short in supply	351			
		360	353	2940	14.83
		347			
	Label defect	103			

		113	112		4.70
		120			
	Label changing	72			
		69	72		3.02
		76			
	Machine cutter problem	81			
		78	77		3.23
		73			
	Machine sensor problem	42			
		52	51		2.14
		59			
Wrapping	Insufficient bottle supply	287			
		290	282		11.85
		269			
	Case cover changing	40		3900	
		50	46		1.93
		47			
	Case queue in front	33			
		41	34		1.42
		29			
	Case cover breaking	110			
		116	109		4.58
		103			
	Disarray of bottle array	480			
		473	478		20.09
		482			
	Machine problem	108			
		113	108		4.53
		103			
Total			**2379**		

In X Litchi flavored juice processing line, the most important processing stages were filing, labeling and wrapping where the most frequent D/T was observed due to different causes that were documented in Table 6.6.3.

6.6.5.2 Wasted bottles calculation of X Litchi flavored juice processing line

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites, and unnecessary motion in the work place. In a single processing line all types of wastes could not be seen.

Table 6.6.4: Wasted bottles of X Litchi flavored juice processing line

Name of stage	No of observ ation	Rejected Bottles	Average of rejected bottle per batch	Average rejected bottle per day (per day 12 batch)	Rejected bottle per million opportu nity	Gap at Six Sigma level	Remarks
Filling	1	26					Contains at three Sigma level
	2	24					
	3	29	24	288	2040	2037	
	4	20					
	5	19					
Date coding	1	33					
	2	29					
	3	31	32	384	2720	2717	
	4	34					
	5	33					
Labeling	1	114					
	2	104					

	3	94	98	1176	8330	8327
	4	90				
	5	88				
Wrapping machine	1	22				
	2	23				
	3	26	21×6=126	1512	1785	1782
	4	19				
	5	17				
Total			**280**	**3360**	**14875**	

*Note: *Opportunity: a situation or a condition for attainment of a goal; here it indicates to get the chance of total number of bottle production in both case of defect and defect free [83].*

Based on the nature of production the manufacturing wastes are varied. Among these manufacturing wastes, defect production was very common in the X Litchi flavored juice processing line. In this processing line defect bottle was considered as the defect production. The amount of defect bottle was documented in Table 6.6.4.

Based on central SS concept it seems that if the amount of defect product is more than 6,210 but less than 66,807 per million product of production then it is considered as the three Sigma productions. From Table 6.6.4, it seems that the total defect product of X Litchi flavored juice process line was 14875 per million product of production which was considered as the three Sigma productions. But the prime target of any manufacturing industry should be Six Sigma production where the amount of defect product should not be more than 3.4 per million product of production. Throughout this study it was expected that 80% of the present manufacturing waste could be reduced after the implementation of lean tools and SS methodologies.

6.6.5.3 Wasted labor of X energy drinks processing line

The unnecessary motion of labor in the processing floor was considered as the manufacturing waste. After the implementation of lean tools and Six Sigma methodology in X energy drinks processing line it was expected that a number of labors could be eliminated which were documented in the Table 6.6.5.

Table 6.6.5: Present and expected labor of X Litchi flavored juice processing line

Name of Stages	No of labor at present state			No of labor at future state		
	O	AO	W	O	AO	W
Syrup processing	1	1	3	1	1	3
Homogenization & pasteurization	1	1	0	1	1	0
Filing	1	1	3	1	1	1
Warming	0	0	5	0	0	2
Labeling	1	1	7	1	1	3
Wrapping	1	2	7	1	1	3
Total	5	6	25	5	5	12

At present state, from Table 6.6.5, it was seen that throughout the different processing stages of X Litchi flavored juice processing line, total labor were 36 where operator (O), assistant operator (AO) and worker (W) were consecutively 5, 6 and 25. At future state, if the lean tools and SS methodologies will implement, it was expected that different types of bottlenecks and NVD activities will be reduced thus the present number of labor will also be reduced from 36 to 22 where operator (O), assistant operator (AO) and worker (W) were consecutively 5, 5 and 12. Because of a number of unwanted labors were engaged to manage the different types of bottlenecks and NVD activities.

6.6.6 Pareto analysis of X Litchi flavored juice processing line

Pareto analysis was performed by drawing the Pareto chart consisting of causes for delay along the X axis and percentage and cumulative percentage of down time along the Y axis. The highest frequency of down time was found for bottle short in supply at the X Litchi flavored juice processing line, while bottle queue in front of filer machine showed the lowest frequency. Different causes of down time with their frequency in terms of percentages and cumulative percentages were documented in Table 6.6.5.

Table 6.6.6: Cumulative percentage of D/T for Pareto analysis of X Litchi flavored juice processing line

Causes of delay times	Down Time(D/T)	Percentage of (D/T)	Cumulative of percentage
Insufficient bottle supply	947	39.80664	39.80664
Disarray of bottle at wrapping machine	478	20.09247	59.89911
Sensor problem of machine	332	13.95544	73.85455
Label defect at labeler	112	4.70786	78.56241
Case cover splitting	109	4.58175	83.14416
Bottle queue in front of filer	105	4.41361	87.55778
Machine cutter problem of labeler	77	3.23665	90.78443
Label changing at labeler	72	3.02648	93.81091
Crock changing of filer	67	2.81630	96.62721
Cover case changing of wrapping machine	46	1.93358	98.56079
Case queue in front of wrapping machine	34	1.43921	100.00000

Different causes of NVD activities or down time at different processing stages of X Litchi flavored juice processing line with their frequency in terms of percentages and cumulative percentages were documented in Table 6.6.6. The causes for NVD activities were arranged in downward movements in terms of their frequency.

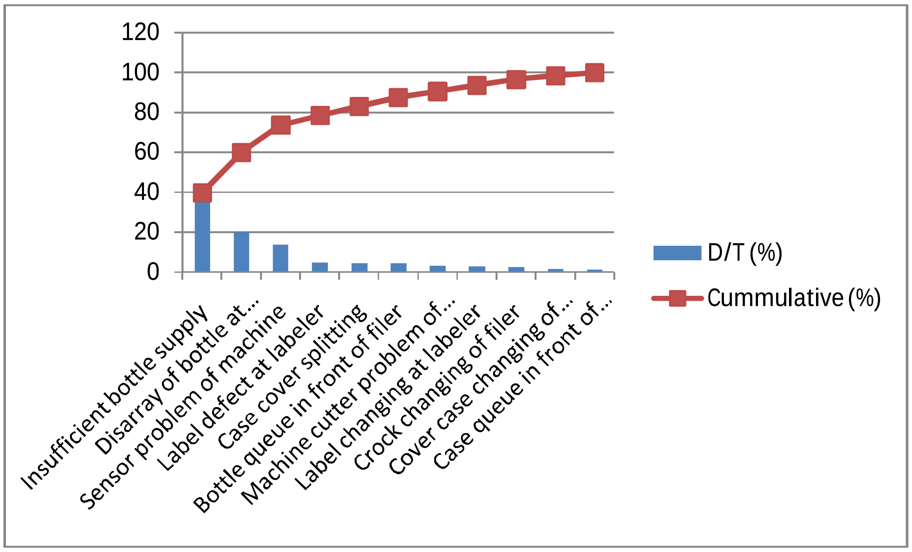


Fig 6.6.3 Pareto chart for X Litchi flavored juice processing line

Pareto chart (Fig 6.6.3) was depicted from Pareto table (Table 6.6.6) by aligning the different causes along with X axis; percentage and cumulative percentage of these causes for NVD activities were aligned along with the Y axis. From Fig 6.6.3, it seems that the pioneer causes beyond the different types of bottlenecks and NVD activities were insufficient bottle supply (39.80%), disarray of bottle at wrapping machine (20.09%), sensor problem of machine (13.95%), label defect at labeler (4.70%), case cover splitting (4.58%), bottle queue in front of filer (4.41%), machine cutter problem of labeler (3.23%), label changing at labeler (3.02%), crock changing of filer (2.81%), cover case changing of wrapping machine (1.93%), and case queue in front of wrapping machine (1.43%).

From Pareto chart (Fig 6.6.3) the most responsible causes could be easily observed and the effective initiatives could be taken to remove these causes. It was expected that if the most frequent first three or 20% causes like as insufficient bottle supply (39.80%), disarray of bottle at wrapping machine (20.09%), sensor problem of machine (13.95%), the 80% NVD activities or down times could be removed. 5S, JIT, TPM, DMAIC and other improving strategies could be effective initiatives to remove these most frequent causes.

6.6.7 Improvement points at present VSM of X Litchi flavored juice processing line

Throughout the observation it was seen that there were some improvement points at different stages of X Litchi flavored juice processing line. The nature of improving point differs from each and another stages.

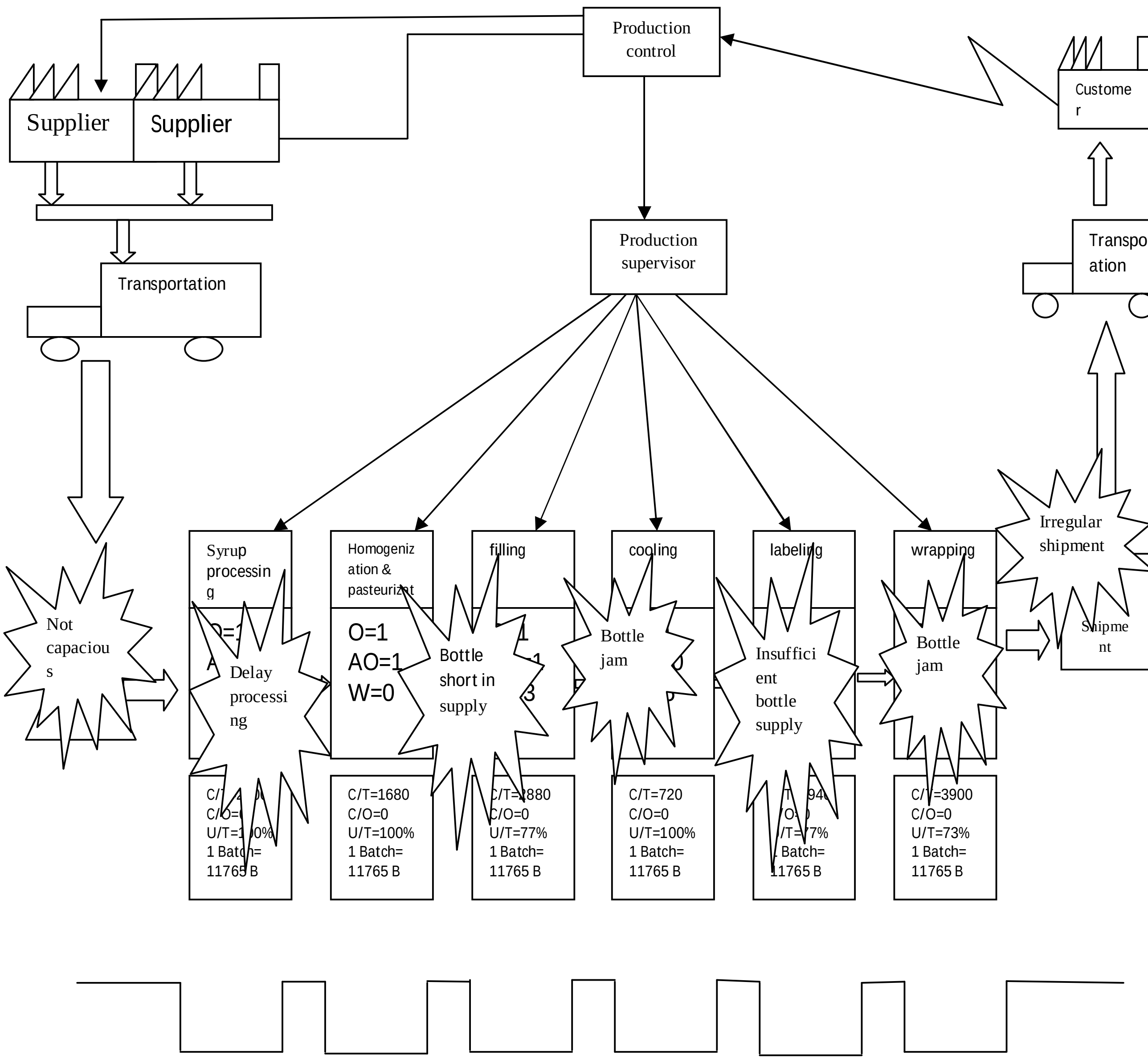


Fig 6.6.4 Present VSM of X Litchi flavored juice process with improvement direction

The crucial improvement points were pointed in Fig 6.6.4. In the stage of raw material or receiving inventory, delay handling of raw materials towards the next stage of syrup processing was observed as the prime point that should be removed in order to reduce the lead time as well as to improve the PCE. Besides these, conventional movement of raw materials like as carry of raw materials sack by labor instead of conveyor belt movement, inventory storage room was soaked and congested, crowd movement were most common. In the syrup processing stage, the delay of syrup processing was the main hindrance beyond the NVD activities and bottlenecks. No cause was indentified that need to solve in the stage of homogenization and pasteurization, because of it was difficult to detect any barrier beyond the bottleneck due to fully pipe flow of syrup towards the next filing stage, but it was observed that this stage was smoothly running and based on previous experience of regarding personnel it was also known that there was no mentionable barrier for bottlenecks.

In the filing stage the basic causes were bottle short in supply, bottle queue in warmer line, crock changing, caper sensor problem. In the stage of cooling bottle jam was observed as the only one problem both in enters and exit of cooling chamber. In the stage of labeling the main causes for bottlenecks or breakdown of machine were bottle short in supply, label defect, label changing, machine cutter problem, machine sensor problem. In case of wrapping stage the basic problems were pointed as insufficient bottle supply, case cover changing, case queue in front, case cover breaking, disarray of bottle array, and machine problem.

In the stage of shipment the basic barrier were irregular shipment and insufficient space for movement. In Fig 6.6.4 only the most frequent cause at different stages of X Litchi flavored juice processing line were pointed. These pointed causes or barriers should be removed in order to reduce the manufacturing wastes and improve the PCE.

6.6.8 Future VSM of X Litchi flavored juice processing line

In the future VSM, after a deep brainstorming and an intense observation in X Litchi flavored processing line the VD and NVD time were calculated and documented in Table 6.6.7.

Table 6.6.7: Future state VD and NVD time analysis of X Litchi flavored juice processing line

Processing stage	Value Added Time (Sec)	Non Value Added Time (Sec)
Receiving Inventory	00	13500 (50%)
Syrup processing	600	900 (50%)
Homogenization & pasteurization	1680	240 (0%)
Filling	2113	201 (80%)
Cooling	00	87 (80%)
Labeling	2028	272 (80%)
Wrapping	2849	360 (80%)
Shipping Inventory	00	12960 (70%)
Total	**9270 (24.45)**	**28642 (75.55)**

Note: VD time- the time that is desired which add the value to goods or service; NVD time- the time that is not desired or that does not add any value to goods or service

It was expected, after the implementation of lean tools and SS methodologies the present state NVD activities or times could be reduced at least up to 80%. In this study, based on intense observation, brainstorming and previous regarding studies it was assumed that the NVD time of receiving stage of X Litchi flavored juice line could be reduced at least 50% (13500 sec) and the NVD time of syrup processing could be also be reduced at least 50% (900 sec). The NVD time of filing, cooling, labeling and wrapping could be reduced at least 80% from the present state and in the future state these NVD times could be consecutively 201 sec, 87 sec, 272 sec and 360 sec which could be seen in Table 6.6.7.

The Fig 6.6.5 was the future VSM of X Litchi flavored juice processing line. The future VSM indicates the materials, information and labor flow of single batch production of X Litchi flavored juice processing line. Each batch contains 2000 L syrup that produce 11765 bottle (B) of X Litchi flavored juice.

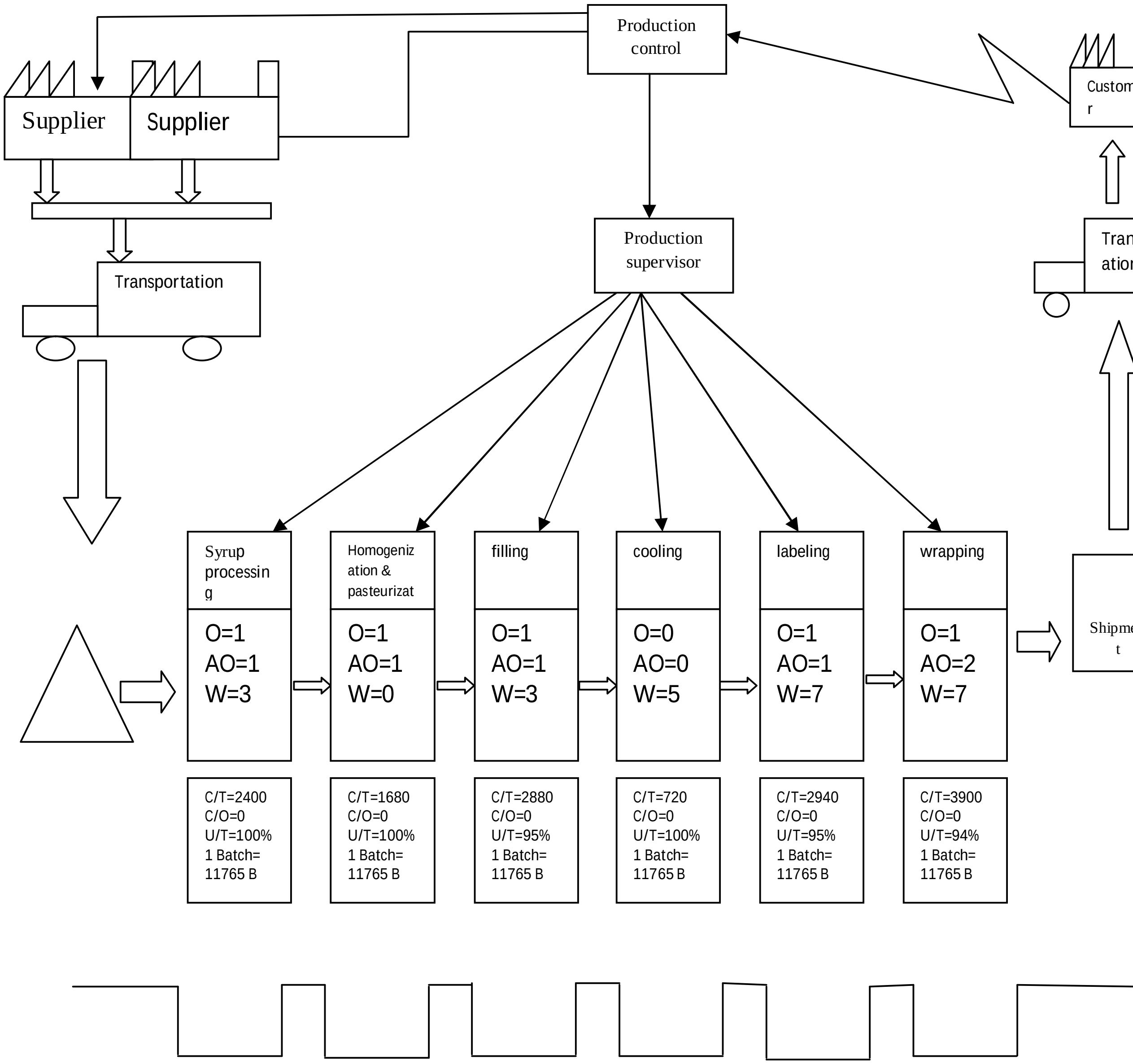


Fig 6.6.5 Future VSM of X Litchi flavored juice process

The basic components of future VSM were customers, production control, production supervisor, suppliers, transportation, different stages of processing line like as receiving inventory, syrup processing, homogenization and pasteurization, filing, cooling, labeling, wrapping and shipment inventory and finally the VD and NVD times that were depicted at the bottom of future VSM of X Litchi flavored juice processing line.

Production control consists of one production manager and two assistant production managers and four supervisors. The production starts with taking the order from customer by electric signal like as over telephone or email. Later required raw materials were collected from the suppliers. Finally raw materials were transformed into finished X Litchi flavored juice throughout the receiving inventory stage to shipment stage.

In this future VSM the basic promising changes were the reduction of total number of labor which was seen at every processing stage, reduction of NVD time and improved Up time (U/T) of X Litchi flavored juice processing line.

In future VSM the total labor including operator, assistant operator and worker could be 22 which was 36 at present VSM i.e. after the implementation of lean tools and SS methodologies it was expected at least 14 labors could be reduced. The U/T of filer, labeler, wrapping machine could be consecutively 96%, 95%, and 94% but at present state the U/T of filer, labeler, and wrapping machine were consecutively 77%, 77% and 73%.

6.6.9 Expected Project Cycle Efficiency of X Litchi flavored process line

In the X Litchi process line,

Value Added time = 9270 Sec

Non Value Added time = 28642 Sec

Lead time = Value Added time + Non Value Added time

= 9270 Sec + 28642 Sec = 37912 Sec

$$PCE = \frac{\text{Value Added time} \times 100}{\text{Lead time}}$$

24.45 %

After the proper implementation of lean tools and SS methodologies it was expected the PCE of X Litchi flavored juice processing line could be 24.45 % while the present PCE was 10.68 %, the NVD time could be reduced from 77458 sec to 28642 sec and lead time could be reduced from 86760 sec to 37912 sec.

6.6.10 Expected Tact time of X Litchi flavored process line

Net available time			**Customer / production Demand**		
Working shifts / day	2	Shifts	Customer demand/day	27450	cases
Hours / shift	10	Hours			
Available time / shift	600	minutes			
Prepare time / shift	40	minutes			
Lunch time / shift	0	minutes	Net available time / day	67200	seconds / day
Planned downtime / shift	0	minutes	Customer demand / day	28010	cases / day
Net working time / shift	560	minutes			
Net working time / shift	33600	seconds	**Tact time**	2.39	seconds / cases
Net available time / day	67200	seconds			

Note: Tact time- is considered as the rate at which customers need products i.e. the products should be produced at least equal to Tact time to meet the customer demand.

As earlier it was mentioned that Tact time was the heart beat of production of any manufacturing industry. As it was lower indicates the faster of production. Throughout this study it was tried to reduce the Tact time. The present Tact time of X Litchi flavored juice processing line was 2.44 sec per case production and it was expected that after the adoption of lean tools and SS methodologies this could be reduced to 2.39 sec per case production. So, it seems that the lean tools and SS methodologies could bring the revolution beyond the speed of production of any processing line.

6.7 Improvement Strategies

To formulate the improvement strategies, it is needed to find out basic causes for NVD activities at different stages of different studied processing lines. After intense brainstorming and a thorough study of the observed processing floors, it was observed that the activities of processing floors contain various forms of NVD activities which could be deduced from the Pareto Analysis. In order to reduce these NVD activities a number of strategic steps have to be taken for improved PCE, Tact time and reduced lead time of regarding processing lines.

6.7.1 Introducing Total Productive Maintenance (TPM)

TPM is a widely using tool in the manufacturing companies over the World. It is a unique Japanese philosophy, which has been developed based on the Productive Maintenance concepts and methodologies. In 1971, this concept was first introduced by M/s Nippon Denso Co. Ltd. of Japan, a supplier of M/s Toyota Motor Company. Total Productive Maintenance is an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns and promotes autonomous maintenance by operators through day-to-day activities involving total workforce [82].

Machine break down is one of the most important issues that concern the people on the processing floor. The reliability of the equipment on the processing floor is very important since one machine breaks down the entire production line could go down. An important tool that is necessary to account for sudden machine breakdowns is TPM. In almost any lean environment setting a TPM program is very important. TPM focuses on the equipment used. It is a holistic approach to equip the maintenance that strives to achieve perfect production with no breakdowns; no small stops or slow running and no defects. There are three components of a TPM: preventive maintenance, corrective maintenance, and maintenance prevention. Preventive maintenance has to do with regular planned maintenance on all equipment rather than random check ups. Workers have to carry out regular equipment maintenance to detect any anomalies as they occur. By doing so sudden breakdown can be prevented which leads toward improvement in the throughput of each machine [83]. Corrective maintenance deals with decision such as whether to fix or buy new equipment. If a machine is always down and its components are always breaking down then it is better to replace those parts with newer ones. As a result the maintenance will last longer and its uptime will be higher. Maintenance prevention has to do with buying the right machine. If a machine is hard to maintain (e.g., hard to lubricate or bolts are hard to tighten) then workers will be reluctant to maintain the machine on a regular basis, which was frequently observed in the studied processing floors that will results in a huge amount of lost money invested in that machine.

Though in recent years, many companies have attempted to implement TPM programs, less than 10 per cent of companies succeed in implementing TPM [84]. Implementing TPM requires the change of the organizational culture and change of existing behaviors of all employees, operators, engineers, maintenance technicians, and managers.

By this study during the observation sudden downs of different machines, especially the filer, labeler and wrapping machine were observed at different processing stages of production lines which were quantified in Table 6.1.3, Table 6.2.3, Table 6.3.3, Table 6.4.3, 6.5.3, and Table 6.6.3. During the down time, sometimes machines were stopped for maintenance or the machines were producing defect product that were accounted as manufacturing waste. To maintain and to prevent the defect production a number of operators, assistant operators and workers were engaged which was also considered as manufacturing waste in term of unwanted motion of labor. So, it seems that if it is possible to implement the TPM, then the manufacturing waste could be eliminated at expected level. The TPM is measured by the Overall Equipment Effectiveness (OEE). For successful implementation of TPM, it is necessary to evaluate the present OEE. The following Tables were contained the present OEE of all observing processing lines.

Table 6.7.1 : OEE of X mango juice processing line -1

Availability rate (A) = (Net Down time ÷ Total good time) × 100 = (3869 ÷ 16080) × 100 = 24.06 %	Net Down time = 3869 sec Total good time = 16080 sec
Percentage of Quality (Q) = [(Total produced-Defected produced) ÷ Total produced] ×100 % = [(28000- 468) ÷ 28000] ×100 % = 98.32 %	Total produced= 28000 B Defected produced = 468 B
Performance rate (P) = [Net Down time - (Management Down time + Start up Down time)] ÷ Net Down time = [3869-(574+240)] = 78.96 %	Net Down time = 3869 sec D/T for management loss= 574 sec Start up loss= 240 sec

Overall Equipment Effectiveness (OEE)	= Availability rate (A) × Percentage of Quality (Q) × Performance rate (P) = 0.2406× 0.9832 × 0.7896% = 18.67 %

Note: B = Bottle

Table 6.7.2 : OEE of X mango juice processing line -2

Availability rate (A) = (Net Down time ÷ Total good time) × 100 = (2482 ÷ 12060) × 100 = 20.58%	Net Down time = 2482 sec Total good time = 12060 sec
Percentage of Quality (Q) = [(Total produced-Defected produced) ÷ Total produced] ×100 % = [(28000- 534) ÷ 28000] ×100 % = 98.09 %	Total produced= 28000 B Defected produced = 534 B
Performance rate (P) = [Net Down time - (Management Down time + Start up Down time)] ÷ Net Down time = [2482-(226+240)] = 93.31 %	Net Down time = 2482 sec D/T for management loss= 226 sec Start up loss= 240 sec
Overall Equipment Effectiveness (OEE)	= Availability rate (A) × Percentage of Quality (Q) × Performance rate (P) = 0.2058× 0.9809 × 0.9331% = 18.83 %

Note: B = Bottle

Table 6.7.3 : OEE of X up processing line

Availability rate (A) = (Net Down time ÷ Total good time) × 100 = (1726 ÷ 6780) × 100 = 25.46%	Net Down time = 1726 sec Total good time = 6780 sec
Percentage of Quality (Q) = [(Total	Total produced= 16000 B

produced-Defected produced) ÷ Total produced] ×100 % = [(16000- 527) ÷ 16000] ×100 % = 96.70 %	Defected produced = 527 B
Performance rate (P) = [Net Down time - (Management Down time + Start up Down time)] ÷ Net Down time = [1721-(266+240)] = 70.68 %	Net Down time = 1721sec D/T for management loss= 266 sec Start up loss= 240 sec
Overall Equipment Effectiveness (OEE)	= Availability rate (A) × Percentage of Quality (Q) × Performance rate (P) = 0. 2546× 0.9670 × 0.7068% = 17.40%

Table 6.7.4 : OEE of X energy drinks processing line

Availability rate (A) = (Net Down time ÷ Total good time) × 100 = (1629÷6780) × 100 = 24.02%	Net Down time = 1629 sec Total good time = 6780 sec
Percentage of Quality (Q) = [(Total produced-Defected produced) ÷ Total produced] ×100 % = [(16000-525) ÷ 16000] ×100 % = 96.72%	Total produced= 16000 B Defected produced = 525 B
Performance rate (P) = [Net Down time - (Management Down time + Start up Down time)] ÷ Net Down time = [1629-(207+240)] ÷1629 = 72.56%	Net Down time = 1629 sec D/T for management = 207 sec Start up loss= 240 sec
Overall Equipment Effectiveness (OEE)	= Availability rate (A) × Percentage of Quality (Q) × Performance rate (P) = 0.2402 × 0.9672 ×0.7256 % = 16.86%

Note: B = Bottle

Table 6.7.5 : OEE of X Banana flavored juice processing line

Availability rate (A) = (Net Down time ÷ Total good time) × 100 = (3921÷ 10440) × 100 = 37.55%	Net Down time = 3921 sec Total good time = 10440 sec
Percentage of Quality (Q) = [(Total produced-Defected produced) ÷ Total produced] ×100 % = [(11765-311) ÷ 11765] ×100 % = 97.35%	Total produced= 11765 B Defected produced = 311 B
Performance rate (P) = [Net Down time - (Management Down time + Start up Down time)] ÷ Net Down time = [3921-(267+ 240)] ÷ 3921= 87.07 %	Net Down time = 3921 sec D/T for management= 267 sec Start up loss= 240 sec
Overall Equipment Effectiveness (OEE)	= Availability rate (A) × Percentage of Quality (Q) × Performance rate (P) = 0. 3755 × 0.9735 ×0.8707 % = 31.82 %

Note: B = Bottle

Table 6.7.6 : OEE of X Litchi flavored juice processing line

Availability rate (A) = (Net Down time ÷ Total good time) × 100 = (2379÷9720) × 100 = 24.47%	Net Down time = 2379 sec Total good time = 9720 sec
Percentage of Quality (Q) = [(Total produced-Defected produced) ÷ Total produced] ×100 % = [(11765-280) ÷ 11765] ×100 % = 97.62%	Total produced= 11765 B Defected produced = 280 B
Performance rate (P) = [Net Down time - (Management Down time + Start up Down time)] ÷ Net Down time =	Net Down time = 2379 sec D/T for management = 185 sec Start up loss= 240 sec

[2379-(185+240)] = 82.13 %	
Overall Equipment Effectiveness (OEE)	= Availability rate (A) × Percentage of Quality (Q) × Performance rate (P) = 0.2447× 0.9762× 0.8213 % = 19.62 %

Note: B = Bottle

Table 6.7.7: Overall Equipment Efficiency (OEE) of observing process lines

Process line	Present OEE	Comments
X mango juice process line-1	18.67 %	In order to attain the World class manufacturing performance the OEE should be at least 85% [83].
X mango juice process line-2	18.83 %	
X up (CSD) processing line	17.40%	
X energy drinks processing line	16.86%	
X Banana flavored juice processing line	31.82 %	
X Litchi flavored juice processing line	19.62 %	

It seems that the lowest OEE was 16.86% of X up processing line and the highest TPM was 31.82% of X Banana flavored juice processing line. But the existing OEE could be improved up to 85%. It was expected throughout the implementation of TPM, it could be obtained at least up to 90% OEE. The machine should be operated in a manner, so that there will be no customer complaints. By implementing TPM it could be possible to reduce the manufacturing cost by 30%, to achieve 100% success in delivering the goods as required by the customer, to maintain an accident free environment, to increase productivity and OPE (Overall Plant Efficiency) by 1.5 or 2 times [85].

Equipment maintenance represents a significant component of the operating cost in transportation, utilities, mining, and manufacturing industries. The potential impact of maintenance on the manufacturing performance is substantial. Maintenance is responsible for controlling the cost of manpower, material, tools, and overhead [86, 87].

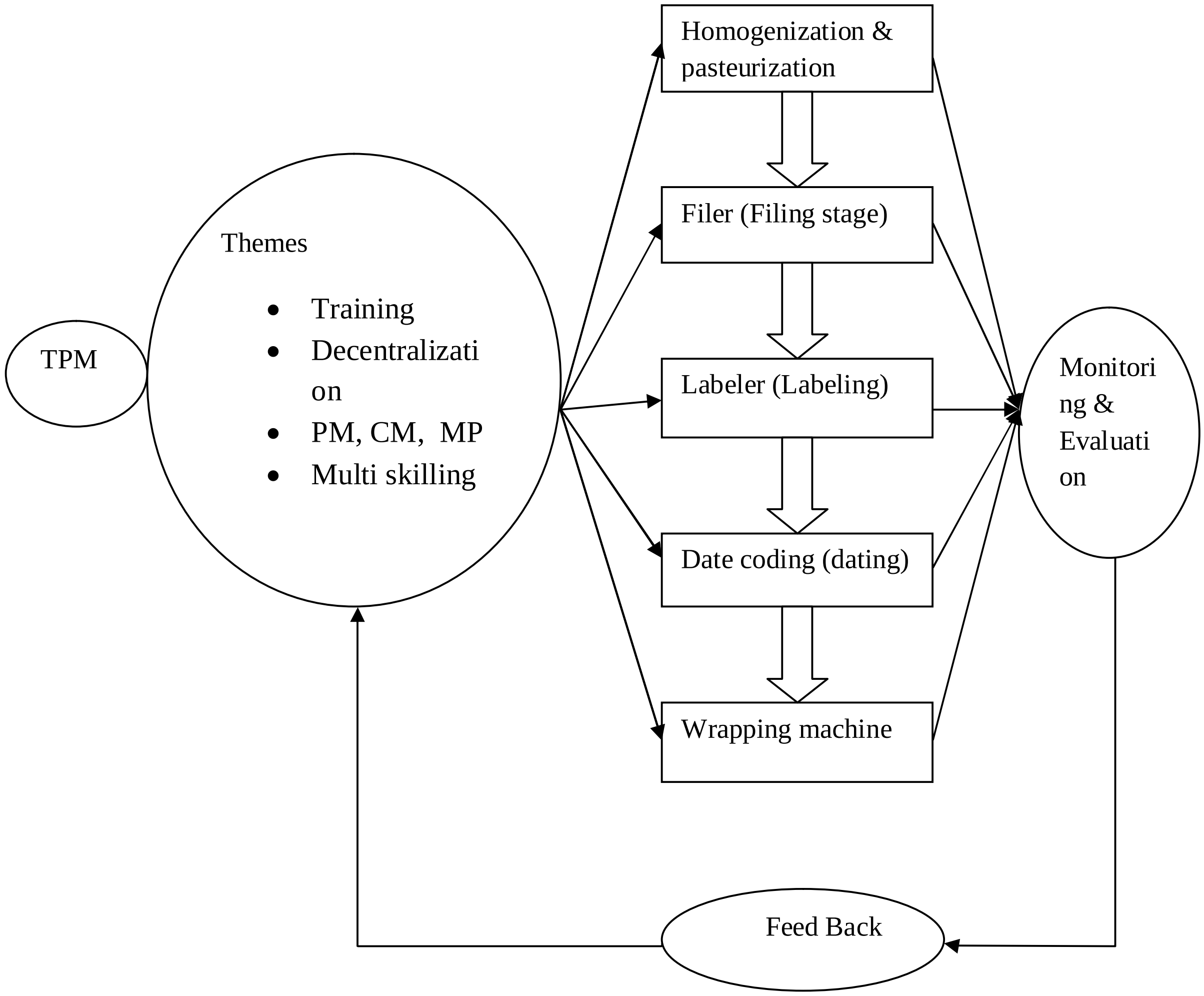
Manufacturers are beginning to realize that maintenance organization and management, and design for maintainability and reliability are strategic factors for success in 1990s [86]. Thus the effectiveness of maintenance function significantly contributes towards the performance of equipment, production and products [88, 89].

Some years ago 100-year-old steel foundry employed most of the principles, tools and techniques of TPM. The results were excellent the average downtime on overhead cranes went from about 17% to 2.5%. Other major equipment showed comparable results. Here are some other results reported by industry.

- MRC Bearings reduced unplanned downtime by 98% in one cell and 99% in another - all within one year.
- Monsanto runs their three-year old TPM start-up plant at 97% on-stream time while most other units run between 85% and 90%.
- 3M reduced their maintenance cost by 60% within three years.
- DuPont reduced off-quality by 69% and improved capacity by 29% in three years.
- Harley-Davidson estimates that the ROI from TPM has been ten-fold to the cost of implementation.
- Kodak reported a $5 million investment in TPM that resulted in a $16 million increase in profits [90].

For the reduction of machine failure it is suggested to implement TPM. It is recommended to follow the following some steps to the machine operator daily. These are:

- Checking the lubrication regularly if needed lubricant the machine
- Reporting oil leakages
- Being alert and recognize unusual noise, vibrations, and temperature which signify impending failure
- Checking bolts for tightness
- Reporting any deterioration in product quality before the issue goes out-of-control



A Strategic frame work for TPM implementation

A strategic frame work is formulated by author in order to implement the TPM in studied juice and beverage processing lines. The basic theme of TPM is formulated by the components of training of regarding operators and labors, decentralization of responsibility instead of central, different types of TPM measurement like as preventive maintenance (PM), corrective maintenance (CM), and maintenance prevention (MP). These components of TPM should be implemented into the basic stages where the machining problems are occurred most frequently like homogenization & pasteurization, filing, labeling, date coding and wrapping. A strong expert team should be established for proper monitoring and evaluation in order to generate a fruitful feedback. The whole system should be operated as a circular system.

So, it is suggested to involve TPM with production management system of juice and beverage sector of X food industry.

6.7.2 Increase Skill Manpower

In the studied processing floors it was observed that there was no skill helper for any operators. But for this reason the change over time and maintenance time was observed due to a limited number of skilled labors were engaged beyond the machine operation and maintenance. The transportation time was also high due to unskilled worker between two stages towards maintenance the products flow. So, it is suggested to hire some skill manpower as assistant operator or as operator especially for labeler, filer and wrapping machine.

6.7.3 Continuous Improvement

Kaizen, also known as continuous improvement, is a long-term approach to work that systematically seeks to achieve small, incremental changes in processes in order to improve efficiency and quality. Kaizen can be applied to any kind of work, but it is perhaps best known for being used in lean manufacturing. Kaizen can be roughly translated from Japanese to mean "good change." The philosophy behind kaizen is often credited to Dr. W. Edwards Deming. Dr. Deming was invited by Japanese industrial leaders and engineers to help rebuild Japan after World War II. He was honored for his contributions by Emperor Hirohito and the Japanese Union of Scientists and Engineers. Continuous improvement is one of the most basic tools of lean production. Kaizen is a Japanese word which indicates the continuous endeavor for bringing the perfection in the production with considering the quality and quantity. Kaizen is a systematic approach to gradual, orderly, continuous improvement. In a production processing line the improvement can be achieved by many ways such as reduction of inventory, reduction of production time, reduction of defective parts.

From a number of continuous improvement tools, 5S is one of the most popular tools for effective continuous improvement tools. Towards the serious waste reduction 5S is the first, modular step. 5S consists of Japanese words Seiri (Sort), Seiton (Straighten), Seiso (Sweep and Clean), Seiketsu (Systemize), and Shitsuke (Standardize). The basic and underlying concept of 5S is look for waste and then tries to eliminate it.

The first S, Seiri (Sort), deals with moving those items that are not currently being used on a continuous basis (e.g., that will not be used for next month or so) away from those that are. If every area has people assigned to it then every people has responsibility to maintain a high standard of housekeeping and cleaning [84].

The second S, Seiton (Straighten), has to do with having the right items in the right area. Items that do not belong to a given area must not be that area. For a given work place area tools must be marked and arranged as belonging in that area. This will make it easier to move those items that are not labeled from that area. Arranging items in the right place will make tools, jigs, fixtures and resource noticeable, detectable and easy to use [84].

The third S, Seiso (Sweep and Clean), deals with cleaning and sweeping the work place methodologically. The work place should look neat and clean and ready to use for the next shift. The work place should be maintained on a regular basis. All tools and items should be in the right place and nothing should be missing. A well maintained work place creates a healthy environment to work with.

The fourth S, Seiketsu (Systemize), deals with maintaining a high standard of housekeeping and work place arrangement. A regular audit should be run and scores should be assigned for areas of responsibilities. If every area has people assigned to it then everyone has responsibility to maintain a high standard of housekeeping and cleaning [81].

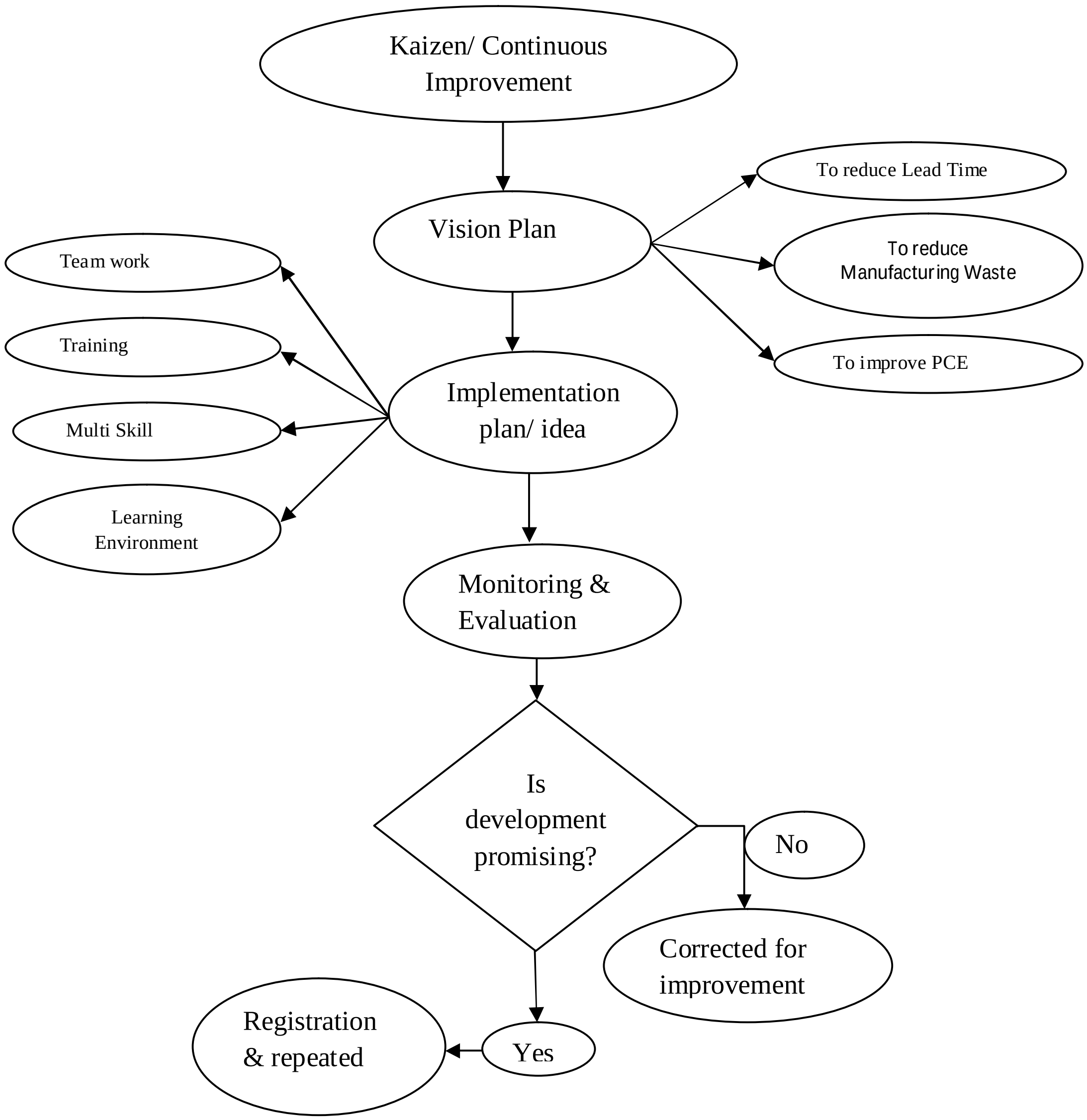
The fifth S, Shitsuke (Standardize), deals with the management accountability to train people to follow housekeeping rules. Management should implement the housekeeping rules in a practiced fashion so that their shop floor, explain what they want from people, reward those who follow and instruct those who do not [81].

Taken together, 5S means good housekeeping and better workplace organization. Kaizen tools such as 5S are not only a means to increase profitability of a firm but also allow companies to reveal potential strengths and capabilities [91, 92].

Key Performance Indicators (KPI) showed that the Scunthorpe mill is achieving its targets for rolling steel in planned weeks and is delivering almost 100% of customers' orders complete on time. Scunthorpe Plate Mill aims to have all orders complete and on time by March 2009, while at the same time reducing lead time [93].

By implementing the 5S taking the delivery of product has increased from 70% of plates on time to 92% on time [94].

So, with the proper implementation of 5S it is expected that the recognized manufacturing waste of studied floors could be reduced as to the desired level.



Strategic plan for kaizen Implementation

A strategic plan for kaizen implementation is developed by author in order to implement the Kaizen in the studied juice and beverage processing lines. 5S was considered as the basic concept of kaizen improvement for this study. In order to implement the 5S it could be needed a proper plan or vision which could be formulated by the management of X juice and beverage sector. The vision plan could be incorporated with the theme of reducing lead time, reducing manufacturing waste and improving PCE. The plan could be implemented by consisting of team work, training, multi skill and learning environment. To implement a new idea a team work will be effective wheel to bring the idea into practical. In order to adopt with new idea training is very important since, in order to kaizen implementation training is very emergence and thus way regarding managerial personnel as well as operator and labor could be belonged of multi skill. It is rational that only multi skilled manpower could be able to monitoring and evaluating whether adopted plans could be promising or not, if it could be promising it should be legislated and if not, the draw backs should be find out in order to promising implementation towards the improved PCE, reduced Tact time, NVD time and lead time.

6.7.4 Standardization of Work

The standardization of worker’s action is the prim principle of waste elimination. Basically the standardized work ensures that each job is organized and is carried out in the most effective manner. In this case it is not the matter that who is doing the job rather than achieving the same level of quality. At Toyota every worker follows the same processing steps all the time. This includes the time needed to finish a job, the order of steps to follow for each job and the parts on hand. By doing this one ensures that line balancing is achieved, unwarranted work in process inventory is minimized and non value added activities are reduced. A tool that is used to standardize work is called ‘Tact’ time. Tact (German for rhythm or beat) refers to how often a part should be reduced in a product family based on the actual customer demand. The target is to produce at a pace not higher than the Tact time [95]. By this study it was suggested to the managerial personnel of the studied processing line to standardize the responsibility of each and every employed worker on the process line towards achieving the same level of quality at the highest level.

6.7.5 Just in Time (JIT)

JIT is a Japanese management philosophy which has been applied in practice since the early 1970s in many Japanese manufacturing organizations. It was first developed and perfected within the Toyota manufacturing plants by Taiichi Ohno as a means of meeting consumer demands with the minimum delays [96]. For this reason, Taiichi Ohno is frequently referred to as the father of JIT. At present, the nature of production technologies has changed tremendously because of the implementation of lean tools and advanced manufacturing technologies. The first element of lean production is the focus on what is most commonly thought of as ‘just in time’ management. Just in Time Manufacturing (JIT) is one of the main principles of lean manufacturing, it is the idea of producing exactly what the customer wants, in the quantities they want, where they want it, when the customer wants it without it being delayed or held up in inventory [97].

Some general guidelines for JIT implementation have been suggested and these form a basis for finding the appropriate way for implementing JIT. Key obstacles such as long change over time; unleveled production schedules; highly variable production processes; large container sizes; severe bottlenecks, and long lead times should be removed before implementing the JIT [97]. That means to implement the JIT the regarding organization has to remove these mentioning obstacles.

Broadly speaking, one can think about JIT implementation from different angles, the most common being people and the engineering angles. However, JIT experts mentioned that it is essential to begin JIT implementation with a good deal of attention first being paid to the people aspects [98, 99]. There are two stages of JIT implementation [95]:

One, prepare the plant and its people for flexibility, low costs, short lead-times and high quality by concentrating on design; maintenance; quality; layout; set-up time; and people. Two, strive to produce zero lead-time with no waste by focusing on: total people involvement; visibility; process data collection; enforced improvement; flow scheduling; inventory control; buffer and lot size reduction, and supplier and customer relationship.

These two stages, however, don't specify a general sequence of steps for the implementation of JIT. Moreover, the ability of the different techniques in both stages depends highly on a specific manufacturing environment. The JIT techniques are grouped into two stages [100]. The first stage of JIT implementation is composed of areas that are necessary for full JIT to work. They focus on four main elements of JIT that can be achieved in the short term. These are simplicity, flow, quality, and fast set-up and lay the foundation for moving on to the more difficult techniques like kanban and JIT purchasing, which are a part of stage two. However, benefits from these programs have often been limited because of unreliable or inflexible equipment [101].

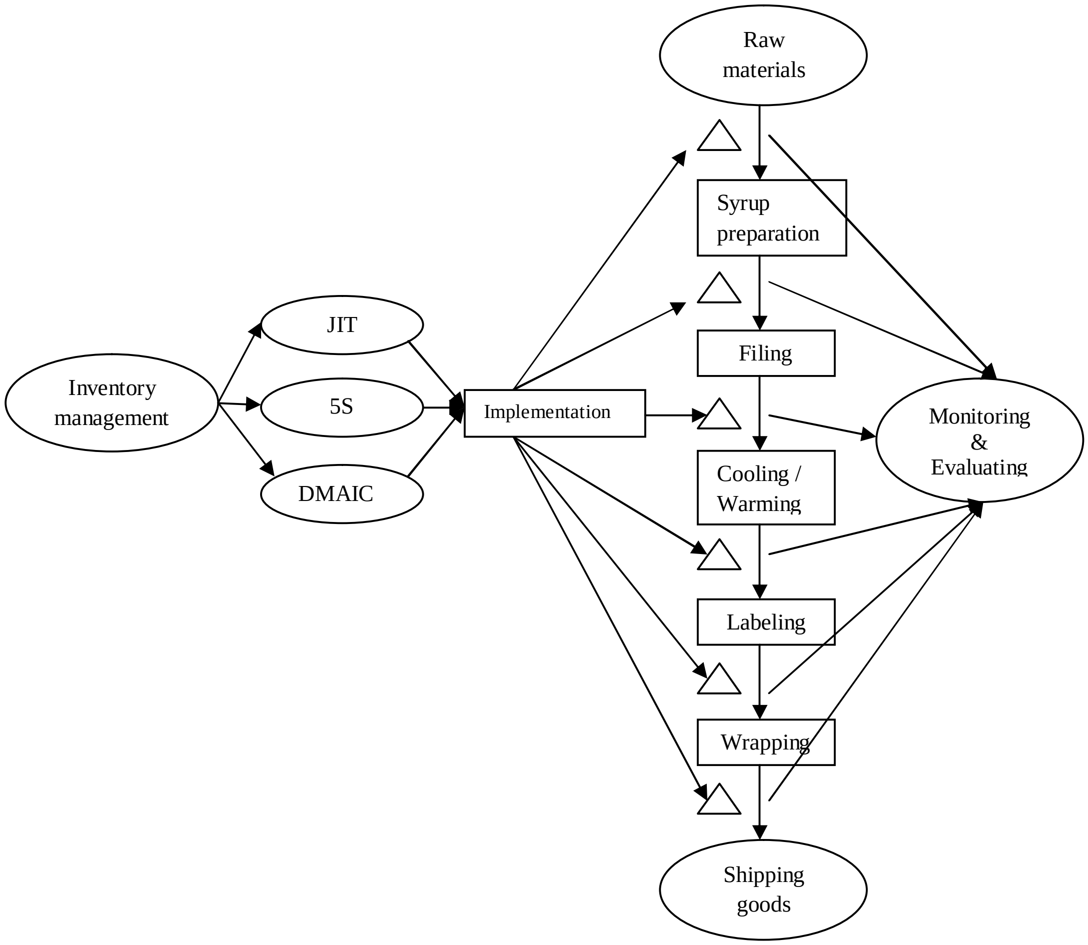
The production process of all the studied processing lines start from raw material inventory and draw the completion of production by the finished goods inventory, although throughout the entire processing system internal inventory were also present at different stages of processing floor that was created by overproduction. Inventory is probably the biggest waste of lean Manufacturing. By implementing the philosophy of JIT this kind of waste of overproduction could be eliminated. It was reported that after the implementation of JIT the efficiency could be gained 30–60%, lead time could be reduced 50-90%, capital expenditures could be reduced 25–30%; and a significant inventory costs could also be reduced [102].

6.7.6 Lead time reduction

The reduction of lead time of production of any product is a continuous improvement process. The lead time of studied different processing lines were first calculated. The various elements that are associated with the lead time were first identified separately and different practical strategies are adopted for lead time reduction or improvement. In general the various components associated with the lead time of any process are waiting time before process, set up time, process time, waiting time after process and transfer time [103]. In this study it was found that queue time, insufficient bottle supply at different stages of production, label splitting, machine sensor inactivity and unsmooth conveyor belt were the basic hindrance beyond the long lead time. After a intense observation of studied processing floors with a sharp brain storming it is proposed that with the proper implementation of continuous improvement, 5S and JIT philosophies the lead time could be reduced by 60-80%.

6.7.7 Inventory management

Inventory management has often meant too much inventory and too little management or too little inventory too much management. By all sectors of economy it is experience that inventory management is a vital problem. Inventories are stockpiles of raw materials suppliers, components, work in process and finished goods that appear at numerous points, throughout a firm's production and logistics channel. Inventory is the stock of any item or resource used in an organization. Inventory management is a set of policies and controls that monitor levels of inventory and determine what levels should be maintained, when stock should be replenished and how large order should be received [104].



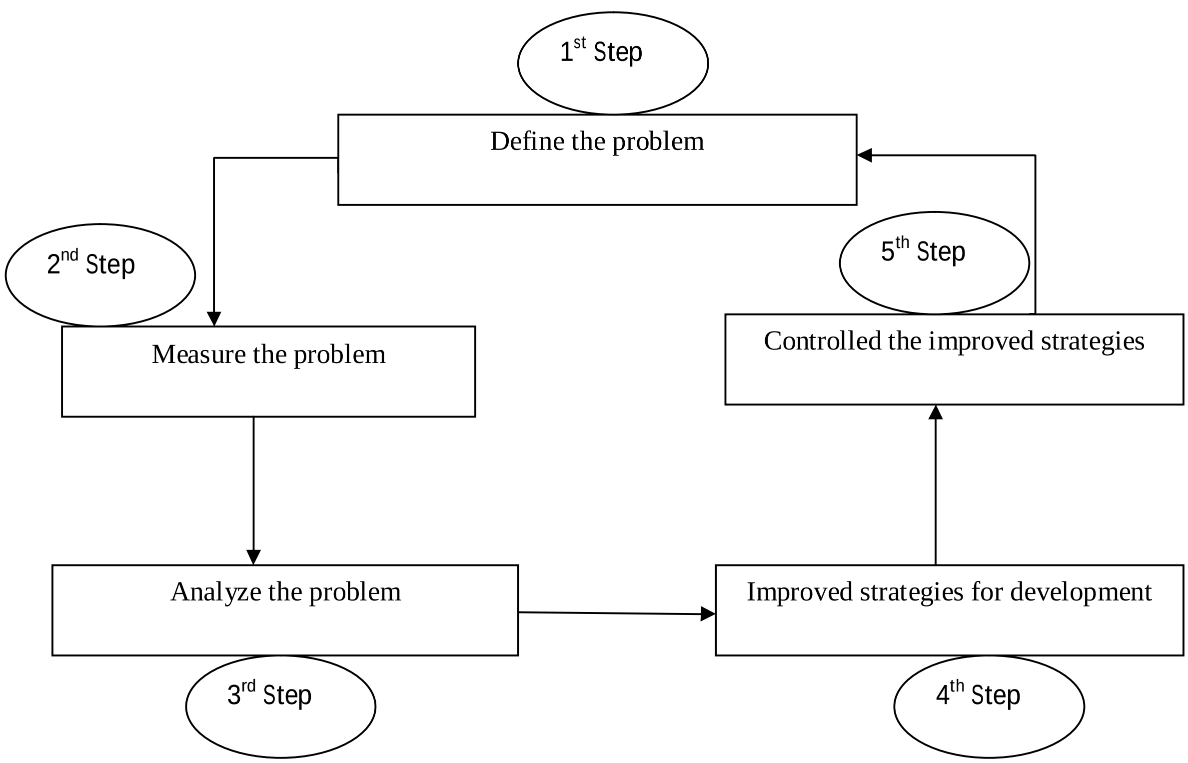
Strategic plan for Inventory Management

From the strategic plan it seems that inventory of each stage should be managed with the proper implementation of JIT, 5S and DMAIC methodologies. Throughout this study it was expected that proper inventory management could be the consequence of successful implementation of JIT, 5S and DMAIC methodologies. From the strategic plan it also seems that between every two stages there is an inventory, so it is emergence to ensure the proper adoption of JIT, 5S and DMAIC methodologies at every processing stage of studied juice and beverage processing lines. After the proper implementation JIT, 5S and DMAIC methodologies 80/20 Pareto principle could be easily achieved and thus 80% existing manufacturing waste could be reduce as well as lead time could be reduced with the improved PCE.

6.7.8 DMAIC methodology

The DMAIC project methodology has five phases [105]:

- **Define** the problem, specifically identify the voice of the customer, and the project goals;
- **Measure** key aspects of the current process and collect relevant data;
- **Analyze** the data to investigate and verify cause-and-effect relationships. Determine what the relationships are responsible for the problem, and attempt to ensure that all factors have been considered. Seek out root cause of the defect under investigation;
- **Improve** or optimize the current process based upon data analysis using techniques such as design of experiments, poka yoke or mistake proofing, and standard work to create a new, future state process. Set up pilot runs to establish process capability;
- **Control** the future state process to ensure that any deviations from target are corrected before they result in defects. Implement control systems such as statistical process control, production boards, visual workplaces, and continuously monitoring of the process.



A strategic plan for DMAIC implementation

A strategic plan was formulated in order to implement the DMAIC methodology for the sake of manufacturing waste reduction. For the first time the problem beyond the manufacturing wastes should be defined. During the study at different processing lines machines problems, unnecessary motions of labor, unwanted downtimes and others most frequently occurred problems were defined. Secondly, the defined problems should be measured in terms of quantitative manner for example the downtimes were calculated in seconds, unnecessary motion of labor were measured in number. Thirdly, these measure problems were analyzed in terms of frequency for example there were different causes for down times where these causes were indentified in terms of frequency of occurrence. Fourthly, an improved strategy were developed to remove these causes beyond the defined problems for example JIT, 5S, Kaizen and DMAIC strategies were formulated and suggested to adopt within the managerial system of studied processing lines in order to removes theses indentified causes at different stages of processing lines. Finally, monitoring and controlling of these strategies should be done properly in order to attain the ultimate goal of this study.

6.8 Discussion

Since, 1990s lean tools are implementing at different automobiles and manufacturing industries over the World, but implementation of lean in food industry is very new and this study was for the first time in a food industry of Bangladesh. Throughout this study it was endeavored to implement lean and SS in the juice and beverage sector of X food industry. To conduct this study, author was inspired by the previous outcomes with the implementation of lean and SS at different manufacturing and service industry that were illustrated by reducing the lead time, improving PCE and eliminating the NVD activities from the processing floor.

This study was conducted in two mango juice, two flavoring juice and two CSD processing lines. These processing floors were evaluated in three steps; firstly, the processing lines were assessed at the present state in order to find out the present lead time, PCE, Tact time by using VSM. An attempt was conducted to find out the different kinds of manufacturing wastes at different processing stages of processing floor. It was also tried to quantify these manufacturing wastes. Secondly, an improvement strategy was developed by involving lean tools and SS methodologies to improve the PCE, to reduce the lead time, Tact time and NVD activities. Thirdly, after the implementation of lean tools and SS methodology an improved PCE, reduced lead time and Tact time were expected.

6.8.1 Project Cycle Efficiency (PCE)

The present PCE of X mango juice processing line-1, X mango juice processing line-2, “X up” processing line, X energy drinks processing line, X Banana flavored juice processing line and X Litchi flavored juice processing line were found consequently as 15.28% , 12.20%, 8.32%, 8.01%, 11.32% and 10.68% that could be 34.05%, 26.91%, 19.46%, 18.84%, 25.60% and 24.45% (Table 6.8.1) after the implementation of lean tools and SS methodologies within present production system. To be an internationally competitive company it’s PCE could be at least 25% [74] but in this study it was seen that all observing processing floor’s PCE was far away than 25% PCE. By this study it was a hopeful finding that after the implementation of lean tools in the X food industry could be an internationally competitive. It seems that (Table 6.8.1) with the proper involvement of lean, the PCE of X mango juice processing line-1, X mango juice processing line-2, X up processing line, X energy drinks processing line, X Banana flavored juice processing line and X Litchi flavored juice processing line could be improved consequently by 123%, 121%, 134%, 135%, 126%, and 129%.

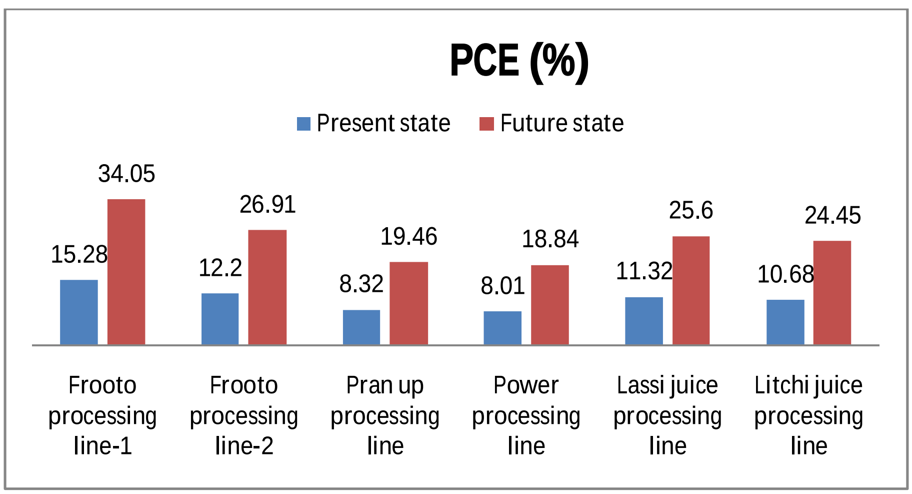


Fig 6.8.1 Comparison of PCE between present state and future state

6.8.2 Lead time improvement

The existing lead of X mango juice processing line-1, X mango juice processing line-2, X up processing line, X energy drinks processing line, X Banana flavored juice processing line and X Litchi flavored juice processing line were found consequently as 99870 sec, 95040 sec, 83867 sec, 83700 sec, 86760 sec and 86728 sec, but it was expected that after the implementation of lean tools and Six Sigma methodologies within present production system the lead time of these observing process lines could be consequently, 44850 sec, 43109 sec, 35866 sec, 35622 sec, 38363 sec and 37912 sec with the promising improvement or reduction of lead time consequently by 55.09%, 54.64%, 57.23%, 57.44%, 55.78%, and 56.28% (Table 6.8.1).

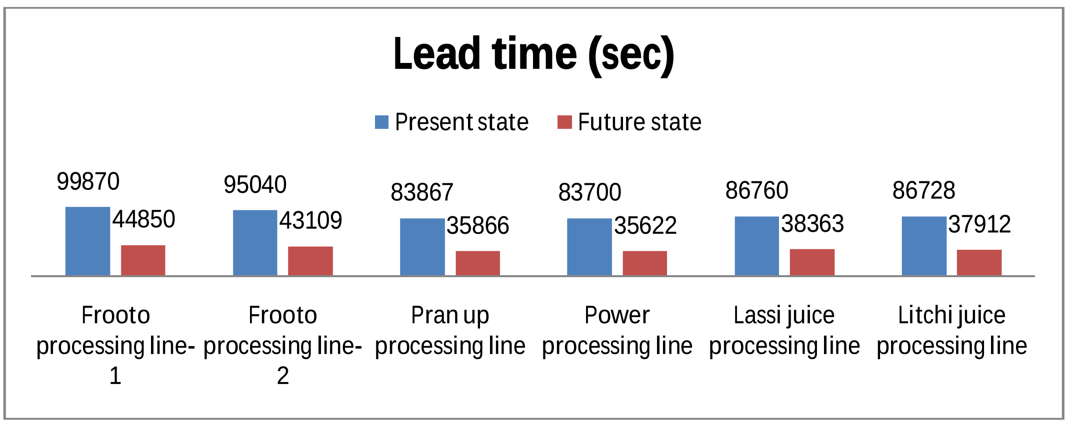


Fig 6.8.2 Comparison of lead time between present state and future state

Table 6.8.1 Comparison study on improvement of PCE, Takt time, Lead time and NVD activities with Lean implementation

Processing line	Present state				Future state						
	PCE (%)	Lead time (Sec)	Takt time (sec / case)	NVD (Sec)	PCE (%)	Lead time(Sec)	Takt time(sec / case)	NVD (Sec)	Improvement of PCE (%)	Reduction of Lead time (%)	Reduction of NVD (%)
Frooto processing line-1	15.28	99870	13.19	84600	34.05	44850	12.89	29580	123	55.09	65.03
Frooto processing line-2	12.20	95040	8.22	83437	26.91	43109	8.03	31506	121	54.64	62.23
Pran up processing line	8.32	83867	7.20	76889	19.46	35866	7.002	28888	134	57.23	62.42
Power processing line	8.01	83700	7.03	76988	18.84	35622	6.84	28910	135	57.44	62.45
Lassi juice processing line	11.32	86760	2.51	76936	25.60	38363	2.45	28539	126	55.78	62.91
Litchi juice processing line	10.68	86728	2.44	77458	24.45	37912	2.39	28642	129	56.28	63.02

6.8.3 Tact time improvement

Tact time is considered as the heart beat of any productive industry. As lowest the Tact time of a production floor, it is considered as the highest rate of productivity. By this study, the present Tact time of X mango juice processing line-1, X mango juice processing line-2, X up processing line, X energy drinks processing line, X Banana flavored juice processing line and X Litchi flavored juice processing line were found consequently as 13.19 sec, 8.22sec, 7.20 sec, 7.03sec, 2.51 sec and 2.44 sec where it was expected that after the proper implementation of lean and smooth adoption of SS methodologies the improved or reduced Tact time of these processing floor would be consequently as 12.89 sec, 8.03 sec, 7.002 sec, 6.84 sec, 2.45 sec and 2.39sec (Table 6.8.1).

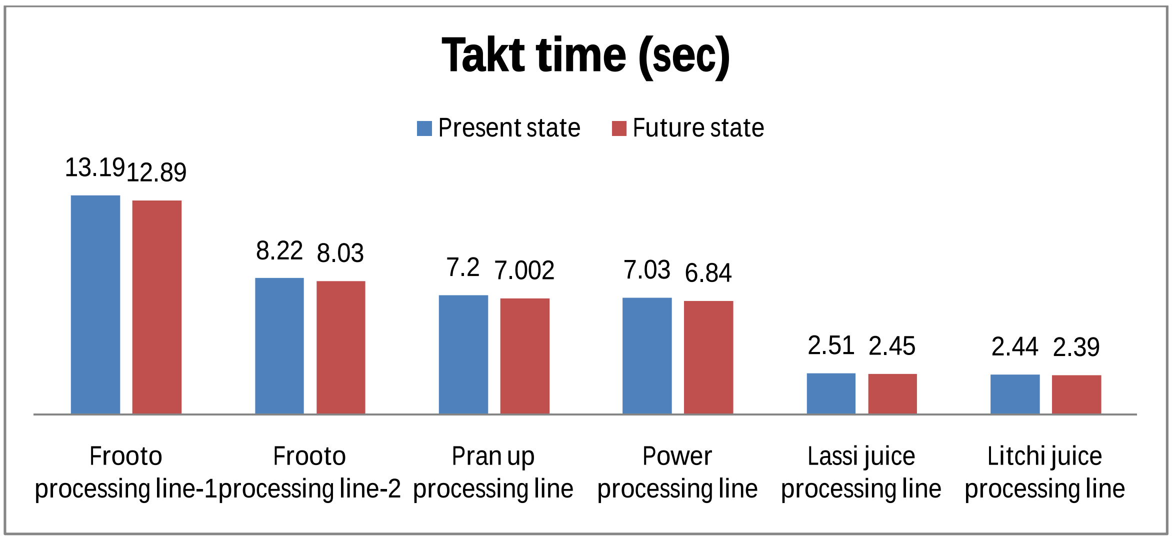


Fig 6.8.3 Comparison of Tact time between present state and future state

6.8.4 Reduction of Non Value Added (NVD) activities

In this study the NVD activities were quantified in terms of time. At present the NVD time of X mango juice processing line-1, X mango juice processing line-2, X up processing line, X energy drinks processing line, X Banana flavored juice processing line and X Litchi flavored juice processing line were found consequently as 84600 sec, 83437 sec, 76889 sec, 76988 sec, 76936 sec and 77458 sec while it was hoped that after the intense involvement of lean the NVD activities and time of these observed processing lines could be reduced consequently by 65.03%, 62.23%, 62.42%, 62.45%, 62.91% and 63.02%.

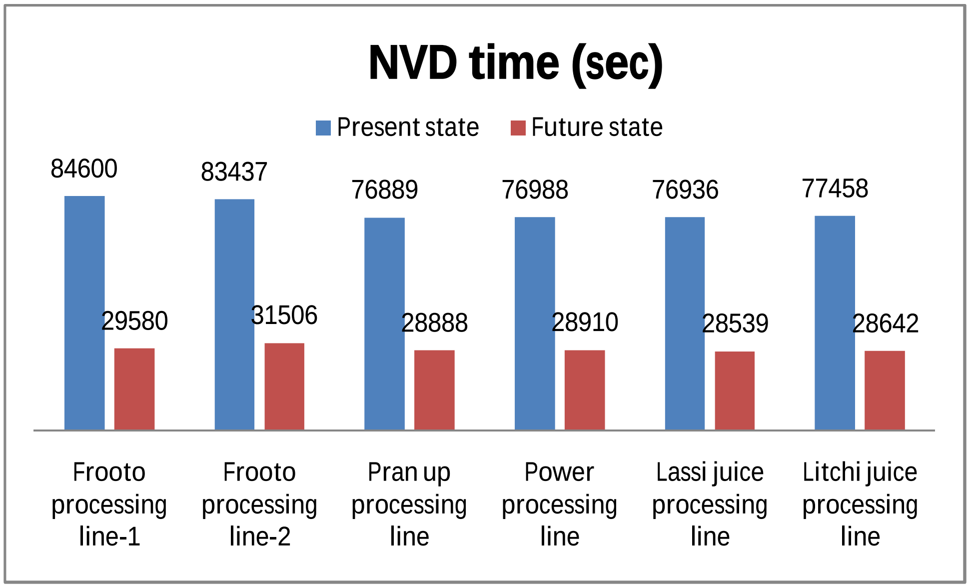


Fig 6.8.4 Comparison of NVD time between present state and future state

6.8.5 Economic benefit with the lean implementation

An economic benefit was calculated by this study which was showed in Table 6.8.2. It was expected that after the proper implementation of lean tools and SS methodology an economic benefit would be 155,098,944 TK. or 2,009,053 USD (exchange rate 77.2 Tk./1 USD) per year by removing the wasted bottles from the observed juice and beverage processing lines.

Table 6.8.2: Economic benefit from reduction of waste bottle loss

X Mango juice process line-1	Wasted bottle per Batch	Wasted bottle per day	Wasted bottle per week	Marketable value of wasted bottle per year
X Mango juice process line-2	468	468×6=2808	(2808×6)=16848	(16848×52×22)= 19,274,112 TK.
X Up (CSD) processing line	534	534×9=4806	(4806×6)=28836	(28836×52×22)= 32,988,384 TK.
X energy drinks processing line	527	527 ×12= 6324	(6324×6)=37944	(37944×52×16)= 31,569,408 TK.
X Banana flavored	525	525×12=	(6300×6)=37800	(37800×52×25)=

juice Processing Line		6300		49,140,000 TK.
X Litchi flavored juice Processing Line	311	311×12=3732	(3732×6)=22392	(22392×52×10)= 11,643,840 TK.
Total				155,098,944 TK.

By reducing the wasted bottle it could be a milestone to achieve the SS production, thus it would also be effective to reduce the NVD time and activities as well as lead time. But alas! at present the production floors remain at a gulf gap towards the SS rating production which was evinced from the Fig 6.8.5.

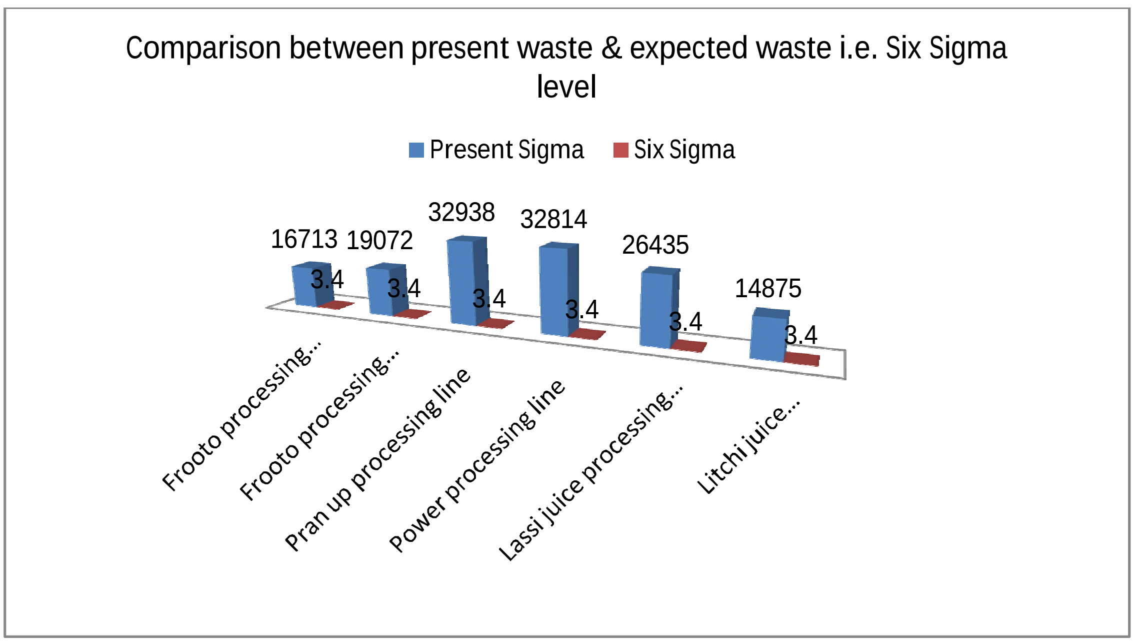


Fig 6.8.5 Comparison of SS rating production between present state and future state

Table 6.8.3: Labor improvement from present state to future state

Present State (per shift)					Future State (per shift)				
Process line	O	AO	W	Total	Process line	O	AO	W	Total
Pran frooto process line-1	6	4	15	**25**	X Mango juice process line-1	5	2	10	**17**

Pran frooto process line-2	5	3	16	**24**	X Mango juice process line-2	5	2	6	**13**
Pran up processing line	5	4	27	**36**	X up (CSD) processing line	5	2	13	**20**
Power processing line	5	5	23	**33**	X energy drinks processing line	5	2	12	**19**
Lassi juice processing line	6	6	18	**30**	X Banana flavored juice processing line	6	5	9	**20**
Litchi juice processing line	5	6	25	**36**	X Litchi flavored juice processing line	5	5	12	**22**
Total	**32**	**28**	**124**	**184**		**31**	**18**	**62**	**111**

The graphical presentation of labor benefit after the implementation of Lean tools and SS can be seen from the Fig 6.8.6.

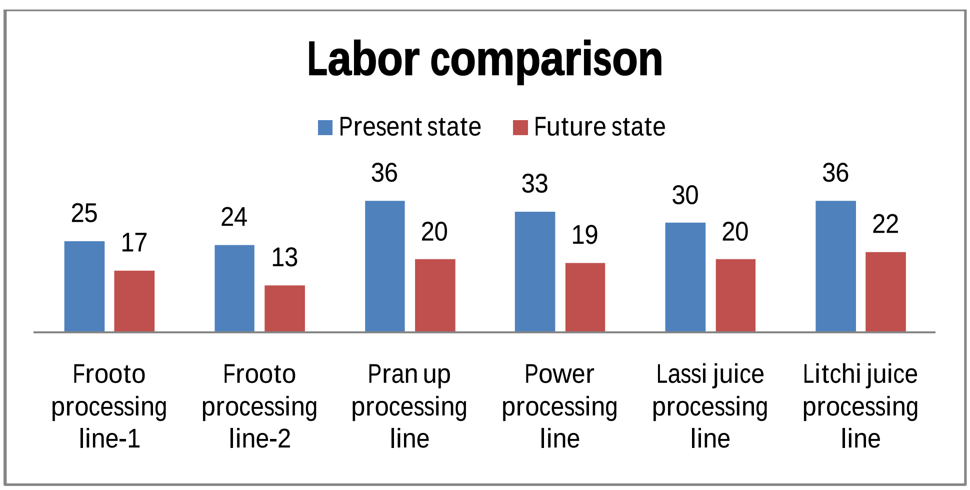


Fig 6.8.6 Comparison of labor benefit between present state and future state

Table 6.8.4: Economic benefit at future state by labor reduced

Labor (per shift)	Present state (per shift)	Future State (per shift)	Improved or reduced labor at future state (per shift)	Improved or reduced labor at future state (per day)	Economic benefit at future state (per month)	Economic benefit at future state (per year)
Operator	32	31	1	**2**	2@12000Tk = 24000	288,000 Tk
Assistant operator	28	18	10	**20**	20@8000Tk .=160000	1,920,000 Tk
Worker	124	62	62	**124**	124@5000Tk = 620000	7,440,000 Tk
Total	184	111	73	**146**	804,000 Tk	9,648,000 Tk

After the reduction of unwanted motion of labor from the observed juice and beverage processing lines it was expected an economic benefit of 9,648,000 Tk. or 124,974 USD (exchange rate 77.2 Tk. /1 USD) could be attained per year (Table 6.8.4).

It was reported that lean production management is the most frequently associated with elimination of seven wastes [105]. It was stated that the purpose of implementation was to increase productivity, reduce lead time and cost, and improve quality [106]. Quality of production management is a major focus in lean manufacturing, because poor quality management should result in huge waste and scraps. The right quality management at right time will help to control the manufacturing process [107]. It is mentioned that companies such as Toyota, Pratt and Whitney, Sikorsky, Delphi, Ford and many other companies have achieved large savings by implementation of lean principles in their manufacturing activities [108]. It was reported that the companies that adopt lean manufacturing as a working philosophy within their organizations can make significant improvement in terms of their operational performance even if it is in a modified format that best suits their particular business culture [109]. The organizations intending to implement the lean tools should first understand the need to use that tools and its application, prepare for its adaption and then identify the ways and measures required for its successful implementation [110]. It was stated that to implement lean thinking in any organization the first step is to identify the VSM. The VSM has been applied in variety of manufacturing industries. It was also described an application of VSM in order to identify the various forms of waste in beverage processing floor [111, 112]. The work in process lines across the value stream should be performed with the minimum NVA activities in order to reduce waiting time, queue time, moving time, setup time and other delays [113]. In this research, the author has successfully applied VSM. So, it could be expected as with other researchers lean tools and SS methodologies implementation will bring the promising outcomes with improved PCE, NVD time reduction, reduced lead time and after all desired economic benefit.

7. SUGGESTION, LIMITATION & CONCLUSION

7.1 Expected Benefit of Study

Throughout this study it is expected that after the proper implementation of Lean tools and SS strategies-

- The PCE of the studied six juice and beverage processing lines would be improved from 121% to 145%
- The Lead time would be reduced by 54.04-57.44%
- NVD time would be reduced by 62.42-65.03%
- Total labor of studied six juice and beverage processing lines would be reduced from 184 to 111
- An economic benefit of 164 million USD could be gained per year

7.2 Suggestions

- The proposed tools and strategies should be introduced within the studied processing lines.
- The tools of VSM, Tact time, PCE should be immediately considered for implementation in the regarding processing lines.
- Lean philosophies and SS strategies should be adopted within the company's management system and a try should be made to create a Lean environment on production floor as well as in the management organization.
- Managerial body should be flexible to innovative thinking.
- Beneficial team work should be practiced prior to proper implementation of Lean tools and SS strategies within the regarding juice and beverage processing lines.
- Multi skill efficiency should be improved by performing of and participating in training program on Lean philosophies and SS strategies.

- The required machines and equipments should be arranged so that the speed of that machines like filer, labeler, wrapper, etc could be controlled in balance way.
- The origin of company of machines and equipments should be same prior to balance reliability because if one machine breaks down the entire production line could go down. In this case I suggest implementing the TPM because it focuses on the equipment and machine used.
- Awareness about the economic and productive benefits of Lean tools & SS methodologies should be created to the production management personnel's as well as regarding workers.
- Training programs on Lean tools and SS methodologies implementation should be arranged frequently for the management personnel & workers.
- Finally I'd like to suggest following my submitted report or thesis book for the knowledge of Lean tools & SS methodologies and trying to implement this.

7.3 Limitations

Each and every task or success has to face some obstacles. Throughout this study it had to face a number of obstacles to draw the completion of this study which could also be considered as the limitation.

- Expected improved PCE or expansion of production is evaluated without changing the present layout of processing lines. Because of the company's personnel were not flexible to permit in taking different required scale of measurement to draw an improved design in order to improved PCE due to their unexpected disruption or hamper in production.
- The required most of data were collected for three times and some of data were collected for five times, if these data were collected for further more times it would be more accurate.
- It was not possible to take data for the continuous time or entire shifting time of production rather than periodic data collection.

- Sometimes the frequent breakdown of machine has brought few difficulties to take data within the data collecting period of time.
- The reluctance of regarding personnel of the observing process lines, in taking data by stopping or disrupting the production.
- As a single person data collector it was a boredom as well as failure in layout measurement.
- It was limited opportunity to collect the enough data of inventory management.
- Regarding books and journals were not more available beyond this study.

7.4 Learner achievement

- The author of this thesis manuscript empirically introduced with some Lean tools and SS methodologies by applying these tools & methods in juice & beverage sectors of X food industry in Bangladesh.
- This work has brought pleasure to author & make him potential in implementing Lean tools & SS methodologies in different manufacturing industries.

7.5 Learner future plan

- To conduct project in different food industries as well as other manufacturing industries in order to reduce the Lean time, NVD activities, Manufacturing wastes and to improve the PCE by using Lean Tools & SS methodologies.
- To provide the consultancy services in food industry and other manufacturing sectors.

7.6 Conclusion

This study was incarnated as a case analysis of six juice and beverage processing lines of X food industry of Bangladesh in order to improve the PCE by reducing NVD activities with the involvement of lean tools and SS methodologies in their managerial strategies. By this study the observed juice and beverage processing lines were analyzed by the VSM, Pareto Analysis, PCE and Tact time. Finally an improvement strategy was formulated with the incorporation of lean tools and SS methodology. Throughout this study it is expected that after the proper implementation of lean tools and SS strategies the PCE of the studied six juice and beverage processing lines would be improved from 121% to 145%, the lead time would be reduced by 54.04-57.44%, NVD time would be reduced by 62.42-65.03%, total labor would be reduced from 184 to 111 and finally an economic benefit of 164.75 tk. or 2.13 million USD (exchange rate 77.2 Tk. /1 USD) could be gained per year.

Lean Six Sigma (LSS) could never help a company to achieve the goals without the support of management. For long term success, a company needs to establish a detailed LSS plan and incorporate this plan into the company's strategies. Building LSS and safety culture in a company and enhancing the awareness and participation of each individual in the company will expedite the efficiency of the improvements and maintain the achieved benefit.

As it was the first experience of author to work with lean tools, each and every task beyond this study could not claim as flawless. After all, it was endeavored up to the best to draw the successful implementation strategy of lean tools and SS Methodology within the studied juice and beverage processing floors of X food industry.

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