Implementation of Lean Manufacturing System (Toyota Way) to a Pineapple Processing Cell

By

Jayawardena R.A.P.C

02/As/A/035

A Research Report Submitted In Partial Fulfillment of the Requirement for the Special Degree of Bachelor of Science In Food Science and Technology

Department of Food Science and Technology

Faculty of Applied Sciences

Sabaragamuwa University of Sri Lanka

Buttala.

August 2007

DECLERATION

The research work described in this thesis was carried out at HJS Condiments Limited under the supervision of Mr. A.C.Pathirage and Dr.K.B.Palipane.

A report on this has not been submitted to another university for another degree.

R.A.P.C.Jayawardena
Department of Food Science and Technology,
Faculty of Applied Sciences,
Sabaragamuwa University of Sri Lanka,
Buttala.

....
Signature

30.10.2007
....
Date

Certified by

Internal Supervisor

Dr.K.B.Palipane,
Head,
Department of Food Science and Technology,
Faculty of Applied sciences,
Sabaragamuwa University of Sri Lanka,
Buttala.

....
Signature

12-11-2007
....
Date

External Supervisor

Mr A.C.Pathirage,
Director,
HJS Condiments Limited,
Block 61,62 & 63,
B.E.P.Z,
Biyagama,

....
Signature

30.10.2007
....
Date

Head/Dept. of Food Sciences & Technology
Faculty of Applied Sciences
Sabaragamuwa University of Sri Lanka
BUTTALA

AFFECTIONATELY
DEDICATED TO MY PARENTS
&
TO ALL MY TEACHERS

ACKNOWLEDGEMENT

First and foremost I wish to express my genuine gratitude to my external supervisor, Mr.A.C. Pathirage, Director, HJS Condiments Limited, for his assistance, tremendous encouragement, highly inspiring guidance and unlimited support extended to me at all times during my work at HJS Condiments Limited.

I would like to convey my sincere thanks to my internal supervisor, Dr.K.B.Palipane, Head, Department of Food Science and Technology, Faculty of Applied sciences, Sabaragamuwa university of Sri Lanka, Buttala for his assistance, encouragement, guidance and his valuable time to make this study a success.

My grateful acknowledgement with special thanks is made to Mrs .D.M Priyadarshine, Lecturer, Department of Food Science and Technology, Faculty of Applied sciences, Sabaragamuwa university of Sri Lanka, Buttala for the personal interest shown and for guidance, encouragement and advice throughout this study.

I would like to thank the staff members of the HJS Condiments Limited and Faculty of Applied Sciences for their kind cooperation extended to me at all times.

ABSTRACT

"Lean manufacturing" is a leading manufacturing paradigm being applied in many sectors of the world economy, where improving product quality, reducing production costs, and being "first to market" and quick to respond to customer needs are critical to competitiveness and success. Lean principles and methods focus on creating a continual improvement culture that engages employees in reducing the intensity of time, materials, and capital necessary for meeting a customer's needs.

The current pineapple chunk processing involves a series of manual processing activities with several non-value added steps. The capacity of the cell is around 4000 jars per day, although the demand is around 6000 jars per day. This study is focused to investigate the current state of the manufacturing process and to develop the future state map by reducing the cycle times with the application of the core principles of lean manufacturing system.

Currently the processing line is capable of meeting the specifications except net weight of the finished product. Juice extraction consumes the highest cycle time in the organic pineapple chunk processing cell and was identified as the "PACE MAKER" activity of the cell, while the 1st peeling ,2nd peeling ,slicing ,de coring and cutting into chunks also exceed the takt rate of production (time given by the buyer to produce a unit of output - 4.68 seconds). Future production flow, Future state map and Implementation plan were developed to achieve takt rate of production by eliminating non-value added time of the pineapple cell. By introducing lean manufacturing tools and techniques an increase of process cycle efficiency by 15.92% was identified. This leads to a cost reduction of 9.42 million per annum although the project initiation cost is estimated as 12.56 million.

CONTENT

Pages

CHAPTER 3

Methodology

CHAPTER 4

Result and Discussion

ABREVIATIONS

HJSC	;	HJS Condiments Limited
HACCP	;	Hazard Analysis and Critical Control Point
FDA	;	Food and Drug Administration
USA	;	United State of America
JASTECA	;	Japan – Sri Lanka Technical & Cultural Association
g	;	Grams
TPS	;	Toyota Production System
NUMMI	;	New United Motor Manufacturing Incorporation
WIP	;	Work In Process
JIT	;	Just In Time
TPM	;	Total Productive Maintenance
DNA	;	Dihydro Nucleic Acid
PCE	;	Process Cycle Efficiency
SP	;	Stock Productivity
Cpk	;	Capability Index
°F	;	Fahrenheit
°C	;	Celsius
min.	;	Minutes
Sec.	;	Seconds
LKR	;	Lanka Rupees
MN	;	Million

LIST OF FIGURES

LIST OF TABLES

CHAPTER 01

INTRODUCTION AND OBJECTIVES

1.1 Company profile

HJS Condiments Limited (HJSC) was formed in September 1993 as a semi automated bottling plant that would produce and export pickles in glass jars (Value addition).The factory was set up at Biyagama Export Processing Zone and commercial exports commenced in 1995.The initial product range included pickled gherkins, onions, and chilies packed in glass jars exported to Japan, Holland, France, Belgium, Spain, Australia and New Zealand. The production line was later upgraded with state-of-the-art technology to produce 5,000 jars per hour.

In 1998 the company ventured in to the manufacture of Pickled Slices in pouch to supply McDonald's – Japan who has a network of over 3,000 restaurants in Japan. Manufacturing facility was set up for slice production and Vat yard to store gherkins to cater this growing market. Currently HJSC supply Pickled Slices to Burger King, Hungry Jacks, and McDonald's in many countries.

In 2001 HJSC diversified into the manufacture and export of Relish to supply diced gherkins to Sauce Makers in Japan. The new production line installed at Biyagama enables the utilization of off-shaped fruits which were previously rejected at the farmer level and the use of off cuts from other production lines at HJSC.

The company also supplies Chutney and Paste made out of local fruits such as Papaya, Mango and Pumpkin to Japan, which are considered to have a growing potential. HJS Condiments Limited has recently commenced a new project for processing pineapple in jars and cans under its product diversification scheme. HJSC has already signed a contract with 'PRIPA Exotic Fruchtimport' in Germany for supplying four containers of Pineapple processing jars means 144,000 jars per month. It was also observed that Sri Lankan Pineapple has ever increasing demand in European countries due to its unique exotic flavor and taste and expected the demand to be increased by the end of year 2007.

Company's Quality Management System is certified under ISO 9001: 2000 while food processing is in accordance with HACCP (Hazard Analysis and Critical Control Point). HJSC has also taken special care to protect environment from its business activities and are certified with ISO 14,000.HJSC is an approved supplier to McDonald's and Burger King, with FDA (Food and Drug Administration) registration to export food products to USA.

HJSC culture hold fast the best corporate heritage and traditions of Hayleys Group. The company recognizes the need to adapt to the changing environment it operates and the need to develop human resources continuously for long term sustainability of the business. The vision and mission of the company has changed recently to meet their goals while satisfying the customer needs more profitably.

1.1.1 HJSC Vision

"To be the number one Pickle manufacturer in Asia and to be the leading fruit & vegetable exporter in Sri Lanka"

1.1.2 HJSC Mission

To be a preferred value adding supplier of,

- Processed pickle products to fast food chains, hotels, restaurants, supermarkets, departmental stores
- Relish to sauce makers
- Paste, preserved fruit & vegetable pieces to sauce and chutney makers
- Organic and conventional fruit & vegetable food products to supermarkets, food Processors

With reputation for quality & reliability.

1.1.3 Achievements of the company

In the short history of 13 years, HJSC has won many awards in recognition of its effort and commitment towards Quality and Productivity Improvement, Excellence in Food Industry and Export Performances.

- **Food Awards of Excellence** – Gold Award (Grocery Large category in 2001 & 2002, awarded by Sri Lanka Food Processor's Association.)

- **'Takai-Akimoto 5'S Award'** – Merit in 2002 & 2003, organized by Japan – Sri Lanka Technical & Cultural Association (JASTECA).

- **'Best Quality Circle Award'** – Manufacturing Sector in 2003, organized by Japan – Sri Lanka Technical & Cultural Association (JASTECA).

- **National Awards for Export Excellence Gold Award** in Processed Foods in 2003 organized by Ministry of Commerce and Consumer Affairs.

- **'Best TPM Team',** awarded at Asian Region Convention on Quality and Productivity – 2004 held in Colombo.

- **National Productivity Award** – 1st Place, Manufacturing Sector – Medium scale in 2003, organized by Ministry of Employment and Labour.

- **National Quality Award,** Manufacturing Sector – Medium Scale, 2005

1.2 Toyota Way

This study addresses the application of lean manufacturing system to the organic fruit processing section at HJSC to reduce cost as a remedy to face escalating operational cost and focuses on operational excellence that would also helps to improve bottom-line and customer confidence. After World War II, Japanese manufactures, particularly in the auto motive industry, were faced with the dilemma of shortage of material, financial, and human resources. Eiji Toyoda and Taichi Ohno at the Toyota Motor Company in Japan pioneered the concept of the Toyota Production System, or what is most commonly known today in the US as "Lean Manufacturing". The basic idea behind the system is eliminating waste. Waste is defined as anything that does not add value to the end product from the customer's perspective (Abdullah, 2000). The primary objective of lean manufacturing is to assist manufactures who have a desire to improve their company's operations and become competitive through the implementation of different lean manufacturing tools and techniques.

Quickly following the success of lean manufacturing in Japan, other companies and industries, particularly in US, copied this remarkable system. The term "Lean" as Womack and Jones (1994) define, denotes a system that utilizes less, in terms of all inputs, to create the same output as those created by a traditional mass production system, while contributing increased varieties for the end customer (Abdullah, 2000). Lean is to manufacture only what is needed by the customer, when it is needed and in the quantities ordered. The manufacture of goods is done in a way that minimizes the time taken to deliver the finished goods, the amount of labour required, and the floor-space required, and it is done with the highest quality, and usually at the lowest cost.

1.3 Product Families

Within a short period of 13 years the company has developed 6 major product families and now accounts for 23% of Island's total Fruit & Vegetable exports. Table 1.1 shows the product families and corresponding products.

Table 1.1: Product families and corresponding products

Product Family	**Products**
Whole Gherkins	Cornichons, Sweet Pickles, Dill Pickles, Genuine Dill Pickles, Sweet & Sour Pickles, Fresh Pack Sweet, Fresh Pack Kosher Dill,
Longitude Cut Gherkins	Sticks, Stackers
Diced gherkins	Sweet Relish, Dill Relish, Gherkin cubes in vinegar, SR 30
Mixed Pickles	Banderilla, Exotic mixed Pickles
Paste/Chutney	Papaya Paste, Pumpkin Paste, Chili Paste, Mango Chutney, Papaya Chutney
Organic Foods - Wet **Organic Foods - Dry**	Pineapple Chunks, Fruit Cocktail Pineapple Rings, Pineapple Tidbits, Banana cubes ,Papaya Slices & Cubes ,Mango Slices Halves & Cubes, Jack Fruit Bulbs

Product families in the organic food processing cell can be mainly divided into two categories based on the specific fruit and vegetable processing requirements as in the Table 1.2.

Table 1.2: Product families and corresponding Process Requirements in Organic Food Processing Cell

Product Family	Pitch	Process specialty/changes
Organic Fruit in Jars(350ml) • Organic Pineapple Chunk • Organic Fruit Cocktail	 Case (6 jars) Case (6 jars)	 Pineapple chunks Packed in 350 ml jars Pineapple, Papaya, Mango, Watermelon chunks packed in 350 ml jars
Organic Fruit & Vegetables Dehydrated	Case (4 pouches)	Packed in pouches

1.4 Identify the Cell

Organic food processing cell was identified as one of the complicated food processing area of HJSC. Currently the cell manufactures more than 8 different products by using fresh fruits like pineapple, papaya, water melon, mango & jack fruit etc. depending on the customer requirement and seasonal availability of the raw materials.

In this study organic pineapple chunk packed in jars with a net weight of 350g was selected. It was observed that current pineapple chunk processing is a batch wise production from issuing up to shipping, which includes 15 different processing activities (Appendix 04).

The current pineapple chunk processing involves a series of manual processing activities with several non-value added steps. The capacity of the cell is around 4000 jars per day (Inputs for the cell includes sound pineapples that are inspected and sorted, peeled, cut into chunks, sorted and packed into glass jars with net drained weight of 220 g) .This study is focused investigate the current state of the manufacturing process of and to develop the future state map with the application of core principles of lean manufacturing system (Toyota Way).

1.5 Overall objective

1.5.1 To reduces the cycle time of pine apple processing cell by introducing lean manufacturing system.

1.6 Specific Objectives

1.6.1 To study current situation and prepare current state map of the pineapple processing cell.

1.6.2 Apply lean principles and design future state map of the pineapple processing cell.

1.6.3 Implement lean projects to eliminate the waste of the pineapple processing line..

CHAPTER 02

REVIEW OF LITERATURE

2.1 Origin of Lean Manufacturing System/Toyota production system (TPS)

Lean manufacturing is a generic process management philosophy derived mostly from the Toyota Production System (TPS). After World War II Japanese manufactures face a dilemma of vast shortage of material, Financial and human resources. The problems that Japanese manufactures were faced with different from those of their western counterparts. These conditions sparked the birth of the Lean manufacturing concept (Zidel, 2006). Toyota Motor Sales Company, led by its president Toyoda recognized that American auto makers of that era were out producing their Japanese counterparts; in the mid 1940's American companies were outperforming their Japanese counterparts by a factor of ten. In order to make a move toward improvement early Japanese leaders such as Toyoda Kiichro, Shigeo Shingo and Taiichi Ohno devised a new, disciplined, process–oriented system, which is known today as the Toyota Production System or Lean manufacturing, Taiichi Ohno, who was given the task of developing a system that would enhance productivity at Toyota is generally considered to be the primary force behind this system. Ohno drew upon some ideas from the west, and particularly from Henry Ford's book "Today and Tommorow".Ford's moving assembly line of continuously flowing material formed the basis for the Toyota Production System. After some experimentations, the TPS was developed and refined between 1945 and 1970, and is still growing today all over the world. The basic underlining idea of this system is to minimize the consumption of resources that add no value to a product (Abdullah, 2000).

In order to compete in today's fiercely competitive market, US manufacturers have come to realize that the traditional mass production concept has to be adapted to the new ideas of lean manufacturing. A study that was done at the Massachusetts institute of technology of the movements from mass production towards lean manufacturing ,as explained in the book "The Machine That Changed The World" awoke the US manufacturers from their sleep. The study underscored the great success of Toyota at NUMMI (New United Motor Manufacturing Inc.) & bought out the huge gap that exited between the Japanese and western automotive industry. The idea came to be adopted in the US because the Japanese companies developed, produced & distributed products with half or less human effort, capital investment, floor space, tools, materials, time and overall expenses (Abdullah, 2000)

2.2 The Lean Focus: Reducing Lead Time by Eliminating Waste

2.2.1 What is waste?

In lean manufacturing waste is anything that adds to the time and cost of making a product but does not add value to the product from the customer's point of view. Value-added activities transform the product into something the customer wants. In manufacturing this is generally a physical transformation of the product to make it to conform to customer expectations. Figure 2.1 shows a simplified version of the steps required to make a steel subassembly. Only the activities shown in dark grey add value. By add value we mean that they transform the product physically toward something the customer wants. The light gray activities are waste—they do not add value from the customer's perspective (Liker *et el*,2000).

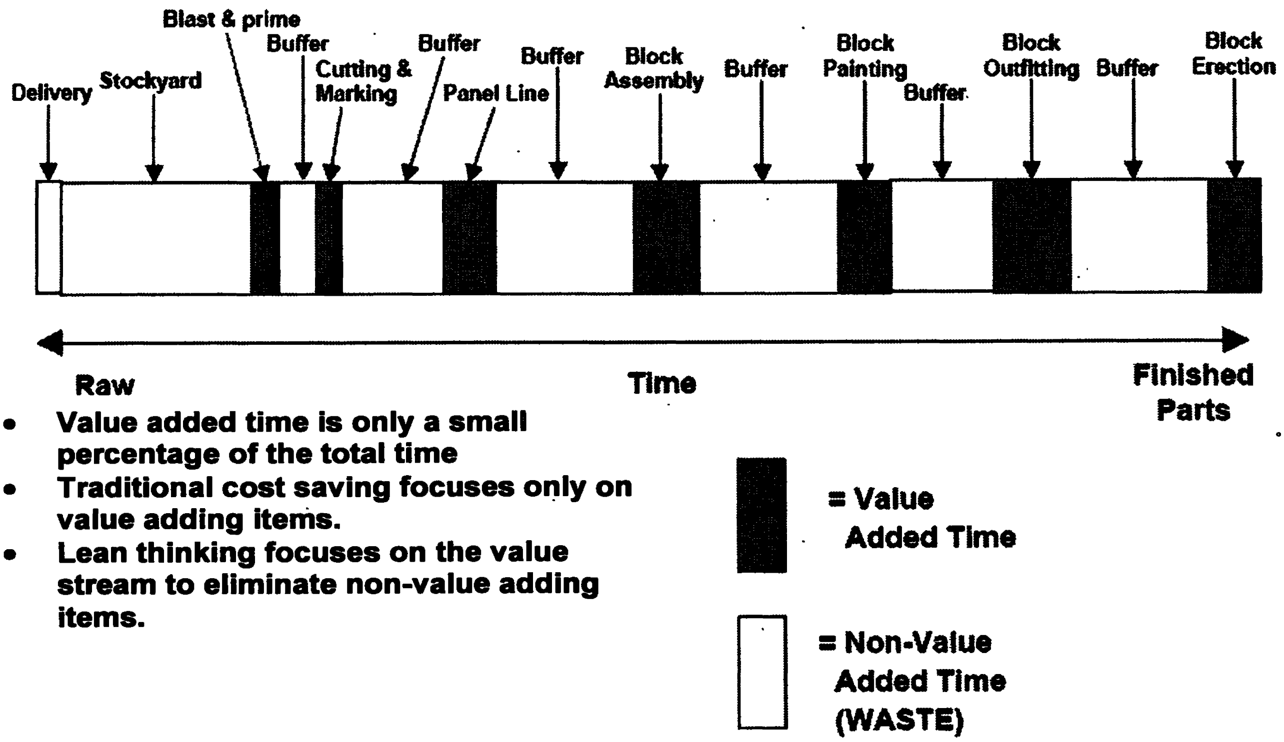


Figure 2.1: Elements of Product Lead time
(Source: Liker *et al*, 2000)

2.2.1.1 Mass Production Thinking

Mass production is a way of thinking that starts with the principle of economies of scale. Bigger is better and making large batches of parts makes more efficient use of individual equipment than small batches with time consuming changeovers. The focus on mass production is individual efficiency – efficient use of individual machines and individual operators. To make the overall system in Figure 01 more efficient mass production thinking attacks the efficiency of value-added activities. For example, one might reduce the cycle time needed cut the steel. It can see in Figure 01 that the total benefit of reducing the cycle time of value-added activities amounts to a small portion of overall lead time, because value-added time is a small portion of total lead-time (Liker *et al*, 2000).

2.2.1.2 Lean Thinking

Lean thinking focuses on value-added flow and the efficiency of the overall system. A part sitting in a pile of inventory is waste and the goal is to keep product flowing and add value as much as possible. The focus is on the overall system and synchronizing operations so they are aligned and producing at a steady pace (Liker *et al*, 2000).

Lean manufacturing is a manufacturing philosophy that shortens the time between the customer order and the product build/shipment by eliminating sources of waste. Waste is anything that does not contribute to transforming a part to your customer's needs. The results of the lean approach are illustrated in Figure 2.2 below. Lean manufacturing will take some waste out of the value-added activity shrinking it down as in the mass production approach, but more importantly, it reduces the pure non-valued added activities, which has the large impact on lead-time.

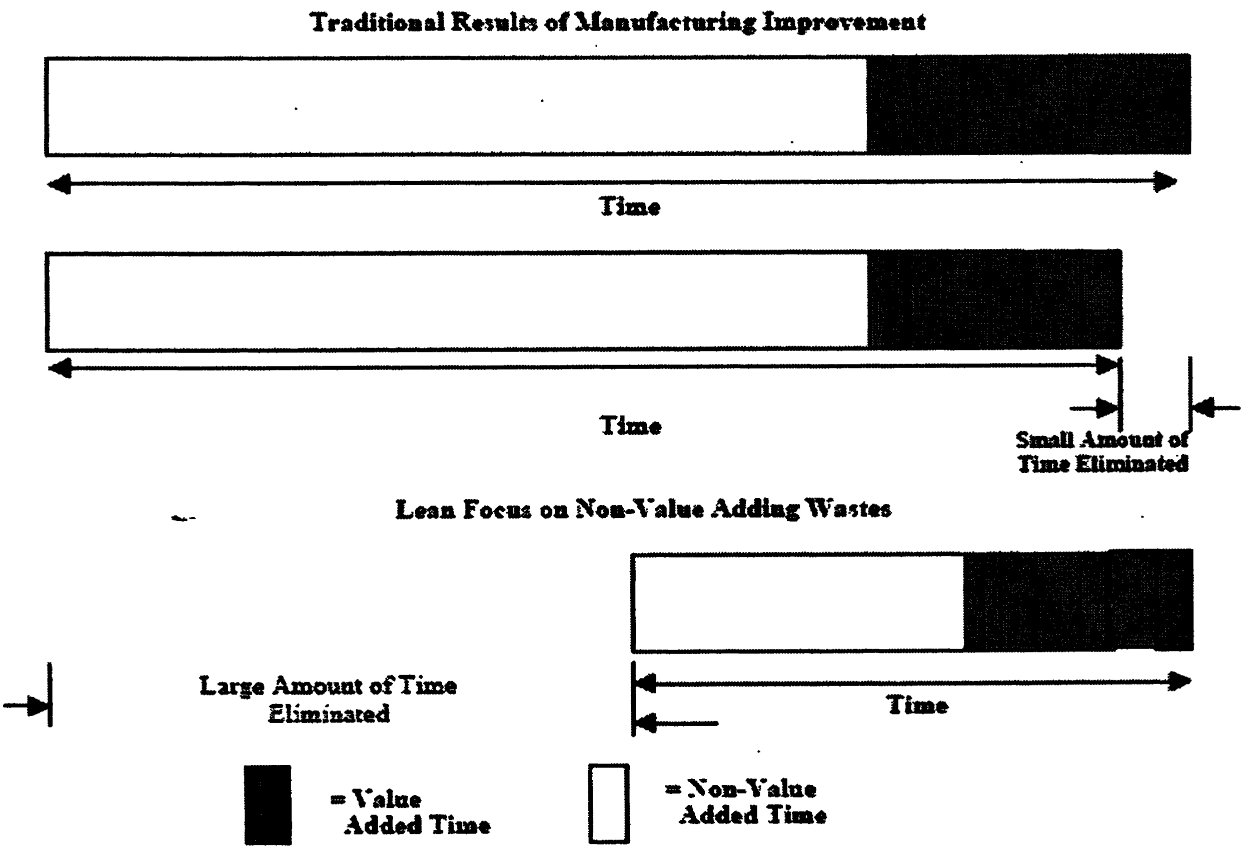


Figure 2.2: Traditional vs. Lean Approaches
(Source: Liker *et al*, 2000)

2.2.2 Recognizing Waste

When applying TPS, it starts with examining the manufacturing process with customer's perspective. The first question in TPS is always "what does the customer want from this process?" (Both the internal customer at the next step in the production line and the final ,external customer) .This defines value through the customer's eyes, then can observe a process and separate the value added steps from the non-value-added steps. This can apply to any process-manufacturing, information or service (Dirgo, 2005).

Toyota has identified seven major types of non-value adding waste in business or manufacturing processes, which are described below. These can apply to product development, order taking, and the office not just a production line (Liker, 2006). There is an eights waste, that Liker has included in his "The Toyota Way" book.

1) **Over production**- Producing items for which there are no orders, which generates such wastes as overstaffing and storage and transportation costs because of excess inventory.

2)**Waiting** (time on hand)-Workers merely serving to watch an automated machine or having to stand around waiting for the next processing step, tool, supply, part, etc., or just plain having no work because of stock out, lot processing delays, equipment downtime, and capacity bottlenecks.

3)**Unnecessary transport or conveyance**-Carrying Work In Process (WIP) long distances, creating inefficient transport, or moving materials, parts, or finished goods into or out of storage or between processes.

4) **Overprocessing or incorrect processing**-Taken unneeded steps to process the parts. Inefficiently processing due to the poor tool and product design, causing unnecessary motion and producing defects. Waste is generated when providing higher quality products than is necessary.

5) **Excess inventory**-Excess raw material, WIP, or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs and delay. Also extra inventory hides problems such as production imbalances, late deliveries from suppliers, defects, equipment downtimes, and long set up times.

6) **Unnecessary movement**-Any wasted motion employees have to perform during the course of their work, such as looking for, reaching for or stacking parts tools, etc. Also walking is waste.

7) **Defects**-Production of defective parts or correction. Repair or rework, scrap, replacement production, and inspection mean wasteful handling time and effort.

8) **Unused employee creativity**-Losing time, ideas, skills, improvements, and learning opportunities by not engaging or listening to your employees (Liker, 2006).

2.3 Model of Lean Manufacturing System

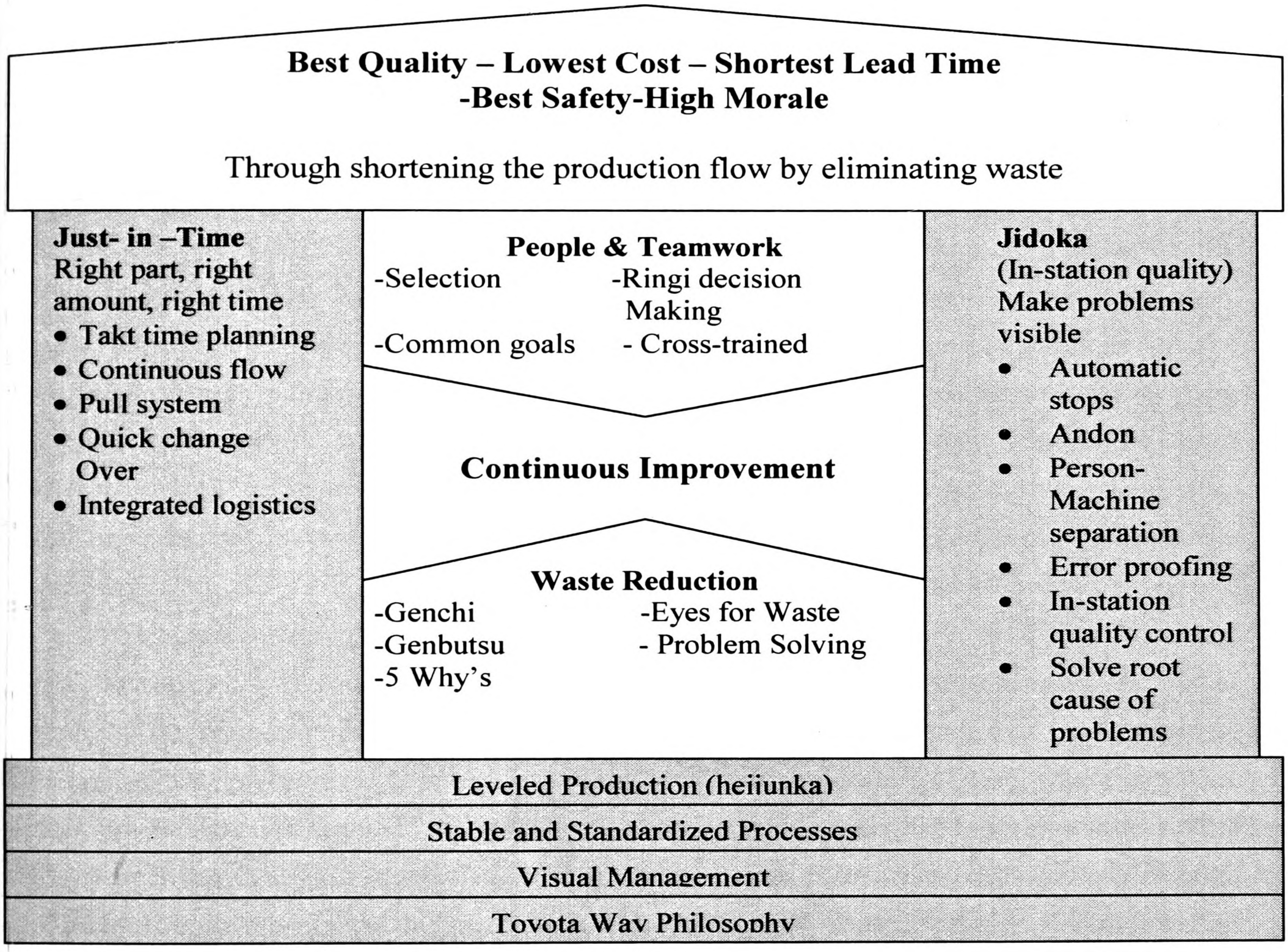


Figure 2.3: The Toyota Production System
(Source: Liker, 2006)

The Toyota Production System (TPS) is depicted as a house as shown in Figure 2.3.Why a house? because a house is a structural system. The house is strong only if the roof, the pillars, and the foundation are strong. A week link weakens the whole system. There are different versions of the house, but the core principles remain the same. It starts with the goals of best quality, lower cost, and shortest lead time – the roof.

There are then two outer pillars-just-in-time, probably the most visible and highly publicized characteristic of TPS,and *jidoka* ,which in essence means never letting a defect pass into next station and freeing people from machines-automation with a human touch. In the center of the system are people. Finally there are various foundational elements, which include the need for standardized, stale, reliable processes, and also heijunika, which means leveling out the production schedule in both volume and variety. A leveled schedule or *heijunika* is necessary to keep the system stable and to allow for minimum inventory. Big spikes in the production of certain products to the exclusion of others will create part shortages unless lots of inventory is added into the system (Liker, 2006).

Each element of the house by itself is critical, but more important is the way the elements reinforce each other. JIT means removing, as much as possible; the inventory used to buffer operations against problems that may arise in production. The ideal of one-piece flow is to make one unit at a time at the rate of customer demand or Takt (German word for meter). Using smaller buffers (removing the "safety net") means that problems like quality defects become immediately visible. This means workers must resolve the problems immediately and urgently to resume production. At the foundation of the house is stability. Ironically, the requirement for working with little inventory and stopping production when there is a problem causes instability and a sense of urgency among workers. In mass production, when a machine goes down, there is no sense urgency: the maintenance department is scheduled to fix it while inventory keeps the operations running. By contrast, in lean production, when an operator shuts- down equipment to fix a problem, other operations will soon stop producing, creating a crisis. So there is always a sense of urgency for everyone in production to fix problems together to get the equipment up ad running. If the same problem happens repeatedly, management will conclude that this is a critical situation and it may be time to invest in total productive maintenance (TPM), where everyone learns how to clean, inspect, and maintain equipment. A high degree of stability is needed so that the system is not constantly stopped. People are at the center of the house because only through continuous improvements can the operation ever attaining this needed stability. People must be trained to see waste and solve problems at the root cause by repeatedly asking why the problem really occurs. Problem solving is at the actual place to see what is really going on (*genchi genbutsu*) (Liker, 2006)

2.5 Principles of the Toyota Way

2.5.1 4P model of the Toyota Way

TPS is the most systematic & highly developed example of what the principles of the Toyota way can accomplish. This consists of foundational 14 principles whose goal is cost reduction by elimination of wastes. The principles are organized in four broad categories as illustrated in the Figure 2.4 (Liker, 2006).

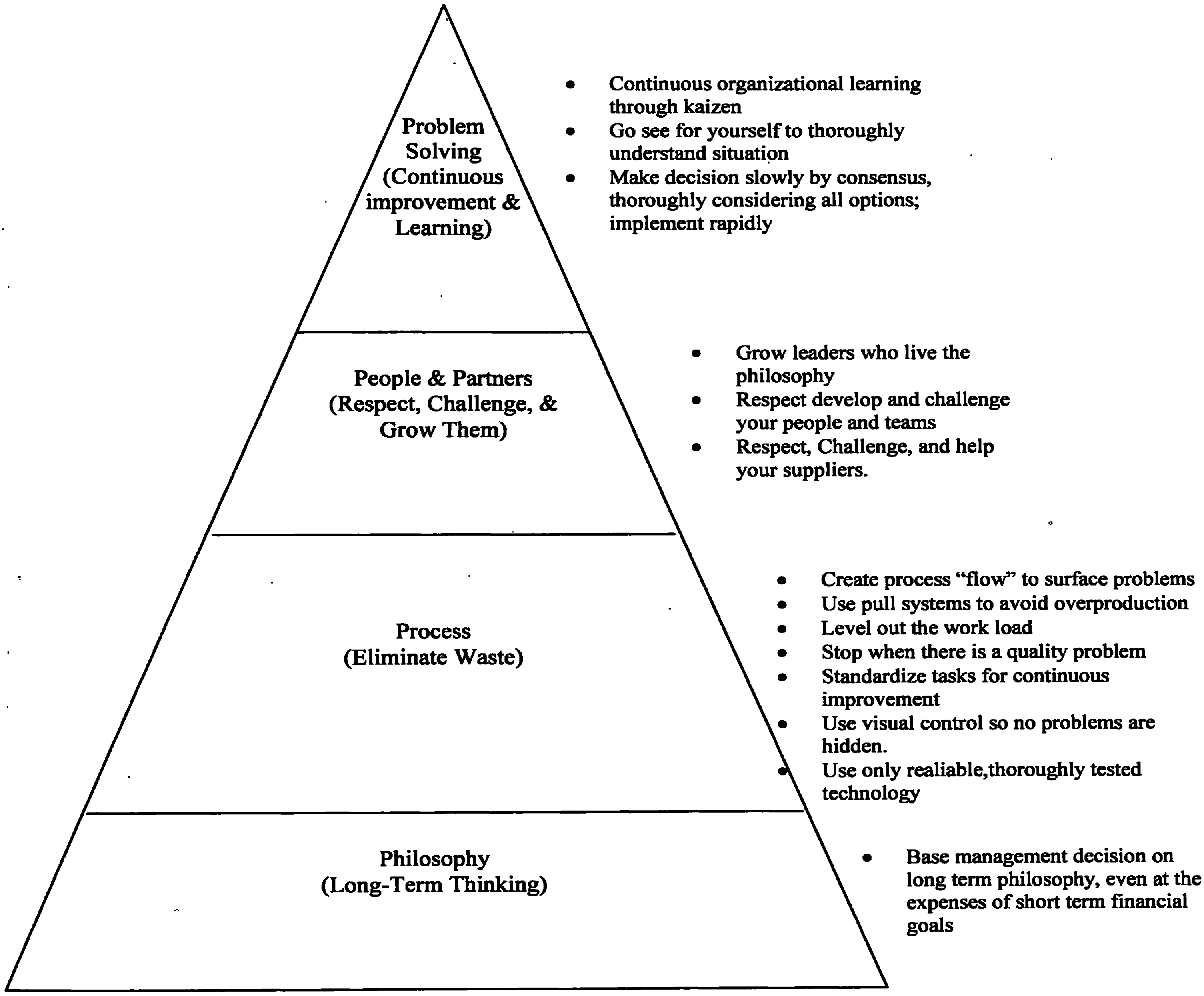


Figure 2.4: "4 P" model of the Toyota Way
(Source: Liker, 2006)

- Long-term **Philosophy**-Toyota is serious about long –term thinking. The focus from the very top of the company is to add value to customers and society. This drives a long-term approach to building a learning organization; one that can adapt to changes in the environment and survive as productive organization. Without this foundation, none of the investments Toyota makes in continuous improvement and learning would be possible.

- The right **process** will produce the right results-Toyota is a process-oriented company. They have learned through experience what processes work, beginning with the ideal one-piece flow. Flow is the key to achieving best quality at the lowest cost with high safety and morale. At Toyota this process focus is build into the company's DNA, and managers believe in their hearts that using the right process will lead to the results they desire.

- Add Value to the organization by developing **Peoples** and partners-The Toyota Way includes a set of tools that are designed to support people continuously improving and continuously developing. For example, one piece flow is very demanding process that quickly surface problems that demand fast solutions-or production will stop. This suits Toyota's employee development goals perfectly because it gives people the sense of urgency needed to confront business problems. The view of management at Toyota is that they build people, not just cars.

- Continuously solving root **problems** drives organizational learning-The highest level of the Toyota way is organizational learning. Identifying root cause of problems and preventing them from occurring is the focus of Toyota's continuous learning system. Tough analysis, reflection, and communication of lessons learned are central to improvement as is the discipline to standardize the best-known practices.

2.5.2 Summary of the 14 principles

Section I: Long-Term Philosophy

Principle 1. Base the management decisions on a long-term philosophy, even at the expense of short-term financial goals.

■ Have a philosophical sense of purpose that supersedes any short-term decision making. Work, grow, and align the whole organization toward a common purpose that is bigger than making money. Understand the place in the history of the company and work to bring the company to the next level. The philosophical mission is the foundation for all the other principles.

■ Generate value for the customer, society, and the economy—it is the starting point. Evaluate every function in the company in terms of its ability to achieve this.

■ Be responsible. Strive to decide your own fate. Act with self-reliance and trust in your own abilities. Accept responsibility for conduct and maintain and improve the skills that enable to produce added value.

Section II: The Right Process Will Produce the Right Results

Principle 2. Create a continuous process flow to bring problems to the surface.

■ Redesign work processes to achieve high value-added, continuous flow.Strive to cut back to zero the amount of time that any work project is sitting idle or waiting for someone to work on it.

■ Create flow to move material and information fast as well as to link processes and people together so that problems surface right away.

■ Make flow evident throughout the organizational culture. It is the key to a true continuous improvement process and to developing people.

Principle 3. Use "pull" systems to avoid overproduction.

■ Provide the downtime customers in the production process with what they want, when they want it, and in the amount they want. Material replenishment initiated by consumption is the basic principle of just-in time. Minimize work in process and warehousing of inventory by stocking small amounts of each product and frequently restocking based on what the customer actually takes away.

■ Be responsive to the day-by-day shifts in customer demand rather than relying on computer schedules and systems to track wasteful inventory.

Principle 4. Level out the workload (heijunka). (Work like the tortoise, not the hare.)

■ Eliminating waste is just one-third of the equation for making lean successful.
Eliminating overburden to people and equipment and eliminating unevenness in the production schedule are just as important—yet generally not understood at companies attempting to implement lean principles.

■ Work to level out the workload of all manufacturing and service processes as an alternative to the stop/start approach of working on projects in batches that is typical at most companies.

Principle 5. Build a culture of stopping to fix problems, to get quality right the first time.

■ Quality for the customer drives the value proposition.

■ Use all the modern quality assurance methods available.

■ Build into equipment the capability of detecting problems and stopping itself. Develop a visual system to alert team or project leaders that a machine or process needs assistance. Jidoka (machines with human intelligence) is the foundation for "building in" quality.

■ Build into the organization support systems to quickly solve problems and put in place countermeasures.

■ Build into company culture the philosophy of stopping or slowing down to get quality right the first time to enhance productivity in the long run.

Principle 6. Standardized tasks and processes are the foundation for continuous improvement and employee empowerment.

■ Use stable, repeatable methods everywhere to maintain the predictability, regular timing, and regular output of the processes. It is the foundation for flow and pull.

■ Capture the accumulated learning about a process up to a point in time by standardizing today's best practices. Allow creative and individual expression to improve upon the standard; then incorporate it into the new standard so that when a person moves on company can hand off the learning to the next person.

Principle 7. Use visual control so no problems are hidden.

■ Use simple visual indicators to help people determine immediately whether they are in a standard condition or deviating from it.

■ Avoid using a computer screen when it moves the worker's focus away from the workplace.

■ Design simple visual systems at the place where the work is done, to support flow and pull.

■ Reduce the reports to one piece of paper whenever possible, even for the most important financial decisions.

Principle 8. Use only reliable, thoroughly tested technology that serves the people and processes.

■ Use technology to support people, not to replace people. Often it is best to work out a process manually before adding technology to support the process.

■ New technology is often unreliable and difficult to standardize and therefore endangers "flow." A proven process that works generally takes precedence over new and untested technology.

■ Conduct actual tests before adopting new technology in business processes, manufacturing systems, or products.

■ Reject or modify technologies that conflict with the culture or that might disrupt stability, reliability, and predictability.

■ Nevertheless, encourage your people to consider new technologies when looking into new approaches to work. Quickly implement a thoroughly considered technology if it has been proven in trials and it can improve flow in your processes.

Section III: Add Value to the Organization by Developing Your People

Principle 9. Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others.

■ Grow leaders from within, rather than buying them from outside the organization.

■ Do not view the leader's job as simply accomplishing tasks and having good people skills. Leaders must be role models of the company's philosophy and way of doing business.

■ A good leader must understand the daily work in great detail so he or she can be the best teacher of the company's philosophy.

Principle 10. Develop exceptional people and teams who follow the company's philosophy.

■ Create a strong, stable culture in which company values and beliefs are widely shared and lived out over a period of many years.

■ Train exceptional individuals and teams to work within the corporate philosophy to achieve exceptional results. Work very hard to reinforce the culture continually.

■ Use cross-functional teams to improve quality and productivity and enhance flow by solving difficult technical problems. Empowerment occurs when people use the company's tools to improve the company.

■ Make an ongoing effort to teach individuals how to work together as teams toward common goals. Teamwork is something that has to be learned.

Principle 11. Respect your extended network of partners and suppliers by challenging them and helping them improve.

■ Have respect for company partners and suppliers and treat them as an extension of the business.

■ Challenge the outside business partners to grow and develop. It shows that company values them. Set challenging targets and assist the partners in achieving them.

Section IV: Continuously Solving Root Problems Drives Organizational Learning

Principle 12. Go and see for yourself to thoroughly understand the situation (genchi genbutsu).

■ Solve problems and improve processes by going to the source and personally observing and verifying data rather than theorizing on the basis of what other people or the computer screen tell you.

■ Think and speak based on personally verified data.

■ Even high-level managers and executives should go and see things for themselves, so they will have more than a superficial understanding of the situation.

Principle 13. Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly (nemawashi).

■ Do not pick a single direction and go down that one path until it has thoroughly considered alternatives. When it has picked, move quickly and continuously down the path.

■ *Nemawashi* is the process of discussing problems and potential solutions with all of those affected, to collect their ideas and get agreement on a path forward. This consensus process, though time-consuming, helps broaden the search for solutions, and once a decision is made, the stage is set for rapid implementation.

Principle 14. Become a learning organization through relentless reflection (hansei) and continuous improvement (kaizen).

■ Once it has established a stable process, use continuous improvement tools to determine the root cause of inefficiencies and apply effective countermeasures.

- Design processes that require almost no inventory. This will make wasted time and resources visible for all to see. Once waste is exposed, have employees use a continuous improvement process (kaizen) to eliminate it.

- Protect the organizational knowledge base by developing stable personnel, slow promotion, and very careful succession systems.

(Liker, 2006)

2.6 Just-in time Production-Philosophy of complete elimination of waste

2.6.1Just-in-Time

"Just-in-Time" means making only "what is needed, when it is needed, and in the amount needed." To efficiently produce a large number of products such as automobiles, which are comprised of some 30,000 parts, it is necessary to create a detailed production plan that includes parts procurement, for example. Supplying "what is needed, when it is needed, and in the amount needed" according to this production plan can eliminate waste, inconsistencies, and unreasonable requirements, resulting in improved productivity (Toyota Corporation, 2007).

A true one piece flow system would be a zero-inventory system where goods just appear when they are needed by the customer. The closest system Toyota has devised to achieve this is the one piece flow cell that builds to order only at the precise time the product is needed. But when pure flow is not possible because processes are too far apart or the cycle times to perform the operations vary a great deal, the next best choice is often Toyota's kanban system (Liker, 2006)

2.6.1.1 Takt Time

Takt is a German word for rhythm or meter. Takt is the rate of customer demand-the rate at which customer buy product (Liker, 2006). It can be used to set the pace of production and alert workers whenever they are getting ahead or behind.

Continuous flow and takt time are most easily applied in repetitive manufacturing and service operations. But with creativity the concepts can be extended to any repeatable process in which the steps can be written out and waste identified and eliminated to create better flow.

2.6.1.2 Benefits of One-Piece Flow

1. Build in quality-It is much easier to build in quality in one-piece flow

2. Creates real Flexibility-Lead time to make a product is very short, hence more flexibility to respond and make what the customer really want

3. Creates Higher Productivity-It is easy to calculate the value added work and then figure out how many people are necessary to reach a certain production rate

4. Frees up Floor Space-In a cell, everything is pushed close together and there is very little space wasted by the inventory

5. Improves Safety-one-piece flow would naturally improves improve safety, because smaller bathes of material would be moved in the factory

6. Improves morale-In one-piece flow, people do much more value-added work band can immediately see the results of the work, giving them both a sense of accomplishment and job satisfaction

7. Reduce cost of inventory-Free up capital to invest elsewhere when it's not invested in inventory sitting on the floor. And companies do not have to pay the carrying costs of the capital they free up. Also the inventory obsolescence goes down

2.6.2 Kanban system (Pull system)

In the TPS, a unique production control method called the "kanban system" plays an important role. The kanban system has also been called the "Supermarket method" because the idea behind it was borrowed from supermarkets. Supermarkets and mass merchandizing stores use produot control cards on which product-related information, such as product name, product code, and storage location, is entered. Because Toyota employed kanban signs in place of the cards for use in production processes, the method came to be called the "kanban system." At Toyota, when a process goes to the preceding process to retrieve parts, it uses a kanban to communicate what parts have been used (Toyota Corporation, 2007).

2.6.2.1 Super market system

A supermarket stocks the items needed by customers when they are needed in the quantity needed, and has all of these items available for sale at any time.Taiichi Ohno (a former Toyota vice president), who promoted the idea of Just-in-Time, applied this concept, equating the supermarket and the customer with the preceding process and the next process, respectively. By having the next process (the customer) go to the preceding process (the supermarket) to retrieve the necessary parts when they are needed and in the amount needed, it was possible to improve upon the existing inefficient production system in which the preceding processes were making excess parts and delivering them to the next process. The system of kanban is illustrated in Figure 2.5.

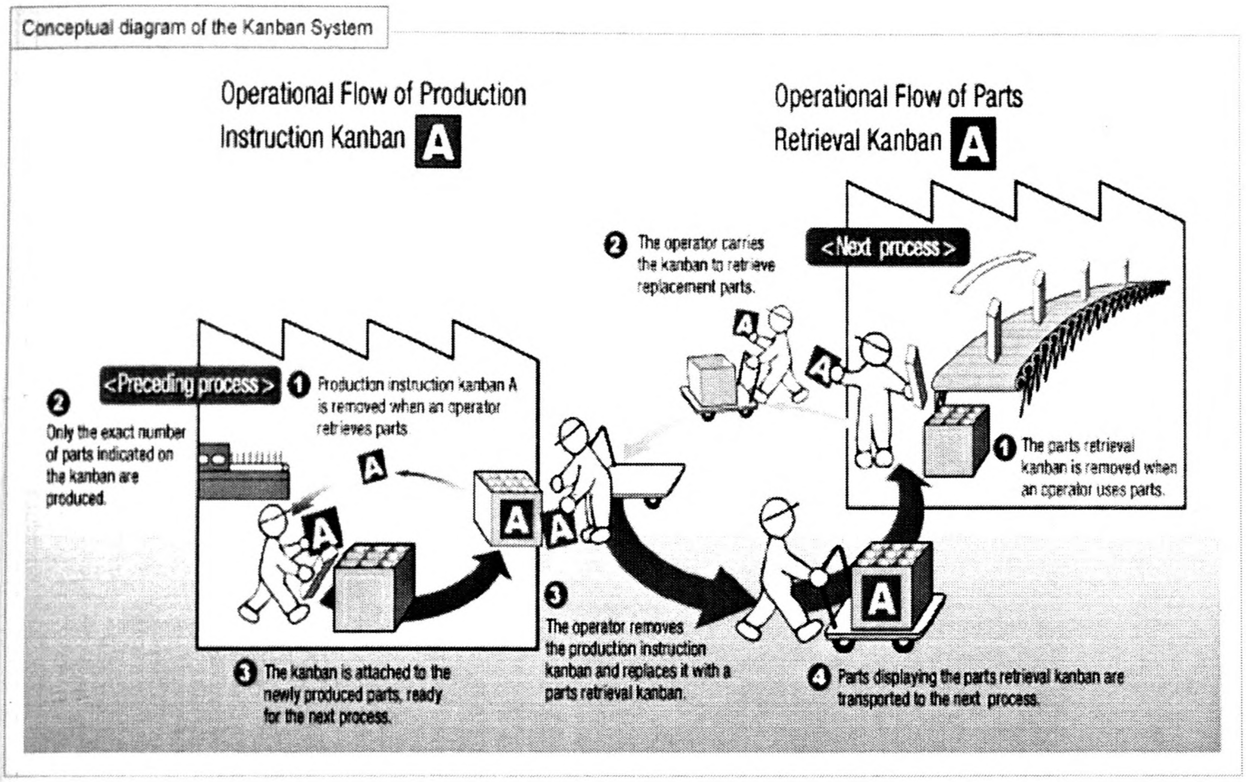


Figure 2.5: Two kinds of kanban (the production instruction kanban and the parts retrieval kanban) are used for managing parts

(Source: Toyota Corporation, 2007)

2.7 Jidoka- Manufacturing high quality products

2.7.1 Automation with a human touch

The term jidoka used in the TPS can be defined as "automation with a human touch." The word jidoka traces its roots to the automatic loom invented by Sakichi Toyoda, Founder of the Toyota Group. The automatic loom is a machine that spins thread for cloth and weaves textiles automatically.

In the olden days, back-strap looms, ground looms, and high-warp looms were used to manually weave cloth. In 1896, Sakichi Toyoda invented Japan's first self-powered loom called the "Toyoda Power Loom." Subsequently, he incorporated numerous revolutionary inventions into his looms, including the weft-breakage automatic stopping device, which automatically stopped the loom when a thread breakage was detected, the warp supply device, and the automatic shuttle changer. Then, in 1924, Sakichi invented the world's first automatic loom, called the "Type-G Toyoda Automatic Loom (with non-stop shuttle-change motion)" which could change shuttles without stopping operation.

The Toyota term "jido" is applied to a machine with a built-in device for making judgments, whereas the regular Japanese term "jido" (automation) is simply applied to a machine that moves on its own. Jidoka refers to "automation with a human touch," as opposed to a machine that simply moves under the monitoring and supervision of an operator.

Since the loom stopped when a problem arose, no defective products were produced. This meant that a single operator could be put in charge of numerous looms, resulting in a tremendous improvement in productivity (Toyota Corporation, 2007).Concept of Jidoka illustrated in Figure 2.6.

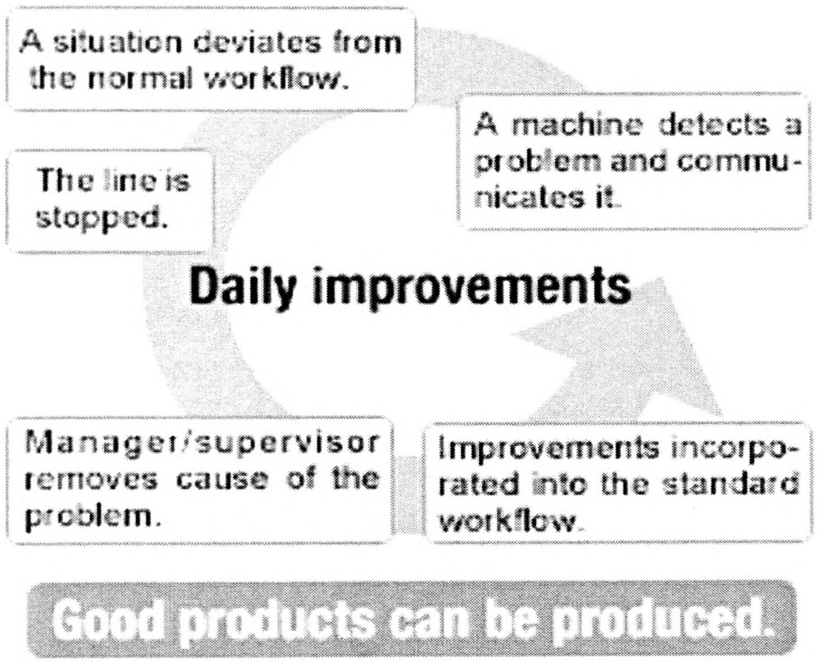


Figure 2.6: Concept of Jidoka
(Source: Toyota Corporation, 2007)

2.7.2 Jidoka and Visual control

Since equipment stop when a problem arises, a single operator can visually monitor and efficiently control many machines. As an important tool for this "visual control" or "problem visualization," Toyota plants use a problem display board system called "Andon" that allows operators to identify problems in the production line at a glance (Liker, 2006).

CHAPTER 03
METHODOLOGY

3.1 Pre-preparation for creating lean flow

Four essential pre requisites were done to effectively apply lean principals to the pine apple processing cell.

3.1.1 Defining of Scope

Start point or trigger that begins the process and what the final deliverable product to the customer were determined

3.1.2 Setting of objectives

Specific goals were set to reduce lead time, improve quality, and reduce cost. The goals were clearly aligned with the overall corporate objectives of the company.

3.1.3 Collection of all relevant documents

Samples of forms and documents used at the manufacturing process were collected with the relevant data.

3.2 Measurement of process capability

To check whether the organic pineapple chunk processing is capable to produce the products within the specification limits , data from some physical attributes as well as chemical attributes were collected via lab reports for about last three months and analyzed with the aid of MINITAB statistical package .

3.3 Creation of state map for current process

3.3.1 Collection of data

Data were collected through a number of different channels. All processing steps were personally observed as it occurs by walking through the processing floor and talked to employees who have tasks in the current state mapping.

Below is a list of the information that was collected at each process step:

1. C/T Cycle Time – how often a part is completed by a process. a stopwatch was used to measure the time
2. C/O Changeover time – the time required to switch from producing one product type to another type.

3. Uptime – the percentage of time in which a machine or process is available on demand.
4. Number of people involved
5. Quantity of units processed
6. Quantity of changeovers for a given time period
7. Downtime
8. Batch sizes

3.3.2 Construction of current state map

When each activity had been observed and feels good about the data, the current-state map was constructed. Each activity was labeled in a process box, and the data for that activity was listed below it. Arrows was used to show the flow of the product, and triangles between the processes boxes was used to depict inventory levels of work in process before each activity. Icons and arrows as showing in Appendix used to draw the map.

Finally, a saw tooth diagram was drawn underneath the value stream to depict process and lead time. The diagram's upper teeth were drawn under process boxes that depict activities in the map. The time to process a single unit of product was written on each of these teeth. The lower gaps of the sawtooth diagram were drawn between process boxes where inventory was represented in the current state. Queue time was shown in the current state map and was calculated using a days-of-inventory method.

Once the current-state map was drawn, the process time for the current state was calculated by adding the times along the upper teeth of the sawtooth diagram. The total lead time was calculated by adding all the times on the upper teeth and the lower gaps together.

3.4 Analysis of Current state of the pineapple processing cell

Following three Toyota categories were identified after analyzing the current state map

1. Value added -What is the actual transformation process core to the product that the customer is paying for
2. Non value added - What is pure waste
3. Non value added, but required

3.4.1 Calculation of lean measures

a) Process cycle efficiency

PCE was calculated by obtaining value added time (approximately the total processing time/ times along the upper teeth of the saw tooth diagram) and divided by the lead time (The total lead time is calculated by adding all the times on the upper teeth and the lower gaps together).

$$PCE = \frac{\text{Value added time}}{\text{Lead time}}$$

b) Stock Productivity

Stock Productivity was calculated with the data obtained from the commercial department and the stores of the company.

Stock Productivity (SP) = Stock turnover * Gross profit margin

Stock turn over = Sales /Average Stock

3.5 Development of lean strategies

3.5.1 Calculating the Takt time

The Takt time of the processing line was calculated as follows.

$$\text{Takt time} = \frac{\text{Available Time (work time-rest time)}}{\text{Daily Demand}}$$

Available time = Working time per day-(Lunch break+Two tea breaks)

3.5.2 Identification of pace maker of the pineapple processing cell

By drawing a graph of cycle time vs. process activity, Pace Maker process and required capacity was identified based on Takt rate of production

3.5.3 Line balancing

Processing steps that exceed the Takt rate of production was identified on the basis of the above graph and future production flow was developed to achieve the Takt rate of production by automated the processing steps as a continuous process.

3.6 Development of future state map

Future state map was created based on the future production flow by combining some number of processing steps to a one step.

3.7 Development of Implementation plan

Implementation plan was developed to make the process lean by propose to install several automated machines.

3.8 Development of budget to make the process lean

Budget was developed according to the implementation plan.

3.9 Performing of Cost benefit analysis

Cost benefit analysis was performed by comparing the pre lean and post lean measures.

Chapter 04

RESULTS AND DISCUSSION

4.1 Defining of scope

Lean tools and techniques are applied to the pineapple chunk processing cell to remove the non value added wastes from the moment the customer gives the company an order to the point when they collect the cash.

4.2 Current Stability and Capability of the Organic Pineapple Processing Cell

Once a process is in statistical control that is producing consistently, probably then wants to determine if it is capable, that is meeting specification limits and producing "good" products confirm to the specifications. By comparing the width of the process variation it can determine process capability, with the width of the specification limits. The process needs to be in control before the assessment of its capability; if it is not, then will get incorrect estimates of process capability. It can assess process capability graphically by drawing capability histograms and capability plots. These graphics help to assess the distribution of data and verify that the process is in control. It can also calculate capability indices (Cpk), which are ratios of the specification tolerance to the natural process variation. The results of chemical and physical attributes, are summarized below

4.2.1 Process Capability Analysis for Total Soluble Solids (Brix) of pineapple juice

Pineapple chunks are packed in its own juice. The juice is concentrated to required strength by heating. Refractometer reading (Brix value) is used to measure the concentration of the juice .Brix is a measurement of the soluble solids content, mainly the sugars of a juice. 1°Brix = 1% sugar w/w. The brix range of extracted clarified pineapple juice (liquid filling) need to be maintained 12-14°, as to the company specification manual (Appendix 01).

According to the Figure 4.01, The Cpk index was calculated using MINITAB computer aided statistical analysis software at 3 sigma level. It indicates whether the process will produce units within the tolerance limits. The Cpk index for Brix is 1.09 it is higher than 1, indicating that the process is capable of producing product within the specification width for total soluble solids at 3 sigma tolerance level.

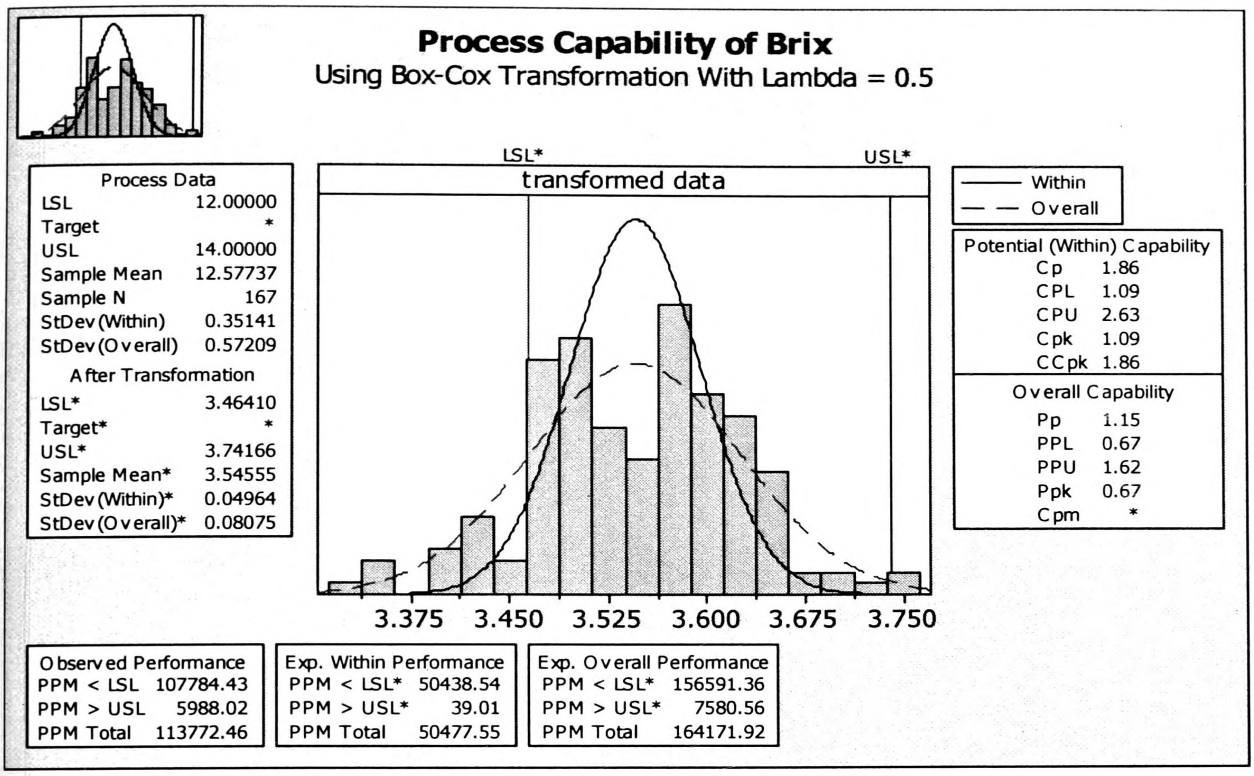


Figure 4.01: Graphical representation of capability analysis for total soluble solids

4.2.2 Process Capability Analysis for pH

The pH value of a food is a direct function of the free hydrogen ions present in that food. Microorganisms, including yeasts, molds and bacteria are sensitive to a food's pH. The pH of a canned food plays a key role in determining the extent of heat processing needed to insure a safe final product. Since the product's pH range maintained at 3.3-3.9 there is no fear of *Clostridium botulinum* growth, these foods require much less heating than low-acid foods. To be safe, such foods need only to reach pasteurization temperatures of 185°F (85°C). These pasteurization temperatures are sufficient to kill all microorganisms except for bacterial spores. Since the spores will not grow because of the low pH. Hence the maintaining of pH value of the product within the above range has great importance.

According to the Figure 4.02, the Cpk index for pH is 1.95, indicating that the processing line is within the specification width for the pH value at 3 sigma limit.

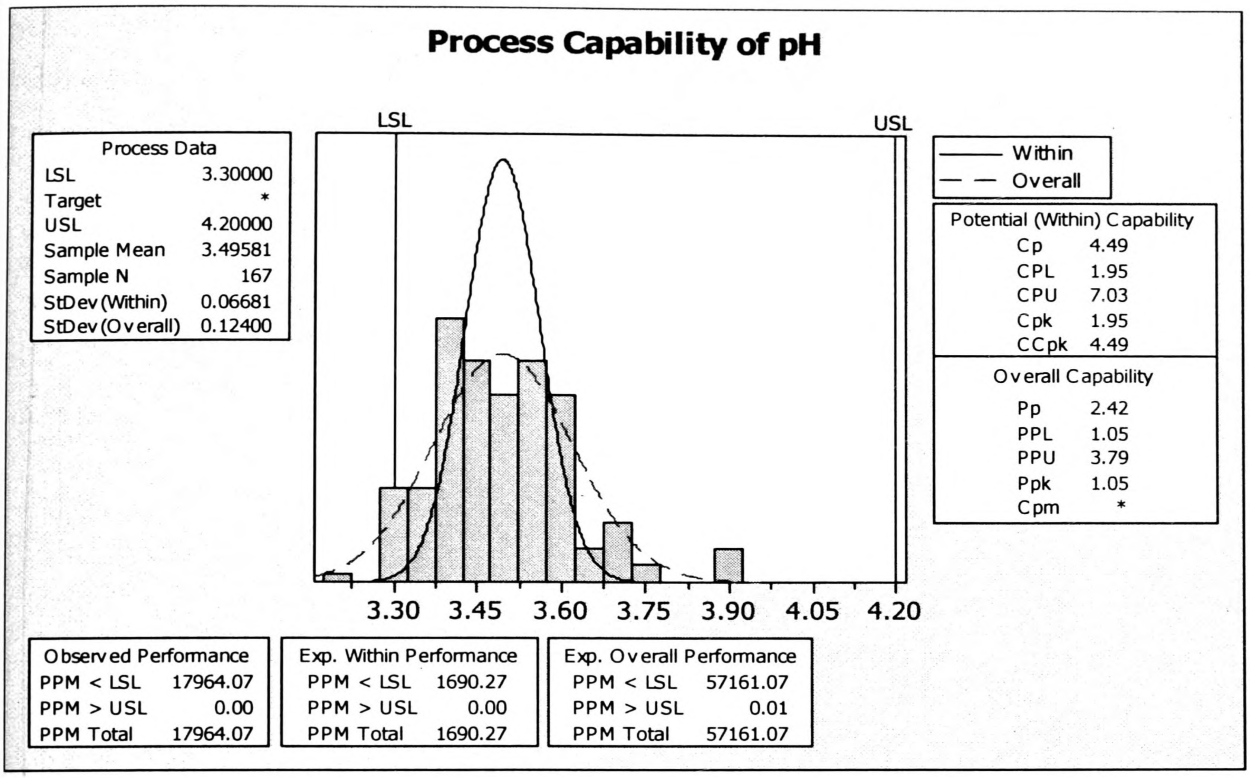


Figure 4.02: Graphical representation of capability analysis for pH

4.2.3 Process Capability Analysis for Net Weight

As to the Figure 4.03 , the Cpk index for net weight is 0.46, indicating that it needs to improve the process by reducing variability and centering the process on the target.

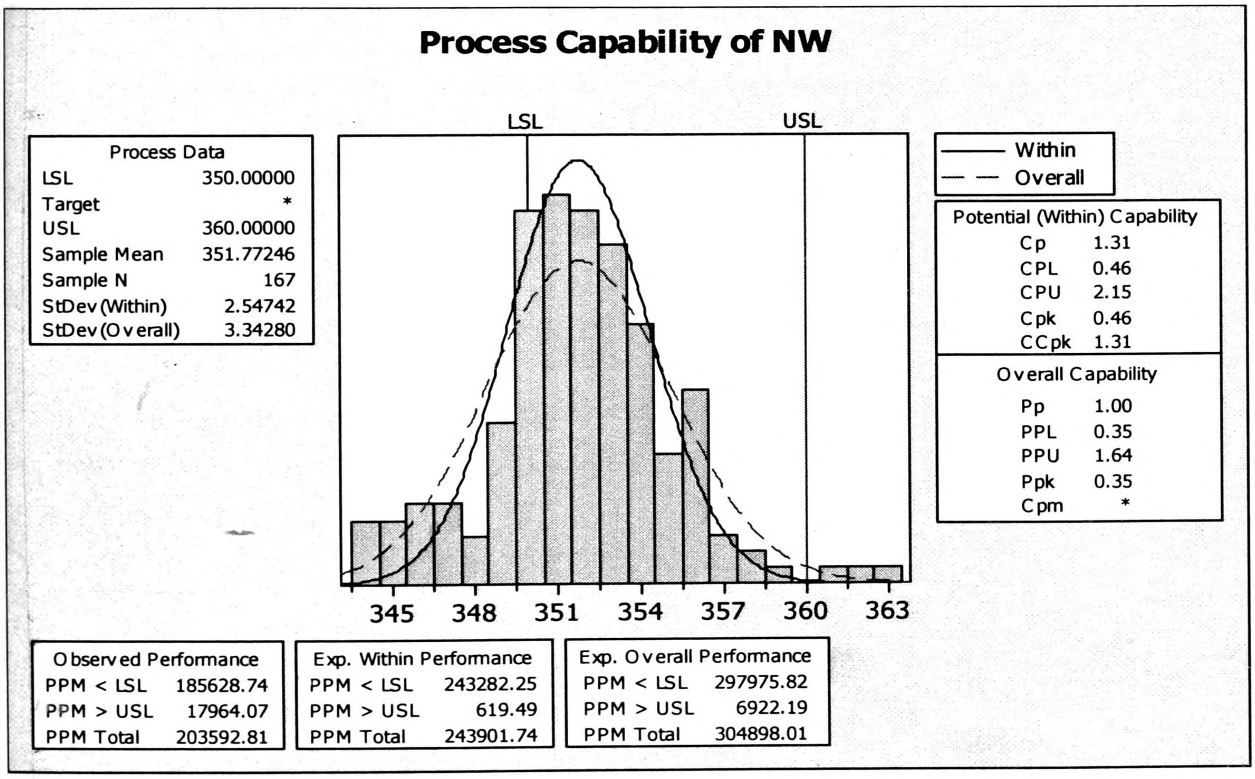


Figure 4.03: Graphical representation of capability analysis for Net Weight

4.2.4 Process Capability Analysis for Net Drained Weight

As illustrated in the Figure 4.04, the Cpk index for net drained weight is 1.31, indicating that the processing line is within the specification width for net drained weight.

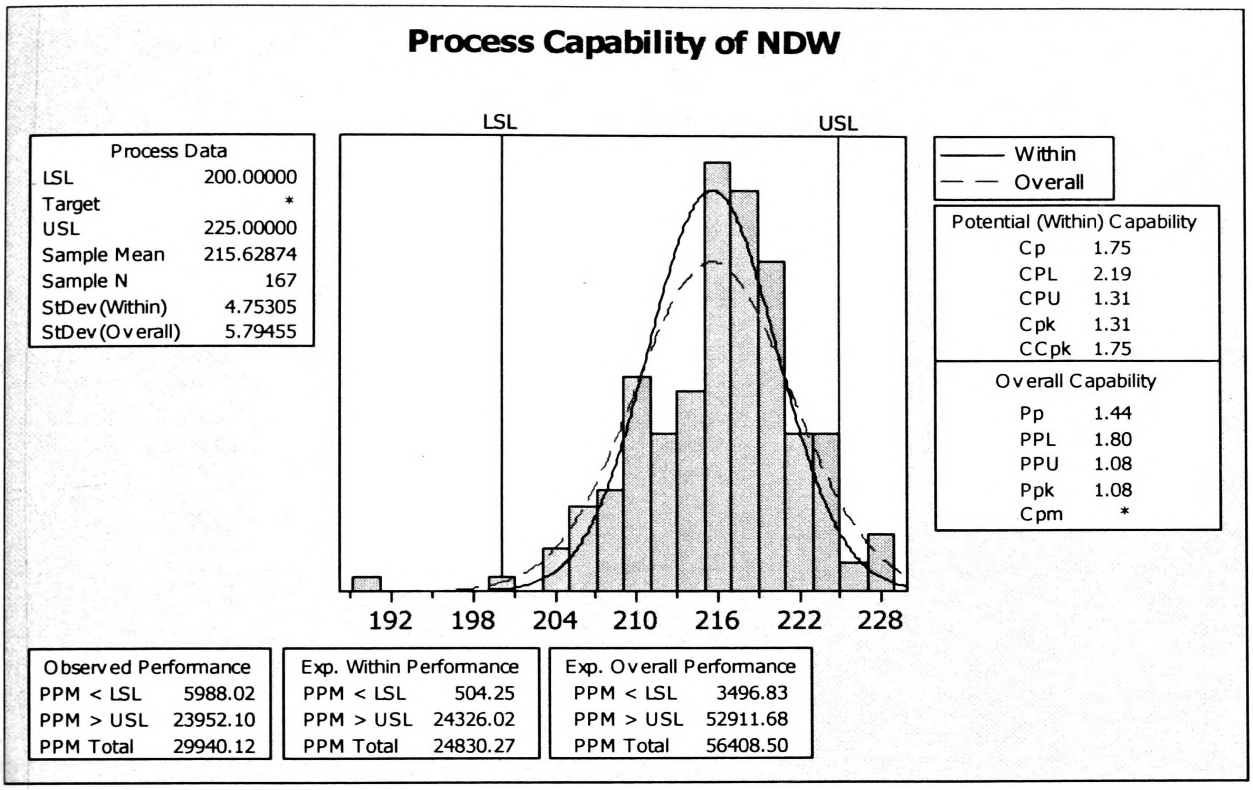


Figure 4.04: Graphical representation of capability analysis for Net Drained Weight

According to the above results it can conclude that the processing line is capable of meeting the specifications except net weight where processing cell needs improvements of the finished product.

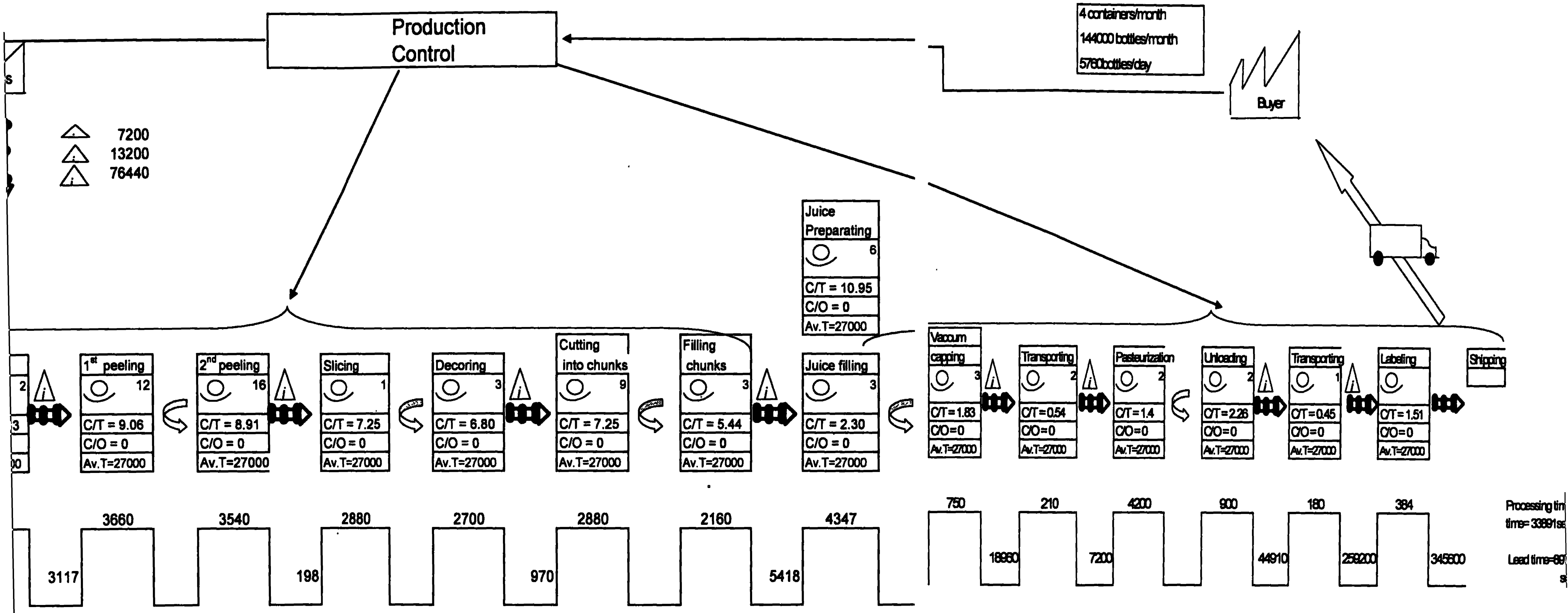
4.3 Current State Map

Cycle times, no of workers and processing time of each activity of the processing steps in the cell was measured after walking through the processing floor, selecting a lot size of 397 jars. These data are given in Table 4.1.

Table 4.1: Processing Time for a Batch of 397 Jars (Organic pine apple chunk in 350ml Jar)

Ac No.	Activity	Processing time (min)	Cycle time (Sec.)/Jar	No of workers
01	Issuing	15.00	2.26	2
02	Removing stem & crown	30.50	4.60	2
03	Washing	38.50	5.83	2
04	1st peeling	60.00	9.06	12
05	2nd peeling	59.00	8.91	16
06	Slicing	48.00	7.25	1
07	Decoring	45.00	6.80	3
08	Cutting into chunks	48.00	7.25	9
09	Filling chunks into jars	36.00	5.44	3
10	Juice extraction	73.00	10.95	6
11	Juice filling	15.50	2.30	3
12	Vacuum capping	12.50	1.83	2
13	Transporting to pasteurization	03.50	0.54	2
14	Pasteurization	70.00	4.20	2
15	Unloading	15.00	2.26	2
16	Transporting to ware house	3.00	0.45	1
17	Labeling	10.00	1.51	10
	Total	582.50	81.44	78

As indicated above total processing time from issuing to labeling for batch of 397 jars of organic pine apple chunk is about 582.5 minutes. Labeling was not done on the same day of processing there was a retention time of over 8 hours from the pasteurizer. According to these data current state map was developed (Figure 4.05).



Production Control
4 containers/month
144000 bottles/month
5760bottles/day
Buyer
7200
13200
76440
1st peeling 12 C/T = 9.06 C/O = 0 Av.T=27000
2nd peeling 16 C/T = 8.91 C/O = 0 Av.T=27000
Slicing 1 C/T = 7.25 C/O = 0 Av.T=27000
Decoring 3 C/T = 6.80 C/O = 0 Av.T=27000
Cutting into chunks 9 C/T = 7.25 C/O = 0 Av.T=27000
Filling chunks 3 C/T = 5.44 C/O = 0 Av.T=27000
Juice Preparating 6 C/T = 10.95 C/O = 0 Av.T=27000
Juice filling 3 C/T = 2.30 C/O = 0 Av.T=27000
Vaccum capping 3 C/T=1.83 C/O=0 Av.T=27000
Transporting 2 C/T=0.54 C/O=0 Av.T=27000
Pasteurization 2 C/T=1.4 C/O=0 Av.T=27000
Unloading 2 C/T=2.26 C/O=0 Av.T=27000
Transporting 1 C/T=0.45 C/O=0 Av.T=27000
Labeling C/T=1.51 C/O=0 Av.T=27000
Shipping
3117
3660
3540
198
2880
2700
970
2880
2160
5418
4347
750
18960
210
7200
4200
900
44910
180
259200
384
345600
Processing tim time= 33891se
Lead time=89

essing Cell

4.4 Analysis of Current state of the pineapple processing cell

4.4.1 Process cycle efficiency (PCE)

PCE measures the percentage of value added time from the lead time of a particular cell. PCE can be calculated by obtaining value added time (approximately the total processing time) and divided by the lead time.

$$PCE = \frac{\text{Value added time}}{\text{Lead time}}$$

Value added time (Processing time) = 33891 seconds

Lead time = 897776 seconds

$$PCE = \frac{33891 \text{ seconds}}{897776 \text{ seconds}} * 100\%$$

$$= 3.77\ \%$$

PCE of the organic pineapple processing cell is 3.77%.Hence it can be concluded that the cell is not a lean process at present. As a lean process is one in which the value – added time in the process is more than 25% of the total lead time of that process. So that, there is a potential of increase the performance of the pine apple processing cell.

4.4.2 Stock Productivity of the Pineapple Chunk Processing Cell

Stock Productivity (SP) = Stock turnover * Gross profit margin

Stock turn over = Sales /Average Stock

Sales = Rs.2637360

$$\text{Average Stock} = \frac{\text{Opening Stock - Closing Stock}}{2}$$

= RS.967068.05-Rs.264161.45 / 2

= Rs.702906.60 /2

= Rs.351453.30

Stock turn over = Rs.2637360/ Rs.351453.30

= 7.50

Gross profit margin = 10%

Stock productivity (SP) = 7.5*10

= 75%

Currently the cell has 75% of stock productivity.

4.5 Lean strategies

4.5.1 Takt Time

Takt time refers to the rate at which customers are buying products from the production line; i.e. the unit production time that must be met to match customer requirements. Takt time is calculated as follows.

$$\text{Takt time} = \frac{\text{Available Time (work time-rest time)}}{\text{Daily Demand}}$$

The throughput required for the products is an average of 144000 jars per month. Assuming that organic fruit processing cell runs 25 days per month, the average daily requirement is 5760 jars per day. The cell also runs one shift per day, which translates to 27000 seconds per day. The result is approximately 4.68 seconds Takt time per a jar.

$$\text{Available time} = 27000 \text{ seconds/day}$$

$$\text{Daily demand} = \frac{144000}{25} = 5760 \text{ jars/day}$$

$$\text{Therefore, Takt rate of production} = \frac{27000 \text{seconds/day}}{5760 \text{ jars/day}} = 4.68 \text{ seconds}$$

This Takt time means that one jar must be completed every 4.68 sec. on an average.

4.5.2 Identification of Pace Maker

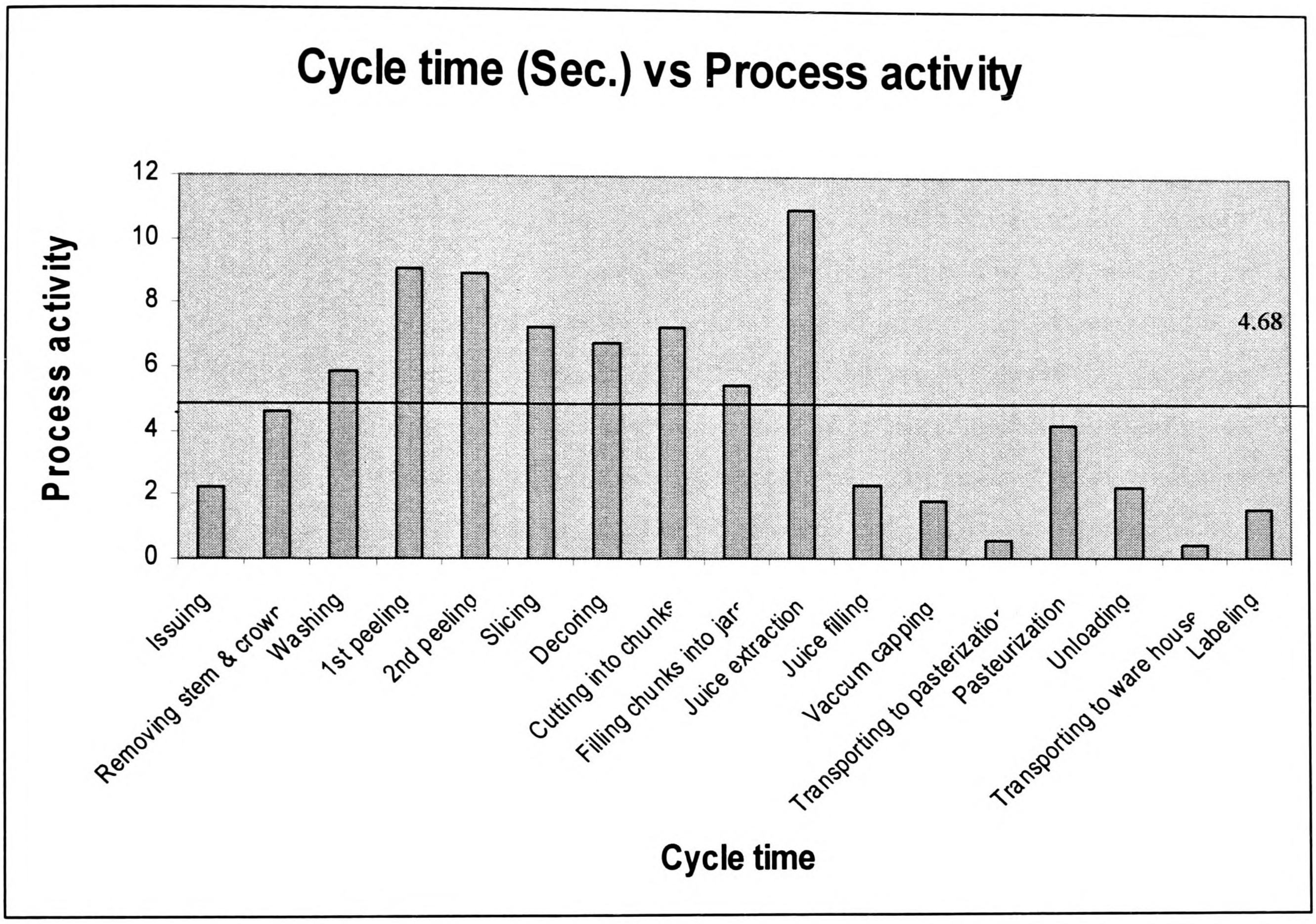


Figure 4.06: Graphical Representation of Cycle time vs. process activity

According to the Figure 4.6, juice extraction consumes the highest cycle time in the organic pineapple chunk processing cell. Since it was identified as the pace maker of the process, while the 1st peeling ,2nd peeling ,slicing ,de coring and cutting into chunks also exceed the Takt time(4.68 sec.) to produce a jar. It was also identified the cell is not a balanced production line and time is wasted at above steps. Hence it is necessary to reduce the time taken to take off a finished product from a cell in order to make the process lean. The way to do this is to reduce lead time and reduce the cycle time of the processes. Therefore it is necessary to create continuous flow or one piece flow of the above processes.

4.5.3 Line Balancing

It was observed that there is an imbalance of the production line, due to that it is impossible to meet the Takt rate of production. As can see from the Figure 4.6 ,out of 15 processing activities of the cell, processes such as juice extraction, 1st peeling ,2nd peeling ,slicing ,de coring and cutting into chunks are considered to be major wastages, because these steps exceed the Takt rate of production. There are some processes which have not utilized their resources up to the level such as issuing, juice filling, transporting, capping. In both ways HJSC make losses as the optimum condition of a process is Takt time equaling to the process cycle time. Time taken for juice extraction is the highest due to the inefficiency of machines and unnecessary movements that need to be done by the people. Because it needs to pass three different machines to extraction the juice and another one for heating. This inefficiency however lead to large number of inventory of jars at the point of juice filling, there is again a inventory at the point of pasteurization it need to transport the filled jars to the pasteurizer using a forklift. So it is necessary to make a balance in all processes of pineapple processing cell to be in line with the Takt rate of production. Figure 4.07 is illustrated the graph of cycle time vs. process activity after line balancing.

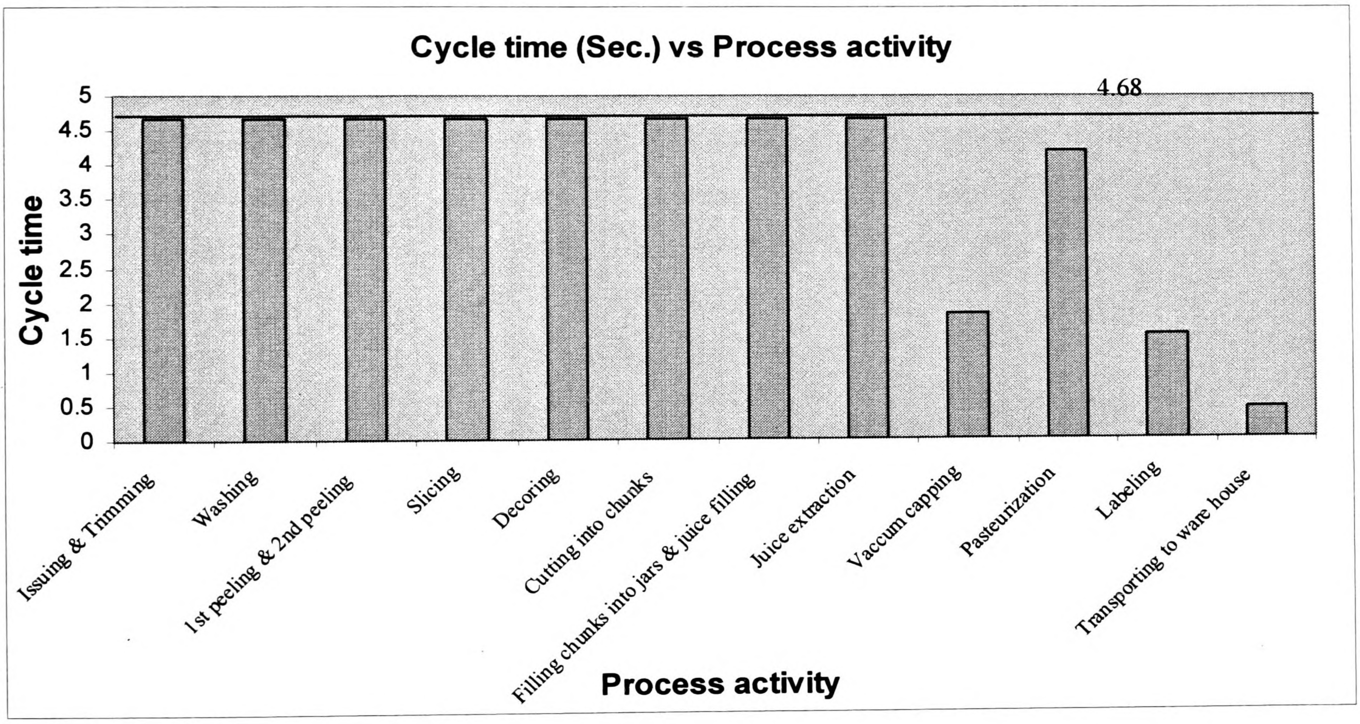


Figure 4.07: Graphical representation of Cycle time (sec.) vs. Process Activity after Line Balancing

4.6 Future State Map

In developing the future state map, metrics that have been calculating under lean strategies need to be considered, which indicates what opportunities available to make the organic pineapple chunk processing cell lean.

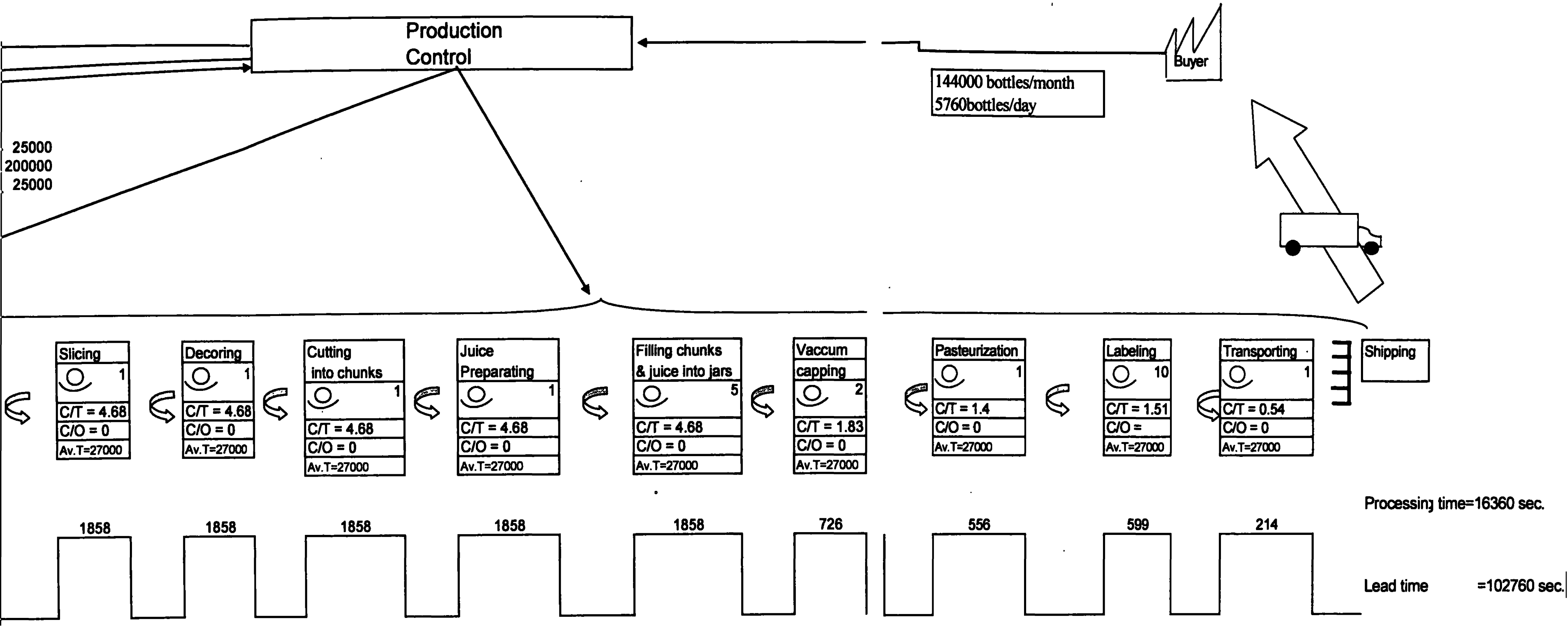
After careful analyzing of the current state map (Figure 4.05) following problems can be identified.

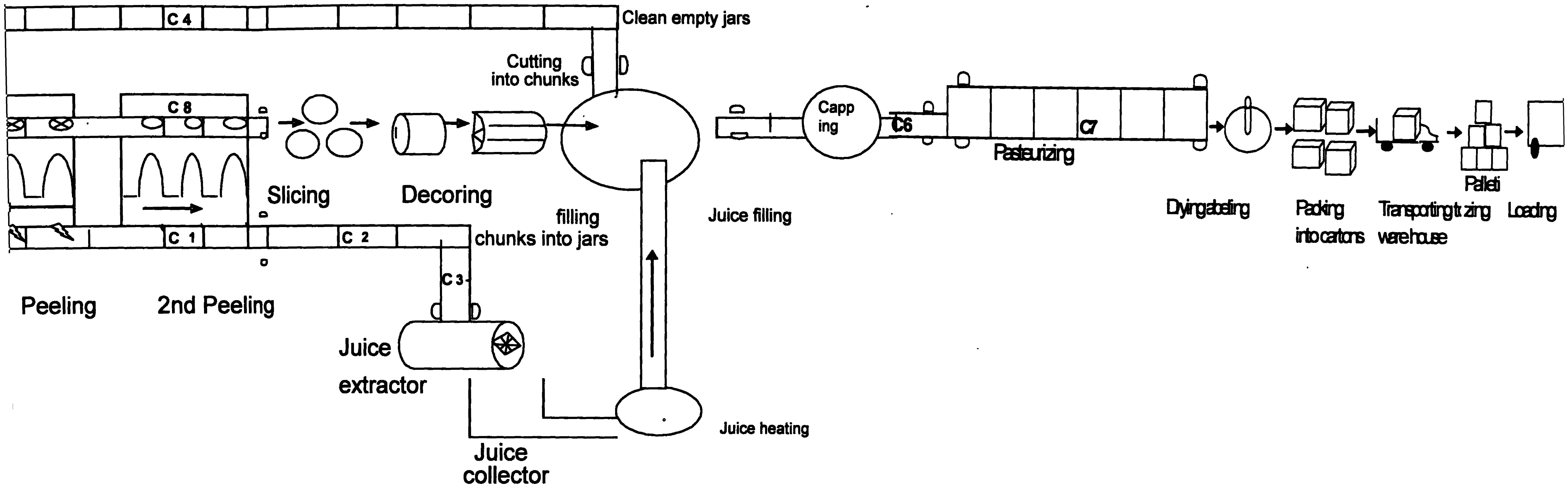
- Rhythm of production in the cell has no control and most steps in the production process are done in the basis of PUSH, and not in the basis of PULL.

- Most of the processes exceed the Takt rate of production while pace maker process takes 10.95 sec. to produce a finished jar. Hence it was observed that these times necessary to reduce up to the level of 4.68 sec. to fulfill the customer demand.

- PCE of the pineapple processing cell is lower than the 25%, so the reduction of lead time is a must to make the process efficient.

A future state map (Figure 4.08) designed to solve all the above problems by applying lean tools and techniques. Then the Future production flow (Figure 4.09) and implementation plan also developed on the basis of the future state map.


Production Control
Buyer
144000 bottles/month
5760bottles/day
25000
200000
25000
Slicing
1
C/T = 4.68
C/O = 0
Av.T=27000
Decoring
1
C/T = 4.68
C/O = 0
Av.T=27000
Cutting into chunks
1
C/T = 4.68
C/O = 0
Av.T=27000
Juice Preparating
1
C/T = 4.68
C/O = 0
Av.T=27000
Filling chunks & juice into jars
5
C/T = 4.68
C/O = 0
Av.T=27000
Vaccum capping
2
C/T = 1.83
C/O = 0
Av.T=27000
Pasteurization
1
C/T = 1.4
C/O = 0
Av.T=27000
Labeling
10
C/T = 1.51
C/O =
Av.T=27000
Transporting
1
C/T = 0.54
C/O = 0
Av.T=27000
Shipping
1858
1858
1858
1858
1858
726
556
599
214
Processing time=16360 sec.
Lead time =102760 sec.



Clean empty jars
C 4
C 8
Cutting
into chunks
Slicing
Decoring
filling
chunks into jars
C 1
C 2
C 3
Peeling
2nd Peeling
Juice
extractor
Juice
collector
Juice filling
Juice heating
Capp
ing
C6
C7
Pasteurizing
Palleti
Packing
into cartons
Loading

4.7 Implementation Plan

Following suggestions can be made to achieve Takt rate of production by eliminating non-value added time of the pineapple cell, which can be indicated as follows.

4.7.1 Create one piece flow introducing conveyor system for issuing fruits

Fruit issuing to the production, removal of stem and crown and washing activities can be combined by introducing conveyor system as illustrated in the future production flow diagram (Figure 4.09).

4.7.2 Designing of feeding table to create a continuous flow

During the study it was understood that 1st and 2nd peeling activities are highly labour involved and need to be improved. Introduction of a peeling machine is extremely difficult as because of the shape of Sri Lankan-grown Mauritius (Queen Group) pineapples and suggestion is made to introduce special feeding table which is equipped with three conveyor belts to carry the waste, raw fruits and peeled fruits as illustrated in the diagram (Figure 4.09). Introduction of the feeding table will create one piece flow eliminating all the inventories. It also has the facility to deliver the 2nd peel to the juice extracting machine for continuous juice extraction.

4.7.3 Automation of juice extraction

It is high priority to set up efficient juice extraction process with Brown Press, which is known to be the most efficient machine so far developed for pineapple juice extraction in the world, as it is the most inefficient process of the pineapple cell. Current juice extraction process is done with three machines and waste time and material significantly. With the aid of Brown Press (Appendix 05) non value added time of juice extraction process can be eliminated. More importantly it will also reduce inventory of filled jars prior to juice filling.

4.7.4 De coring

In the current process de coring is manually done and creates unnecessary inventory and waste. To make this activity efficient and continuous it is recommended to introduce de coring machine with two sizes.

4.7.5 Cutting

Current cutting process is completely manual process and create inventory. Manual cutting also makes uneven pieces giving a dull appearance to the product. To convert this activity into one piece flow and also to improve appearance of the finished product it is recommended to introduce automatic tidbit cutter (Appendix 06).

4.7.6 Chunks and juice filling

Currently chunks filling and juice filling are two separate activities and it is recommended to combine these two activities by creating a cell as illustrated in the future flow diagram (Figure 4.09).

4.7.7 Loading of jars to the pasteurizer

It is of high priority to install a conveyor belt form capping machine to the pasteurizer.Regullar accumulation of jars at the point of pasteurization and the delaying of loading to the pasteurizer are critical to both time and quality and installation of conveyor belt will improve quality of the product while creating a continuous flow.

4.7.8 The labeling

Current labeling process is done far away from the pasteurizer and doesn't make complete product at the end of the day. So it is necessary to install a labeling machine at the end of the pasteurizer to have a complete product at the end of the day.

4.7.9 Development of competency level of the staff

It was understood that efficiency of the pineapple cell depends lot on competence level of the workers work there and multifunction worker training will increase productivity of the cell. So it is recommended to have multifunction worker training time table as illustrated bellow (Figure 4.10) to improve competence of the workers for better productivity of the cell.

Name Section/Group Date														Remarks			
														Capabilities			Man power needs Work manner
No.	Name																
1		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
2		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
3		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
4		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
5		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
6		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
7		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
8		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
9		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
10		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
Result of training	Beginning of year													● 100% performance			
	Middle of year													◕ 75% performance			
	End of year													◑ 50% performance			
Remarks	Jobs Needs													⊕ in training			

Figure 4.10: Multi function worker training time table

4.8 Budget to Make The Process Lean

Table 4.2: Budget to Make the Process Lean

Item No.	Item	Cost LKR
01	Sorting & trimming belt	200,000.00
02	Washing bath	18,000.00
03	1st peeling table & 2nd peeling table	500,000.00
05	Peel waste bin	50,000.00
06	Slicing machine	5,528,244.00
07	De coring machine	880,230.00
08	Disintegrator	1,032,300.00
09	Juice extractor	2,153,400.00
10	Jar Delivery Conveyer Belt 1	200,000.00
11	Jar Delivery Conveyer Belt 2	200,000.00
12	Empty Jar Washing Machine	1,200,000.00
13	Installation Charges (including electricity & pneumatic)	600,000.00
Total		**12,562,174.00**

4.9 Cost Benefit Analysis

Table 4.3: PCE before and after the Lean project

Criteria	**Pre-Lean**	**Post- Lean**
Processing time	33891 sec.	16360 sec.
Lead time	897776 sec.	102760sec.
Process Cycle Efficiency	3.77%	15.92%
Labour allocation	78	47
LKR Savings per jar	-	(10.95-4.68) /3600 * 3132
LKR Savings per day	-	(10.95-4.68)/3600* #3132*5760
LKR Saving per annum 144000* 12	-	(10.95-4.68)/3600* #3132*144000*12=9.42 MN
LKR Saving per annum	-	**9.420,000 .00**

#3132 LKR; cost per an hour of the cell

CHAPTER 05

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

- Pineapple chunk processing line is capable of meeting the specifications except net weight where processing cell needs improvements of the finished product.

- PCE of the organic pineapple processing cell is 3.77%.Hence it can be concluded that the cell is not a lean process at present

- Juice extraction consumes the highest cycle time (10.95 sec.) in the organic pineapple chunk processing cell. Since it is identified as the pace maker of the process, while the 1st peeling ,2nd peeling ,slicing ,de coring and cutting into chunks also exceed the TAKT time (4.68 sec.) to produce a jar

- Through the implementation plan it can achieve the TAKT rate of production by developing the new production flow. Thereby it can increase the PCE up to the level of 15.92%

- By implementing the project it can save LKR 9.42 million per annum although the project initiation cost is estimated as LKR 12.56 million.

5.2 Recommendation

- It is suggested to implement lean manufacturing system for the whole range of production processes in order to reach the optimum level of productivity which will enable the HJSC would be a lean enterprise

REFERENCES

Abdullah , F. (2003), Lean Manufacturing Tools and Techniques in the Process Industry with a Focus on Steel,(Accessed from: http://etd.library.pitt.edu/ETD/ available/etd-05282003-114851/unrestricted/Abdullah.pdf,13th May 2003)

Dirgo,R (2005) Look Forward Beyond Lean & Six Sigma,J Ross publishing USA, pp226

Liker, J.K.(2006),The Toyota Way,Tata McGraw-Hill publishing Company Limited India, pp330

Liker ,J.K., Lamb T.(2000), Lean Manufacturing Principles Guide version 05 (Accessed from http://www.usashipbuilding.com/projects/deliverables/ase_910001.pdf, June 26th 2000)

Liker, J.K,Meier D.(2006),The Toyota Way Field Book, Tata McGraw-Hill Publishing Company Limited India, pp520

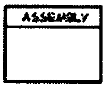
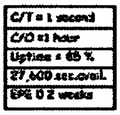
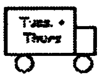
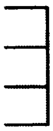
Toyota Motor Corporation(1997-2007),Vision and Philosophy,(Accessed from: http://www.toyota.co.jp/en/vision/production_system/,3rd July 2007)

Zidel,T.G.(2006),A Lean Guide to Transforming Health Care,ASQ Quality press Wisconsin, pp169

APPENDIX

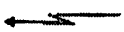
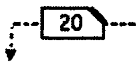
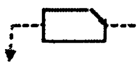
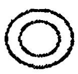
Appendix I

MATERIAL FLOW ICONS

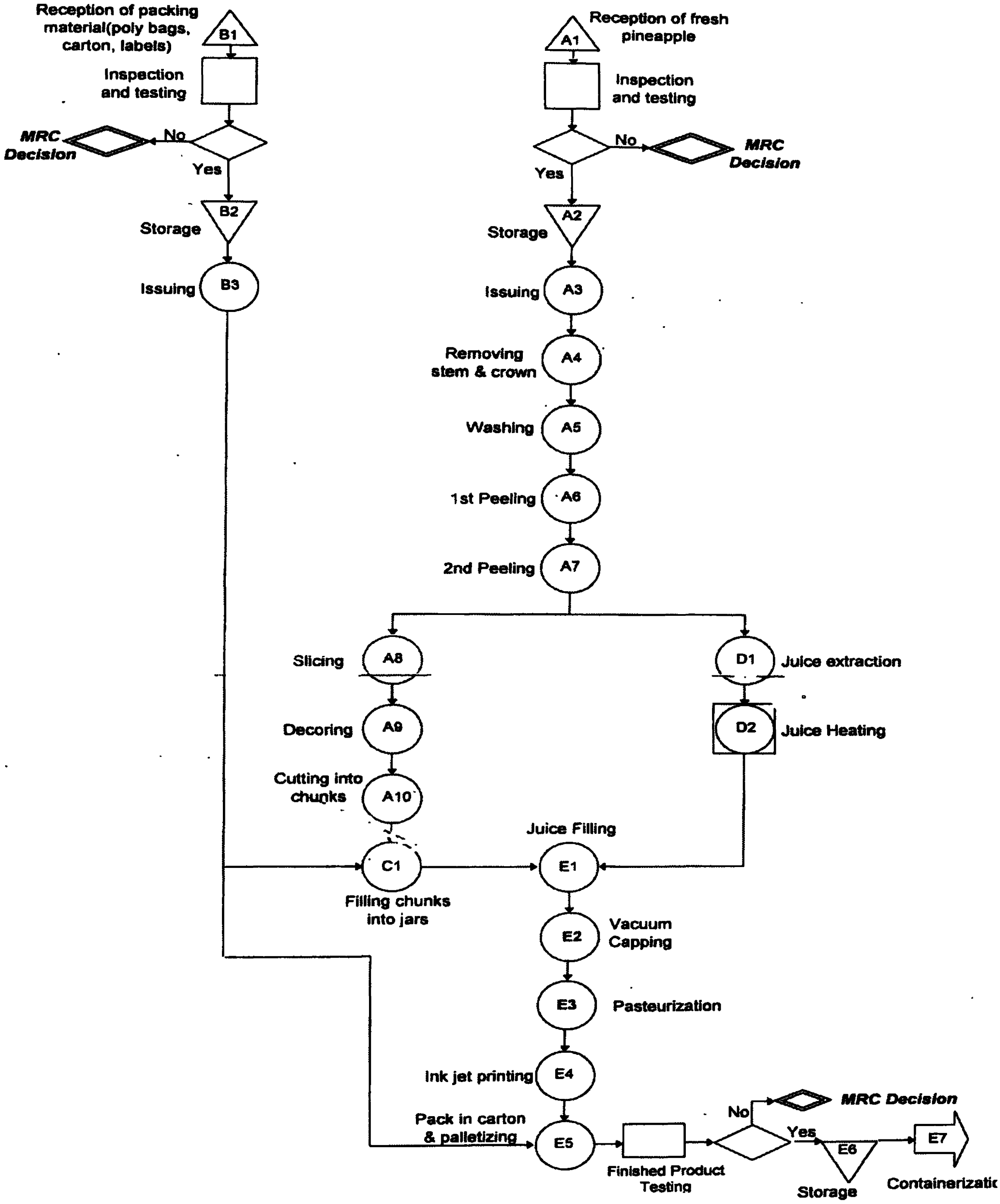
	Represents	Notes
	Manufacturing Process	One process box equals an area of flow. All processes should be labeled. Also used for departments, such as Production Control
	Outside Sources	Used to show customers, suppliers, and outside manufacturing processes
	Data Box	Used to record information concerning a manufacturing process, department, customer, etc.
	Inventory	Count and time should be noted
	Truck Shipment	Note frequency of shipment
	Movement of production material by push	Material that is produced and moved forward before the next process needs it; usually based on a schedule
	Movement of finished goods to the customer	
	Supermarket	A controlled inventory of parts that is used to schedule production at an upstream process
	Withdrawal	Pull of materials, usually from a supermarket
	Transfer of controlled quantities of material between processes in a „First-In-First-Out“ sequence	Indicates a device to limit quantity and ensure FIFO flow of material between processes. Maximum quantity should be noted

Appendix II

INFORMATION FLOW ICONS

	Represents	Notes
	Manual Information flow	For example: production schedule or shipping schedule
	Electronic Information Flow	For example via electronic data interchange
	Information	Describes an information flow
	Production Kanban (dotted line indicates Kanban paths)	The „One-per-container" kanban. Card or device that tells a process how many of what can be produced and gives permission to do so.
	Withdrawal Kanban	Card or device that instructs the material handler to get and transfer parts (i.e. from a supermarket to the consuming process).
	Signal Kanban	The „one-per-batch" kanban. Signals when a recorder point is reached and another batch needs to be produced. Used where supplying process must produce in batches because changeovers are required.
	Sequenced-Pull Ball	Gives instruction to immediately produce a predetermined type and quantity, typically one unit. A pull system for subassembly processes without using a supermarket.
	Kanban Post	Place where kanban are collected and held for conveyance.
	Kanban Arriving in Batches	
	Load Leveling	Tool to intercept batches of kanban and leve the volume and mix of them over a period of time.
	„Go See" Production Scheduling	Adjusting schedules based on checking inventory levels.

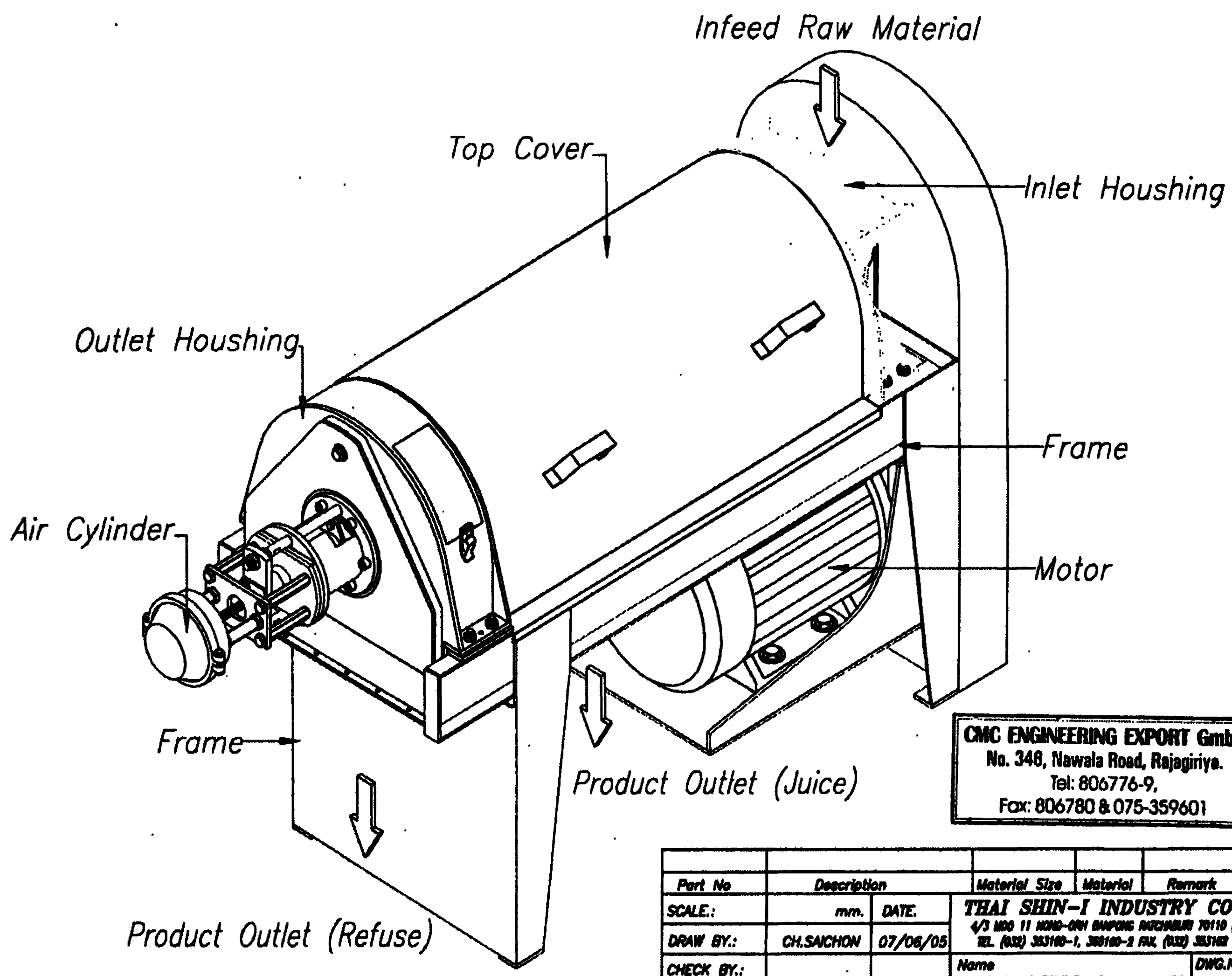
PROCESS FLOW DIAGRAM



HJS CONDIMENTS LIMITED	SPECIFICATION MANUAL	Section : XII
	ORGANIC PINEAPPLE CHUNKS 6/350 ml	Page : 116
		Issue No. : 1
		Issue Date : 20.10.2006

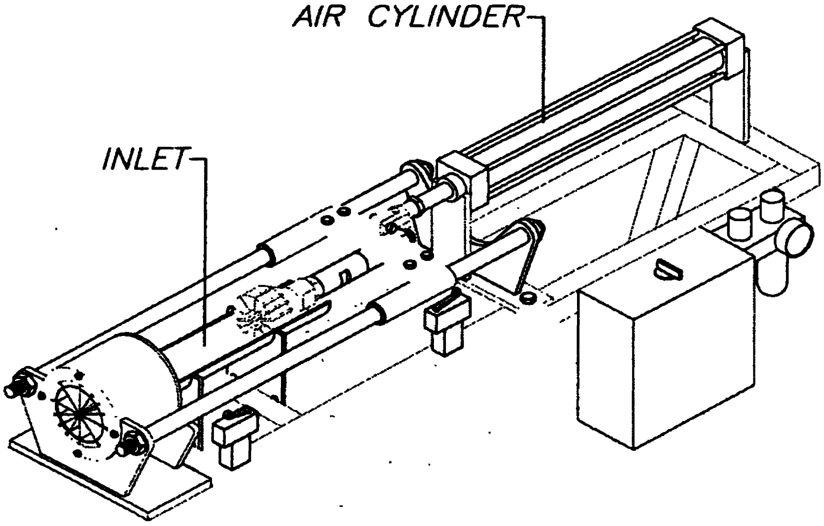
Product Description	Whole sweet & sour I from & half of ripped pineapple chunks & juice to be directly consumed without pre-preparation, as an appetizer or as an ingredient of a fruit salad. Could be consumed by high risk groups (immuno compromised, elderly etc.). Product to be sold in fast food chains, hotels, restaurants, supermarkets and in departmental stores.
Physical Attributes	Net Weight : ≥ 350 g Net Drained Weight : ≥ 200 g Count Per Jar : NA Vacuum : NA Cap Security : 3 – 9 mm
Chemical Attributes	PH : 3.3 -3.9 Total Soluble Solids (° Brix) : 12 – 14 °
Microbiological Attributes	Total plate Count at 35° : Below 300 CFU / g Coliforms : Negative Yeast & Mould Count : Below 10 CFU / g Salmonella : Negative
Pineapple	Type : Fresh Pineapple Texture : Firm Colour : Major Defects (Rotten / Spoil, Peeled off) : Nil Minor Defects (Mechanical damages) :
Solid Spices per jar	NA
Liquid Recipe	Pineapple juice Only.
Packaging	Jar : 350 ml . Cap : 63 mm gold
Shelf Life	Expiry Date – 2 Years from th[illegible] at normal retail temperatures.
Ink Jet printing	Top of the cap Factory Code Year Month Date Batch BATCH 0 0 00 00 0 00. 00 Date Month Year
Labeling	Organic Pineapple 350 g Labels
Type of Carton	Un Printed Cartons 6/350
Pallet	NA
Carton Arrangement	No of jars/ Carton - nos No of Cartons / Container - nos
Special Distribution Control	No physical damage, exposure to excess humidity or temperature extremes.

PREPARED BY Asst .Manager – Production Control	REVIEWED BY Asst. Manager – Production	APPROVED BY General Manager – Production



CMC ENGINEERING EXPORT GmbH
No. 346, Nawala Road, Rajagiriya.
Tel: 806776-9,
Fax: 806780 & 075-359601

Part No	Description		Material Size	Material	Remark	Q.T.Y.
SCALE.:	mm.	DATE.	THAI SHIN-I INDUSTRY CO.,LTD.			
DRAW BY.:	CH.SAICHON	07/06/05				
CHECK BY.:			Name: BROWN PRESS		DWG.No. PRESS-01.	
APPROVE BY.:						



OVERALL DIMENSIONS : W50xL130xH102cm.

Part No	Description	Material Size	Material	Remark	Q.T.Y.

SCALE.:			THAI SHIN-I INDUSTRY CO.,LTD. 4/3 MOO 11 NONG-ORH BANPONG RATCHABURI 70110 (THAILAND) TEL. (032) 353160-1, 368160-2 FAX. (032) 353162	
DRAW BY.:	CH. SAICHON	30/4/03		
CHECK BY.:			Name AUTO.TIDBIT CUTTER	DWG.No. TIDBIT-06
APPROVE BY.:				

D:\TSI001\DRAW-ISO\TIDBIT-06-ISO

National Digitization Project

National Science Foundation

Institute : Sabaragamuwa University of Sri Lanka

1. Place of Scanning : Sabaragamuwa University of Sri Lanka, Belihuloya
2. Date Scanned : 2017-09-25
3. Name of Digitizing Company : Sanje (Private) Ltd, No 435/16, Kottawa Rd, Hokandara North, Arangala, Hokandara
4. Scanning Officer

Name : S.A.C. Sadaruwan

Signature : ......

Certification of Scanning

I hereby certify that the scanning of this document was carried out under my supervision, according to the norms and standards of digital scanning accurately, also keeping with the originality of the original document to be accepted in a court of law.

Certifying Officer

Designation : Librarian

Name : T. N. Neighsoorei

Signature : ......

Date : 2017-09-25

Mrs.T.N.NEIGHSOOREI
(MSSc.PGD.ASLA,BA)
Librarian
Sabaragamuwa University of Sri Lanka
P.O.Box 02 Belihuloya,Sri Lanka
Tele.0094 45 2280045
Fax:0094 45 2280045

"This document/publication was digitized under National Digitization Project of the National Science Foundation, Sri Lanka"