# APPLYING TOYOTA PRODUCTION SYSTEM TO A LOCAL GLASS MANUFACTURER IN THAILAND: A CASE STUDY OF PMK-CENTRAL GLASS COMPANY LTD.

BURANIT RATTANACHUEN

A THEMATIC PAPER SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF BUSINESS ADMINISTRATION (BUSINESS MODELING AND ANALYSIS)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
2010

Thematic Paper
entitled

# APPLYING TOYOTA PRODUCTION SYSTEM TO A LOCAL GLASS MANUFACTURER IN THAILAND: A CASE STUDY OF PMK-CENTRAL GLASS COMPANY LTD.

……………………………………
Ms. Buranit Rattanachuen
Candidate

……………………………………
Mr. Pandej Chintrakarn, Ph.D.
Major-advisor

……………………………………
Ms. Ornlatcha Sivarak, Ph.D.
Co-advisor

……………………………………
Prof. Banchong Mahaisavariya,
M.D., Dip Thai Board of Orthopedics
Dean
Faculty of Graduate Studies
Mahidol University

……………………………………
Asst. Prof. Yingyot Chiaravutthi, Ph.D.
Program Director
Master of Business Administration
Program in Business Modeling and Analysis
International College
Mahidol University

Thematic Paper
entitled

# APPLYING TOYOTA PRODUCTION SYSTEM TO A LOCAL GLASS MANUFACTURER IN THAILAND: A CASE STUDY OF PMK-CENTRAL GLASS COMPANY LTD.

was submitted to the Faculty of Graduate Studies, Mahidol University
for the degree of Master of Business Administration
(Business Modeling and Analysis)
on
November 27, 2010

……………………………………
Ms. Buranit Rattanachuen
Candidate

……………………………………
Asst. Prof. Sittisak Leelahanon, Ph.D.
Chair

……………………………………
Mr. Pandej Chintrakarn, Ph.D.
Member

……………………………………
Ms. Ornlatcha Sivarak, Ph.D.
Member

……………………………………
Prof. Banchong Mahaisavariya,
M.D., Dip Thai Board of Orthopedics
Dean
Faculty of Graduate Studies
Mahidol University

……………………………………
Assoc. Prof. Rassmidara Hoonsawat,Ph.D.
Dean
International College
Mahidol University

# ACKNOWLEDGEMENTS

This thematic paper has been successfully completed with the great support and assistance of my major advisor, Dr. Pandej Chintrakarni, and my co-advisor, Dr. Ornlatcha Sivarak. I wish to thank them for their kind advice and great guidance on this research. I would like to thank Asst. Prof. Dr. Sittisak Leelahanon, who is the external examiner of this thematic paper defense, for his helpful suggestions in improving the research.

I also would like to thank PMK-Central Glass Company ltd for their valuable time and great support in allowing me to visit their factory as well as explaining and sharing the company data regarding to the TPS's project that was written in this research.

Finally, I wish to thank my family, especially my husband, my brother and mother for their kind encouragement and always being besides me to study and complete this master degree with great love and care.

Buranit Rattanachuen

APPLYING TOYOTA PRODUCTION SYSTEM TO A LOCAL GLASS MANUFACTURER IN THAILAND: A CASE STUDY OF PMK-CENTRAL GLASS COMPANY LTD.

BURANIT RATTANACHUEN 5038676 ICMA/M

M.B.A. (BUSINESS MODELING AND ANALYSIS)

THEMATIC PAPER ADVISORY COMMITTEE: PANDEJ CHAITRAKARN, Ph.D. (ECONOMICS), ORNLATCHA SIVARAK, Ph.D. (MANAGEMENT SCIENCE)

## ABSTRACT

This research aimed to study the principles of the Toyota Production System (TPS) and its application to the real practice of local glass manufacturing in Thailand in order to minimize 7 types of waste. For this research, PMK-Central Glass Company limited was selected as a representative for Thailand. This company had objectives to speed up its production and operations or reduce the lead-time to satisfy the customers, as well as to efficiently use the resources in terms of capital (machines), labor time, land (plant space), etc.

The researcher visited their factory, located at Banpong in Ratchaburi province to observe their TPS project's implementation since it started with basic training for PMC's staff, hearing much useful advice from Toyota experts, seeing their real practices- including participation from employees and management - in order to understand and be able to collect the related data in order to compare the situation before and after the TPS project.

PMC has learned and adopted many activities from TPS principles to its production and operations, such as Visual control by using Kanban as an information system to efficiently organize and control the order of its production. It used the 2 "S"- Sort and Straighten - program plus Continuous Flow of work to find the best ways to minimize the distance to move glass through-out the process. It also included standardized work, which reduced the requirement for labor and the lead-time as well as reducing defects and human errors. PMC's production used the "Pull system" (Just-in-time J.I.T.) to eliminate overproduction or to produce according to customer orders.

For the company's hard effort, the results were satisfactory. PMC could reduce its total lead-time from 32 to 19 days, increase productivity from 22.58 to 30.75 pieces per man hour while reducing the number of workers required - from 43 to 35 persons - from standardized work, production control and many other improvements from following the TPS principles. With Continuous flow, they could reduce the glass movement distance from 573 to 390 meters and reduce the plant area from 162 to 54 sq.m. By improving many aspects of the production process, the company anticipated a reduction in both defects and waste.

The Toyota Production Principles are very useful and practical for many industries and organizations without requiring a large capital investment. The writer hopes that this paper would be of benefit to and provide motivation to others to encourage them to adopt this production system from Toyota in order to improve their organizations.

KEY WORDS : TOYOTA PRODUCTION SYSTEM (TPS)/ PMK-CENTRAL GLASS COMPANY LIMITED / IMPROVED PRODUCTIVITY RESEARCH/ JIDOKA/ JUST-IN-TIME (JIT)/ KANBAN

84 pages

การประยุกต์ใช้หลักการผลิตแบบโตโยต้ากับอุตสาหกรรมการผลิตกระจกในประเทศไทย โดยใช้กรณีศึกษาจากบริษัท กระจก พีเอ็มเค เซ็นทรัลจำกัด
APPLYING TOYOTA PRODUCTION SYSTEM TO A LOCAL GLASS MANUFACTURER IN THAILAND: A CASE STUDY OF PMK-CENTRAL GLASS COMPANY LTD

บูรณิจฉ์ รัตนชื่น 5038676 ICMA/M

บธ.ม. (การวิเคราะห์และการสร้างตัวแบบธุรกิจ)

คณะกรรมการที่ปรึกษาสารนิพนธ์: ปานเดช ชินตระการ Ph.D. (ECONOMICS), อรลัชชา ศิวรักษ์ Ph.D. (MANAGEMENT SCIENCE)

บทคัดย่อ

งานวิจัยฉบับนี้จัดทำขึ้น เพื่อศึกษาหลักการผลิตของโตโยต้า (TPS) และการนำหลักการนี้มาประยุกต์ใช้ในอุตสาหกรรมการผลิตกระจกในประเทศไทย เพื่อลดการสูญเปล่าทั้ง 7 ประการ การวิจัยครั้งนี้ ผู้จัดทำได้เลือกศึกษาจากประสบประการณ์ของบริษัท กระจก พีเอ็มเค เซ็นทรัล จำกัด เป็นห นึ่งตัวอย่างกรณีศึกษาในประเทศไท ย บริษัทนี้มีวัตถุประสงค์ในการเพิ่มความเร็วในการผลิตและการจัดการ และใช้ทรัพยากรต่างๆอย่างคุ้มค่า

ผู้จัดทำได้ไปเยี่ยมชมโรงงานของบริษัทพีเอ็มซี ที่อำเภอบ้านโป่ง จังหวัดราชบุรี เพื่อศึกษาการดำ เนินงานของโครงการนี้ ตั้งแต่การฝึกอบรมพนักงาน การแนะนำของคณะผู้เชี่ยวชาญจากโตโยต้า ติดตามการปฏิบัติงานจริง สังเกตการมีส่วนร่วมและการให้ความร่วมมือของฝ่ายบริหารไปจนถึง พนักงานในสายการผลิต เพื่อทำ ความเข้าใจและสามารถรวบรวมข้อมูลต่างๆที่เกี่ยวข้อง เพื่อเปรียบเทียบการปฏิบัติงานทั้งก่อนและหลังการนำหลักการของโตโยต้ามาใช้

บริษัทพีเอ็มซีได้ศึกษาและนำหลักการ สำคัญๆของโตโยต้ามาใช้อย่างจริ งจัง เช่น การควบคุมสิ่งต่าง ๆด้วยการมองเห็นโดยตรง จากป้ายหรืออุปกรณ์แบบคัมบัง Kanban เพื่อช่วยจัดระเบียบและควบคุมลำดับการผลิตอย่างมีประสิทธิ์ภาพ, ใช้ 2 ส. จากหลักการ 5 ส. (คือ สะสางและสะดวก ), สร้างมาตรฐานการผลิต , ปรับสายการผลิตให้เป็นไปแบบต่อเนื่อง Continuous process flow หรือปรับระบบการผลิตเป็นแบบเรียบ หาวิธีย่นระยะทางการเคลื่อนย้ายกระจกตลในกระบวนการให้สั้นที่สุด สร้างมาตรฐานการทำงานขึ้น ซึ่งทำให้สามารถลดจำนวนพนักงาน ลดเวลาการทำงาน ลดของเสียที่มีตำหนิ และความผิดพลาดของคน บริษัทพีเอ็มซีใช้ระบบการผลิตแบบดึง คือจะผลิตสินค้า ตามจำนวนความต้องการของลูกค้า ตามเวลาที่ต้องการ และให้ทันเวลา (Just In Time) ไม่ผลิตมากๆจนเกินความจำเป็น

ผลจากความทุ่มเทและการมีส่วนร่วมของทุกๆฝ่ายตั้งแต่ระดับปฏิบัติการไปจนถึงผู้จัดการและผู้บริหาร ทำให้บริษัทพีเอ็มซีประสบความสำเร็จในระดับที่น่าพอใจ โดยบริษัทสามารถย่นระยะเวลาการผลิตและ การดำเนิน การ ตลอดทั้งกระบวนการ จาก 32 วัน เหลือเพียง 19 วัน เพิ่มศักยภาพการผลิตของพนักงาน คนหนึ่งจาก 22.58 ชิ้น เป็น 30.75 ชิ้น ต่อ ชม. ทั้งยังสามารถลดจำนวนพนักงานจาก 43 คนเหลือ 35 คน ,สามารถย่นระยะทางการเคลื่อนย้ายกระจก จาก 573 เมตรลงเหลือ 390 เมตร และสามารถลดพื้นที่ในการผลิตจาก 162 ตร.ม.ลงเหลือเพียง 54 ตร.ม. จากการ พัฒนาประสิทธิ์ภาพการผลิตทั้งหลายในครั้งนี้ ทำให้บริษัทสามารถลดความเสียหายและสูญเปล่าได้อีกด้วย

หลักการผลิตของโตโยต้านี้มีประโยชน์อย่างมาก เพราะสามารถนำไปใช้ได้จริงในอุตสาหกรรมหรือองค์กรต่างๆ โดยไม่ต้องใช้เงินลงทุนอะไรมาก ผู้จัดทำสารนิพนธ์ฉบับนี้ หวังไว้เป็นอย่างยิ่งว่า เนื้อหาสาระและข้อมูลจากการวิจัยในครั้งนี้ จะเป็นประโยชน์ เป็นแบบอย่าง และแรงจูงใจในการนำหลักการผลิตจากโตโยต้านี้ไปปรับใช้ในองค์กรต่างๆได้

84 หน้า

# CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF FIGURES (cont.)

# CHAPTER I
# INTRODUCTION

## 1.1 Background

### 1.1.1 Toyota's success

Toyota Motor Corporation has been rapidly expanding. It has become one of the top ten largest companies in the world and is the world's largest manufacturer of automobiles ahead of General Motor in the U.S. Toyota consistently outperforms competitors in quality, productivity, cost reduction, sales growth, and market capitalization. Toyota sold 7.4 million vehicles worldwide in 2005, 30 percent more than in 2001. It is currently as profitable as all the other car companies combined. In the United States, Toyota has roughly double the sales of Honda and has replaced Chrysler Group as the number three seller.

**1.1.2 TPS's Background**

After the second World War, while other major American automakers - GM and Ford relied on mass production, exploited economies of scale with single purpose machines to produce as many parts as cheaply as possible.

Toyota in Japan had limited resources and plant space. Mass production was not applicable to Japanese maker like Toyota. It adapted Ford's manufacturing process to achieve high quality, lower costs, shorter lead time and flexibility. Kiichiro Toyoda cited Henry Ford and The American supermarket system of replacing products on the shelves just in time as customers purchased them as the inspiration from his study trip to Ford's plants in Michigan to see the automobile industry. Toyota was driven to produce low volumes of different models using the same assembly line. It creates efficiency by eliminating seven types of waste, ranging from the raw materials to worker time. It examined every activity and asked how each contributes to customer value.

Toyota has been widely recognized for creating an important management system that many manufacturing and service businesses try to imitate. The core of the company's success was the Toyota Production System (TPS) or also known as "Lean manufacturing or Lean management," Womack et al. (1990) which was established by Toyota engineers, named Taïchi Ohno and Shigeo Shingo from the late 1950s through to 1970 to get as much as possible out of every part, every machine, and every worker.

The Toyota Production System (TPS) or Lean manufacturing concept consists of several important terms: Just-In-Time practices, resource reduction, improvement strategies, defect control, Jidoka (to stop and fix problems as soon as they arise), standardization and and kaizen (continuous improvement). Toyota was able to reduce lead-time and total costs greatly, highlight the problems while increasing productivity and quality by using TPS. Petterson, J. (2009). These principles and practices can be applied to any organization.

### 1.1.3 Company Background


Glass is considered to be a key part of automotive manufacturing, The construction industry, and architectural design. Petch Mongkol Co., Ltd. (PMK) was founded forty years ago, established for making Automotive Glass under name “Petchmongkol Safety Glass Co., Ltd.” or “Diamond Glass”. On October 1, 1998, Central Glass Co., Ltd. (CGC), one of the top three leading glass manufacturers in Japan, became a joint investor with PMK Company. Then PMK changed their name to PMK-Central Glass Co., Ltd. (PMC).

Over time, the company has strived to develop appropriate production processes, techniques, gained expertise and experience. This has resulted in an expanding production line that responds well to the changing demands of both the domestic and international markets.

Today, the company has earned high recognition and trust from customers both domestic and worldwide. PMC has become a leading glass manufacturer in Thailand, producing safety glass for vehicles, energy saving and safety glass for architectural and interior design, and other extended industries.

Its head office is located at Omnoi, Krathumban, Samutsakorn province with area of 3 rai. Its plant is located at Bangpong, Ratchaburi province, which has more than 1,200 full time workers and an area over 55 rai or 101,000 sq.m.

Even though PMK-Central Glass has long been established in the market for over 30 years, but it still faces intensive competition from either large manufacturer or smaller makers. PMC could achieve production of the higher quality glass than other competitors in the market, but it took a longer lead-time from customer order to product delivery.

PMC had always received complaints from customers regarding slow speed or long lead-time. They could not produce glass as fast as their competitors. This problem caused a loss of potential sales to those, with limited time and demanded a quick supply. Thus, PMK had been looking for ways to speed up their production and operation process, while maintaining quality and they eventually improved their performance by implementing the Toyota Production System (TPS) or Lean manufacturing principle.

## 1.2 Research Objective

The objective of this paper is to study the application of the Toyota Production System (TPS) to a local glass manufacturer in Thailand named "PMK-Central Glass company ltd" as a model for a Thai organization as well promoting the use of these TPS principles to improve widely any other organization.

## 1.3 Benefit of Study

There is some but still only limited study on the application of Toyota Production System (TPS) available in Thailand. This paper hopes to contribute to a better understanding of the Toyota Production System (TPS)'s principles, its application and benefits. This study of the implementation of the Toyota Production System (TPS) to PMK-Central Glass could serve as a case study to demonstrate on how the principles can be applied in practice, illustrate what activities were actually being done before and after the project and what are the consequences. So other industries and organizations could learn from their experience and problems.

## 1.4 Scope and Limitation of Study

This paper studied the experience of one manufacturer named “PMK-Central Glass” as a representative of local industry in Thailand. It was subjected to limitations and restrictions in collecting and accessing to the internal information of the business, which was not disclosed to the public. It would be beneficial, if the other researchers could extend their study to a broader perspective of various other industries.

# CHAPTER II
# LITERATURE REVIEW

The literature review in this chapter consists of two parts. The first part will explain the Toyota Production's definition and principles, the second part will mention existing papers on the application of the TPS principles to other businesses or organizations, which have adopted Toyota's success both internationally and in Thailand.

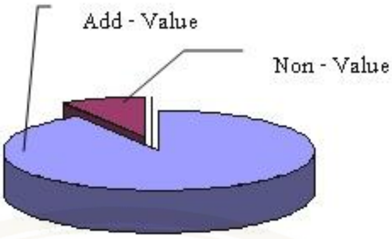
## 2.1 Toyota Production System

The Toyota Production System and Mass production have opposite positions or attitudes. Mass production viewed that machine down time was wasteful, because a machine shutting down for any repair did not yield output. But TPS principles viewed that it was better to idle a machine or to stop producing parts sometime, if there was no customer order or need. Over production was a fundamental waste in TPS. Transition from mass-production system to Just-in-Time value-based system where product flow depends on customer's order, is called "Lean transition" or TPS.

For Toyota this was to make the vehicles ordered by customers in the quickest and most efficient way possible, by focusing on keeping production lines flexible and operations with a short lead-time. Its goals were to occupy less human effort, less inventory, less time to develop and produce products, and less space in producing top quality products in the most efficient and economical manner possible.

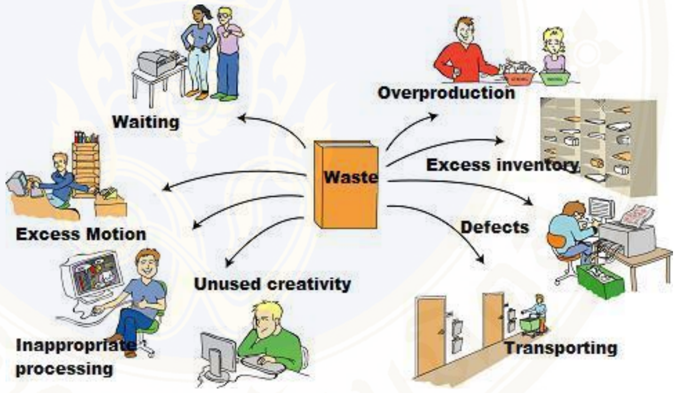
Womack and Jones, (1996) defined the Toyota Production System as a manufacturing philosophy and methodology created by Toyota over 50 years ago. The main objective of TPS or Lean manufacturing was to eliminate wastes from the entire process, including production and operations in that factory.

**Figure 2.1 Non-value work**




Waste or "muda" is defined as anything that customer is not willing to pay or does not add value to the process. Liker, J.K. (2004) Lean is focusing on preserving value with less work. There are seven kinds of "muda" that are addressed in the TPS, defined by Ohno, T. (1988).

**Figure 2.2 Types of Waste**




1. Overproduction: Producing more than the customer or immediate in-process needs.
2. Excess inventory and work in progress
3. Over processing or Inappropriate processing: Inefficient processing, doing more than is required and desired by the customer.
4. Unnecessary Transport: The excess movement of materials or product that is not actually required to perform the processing.
5. Excess motion: The excess walking of people or moving of equipment more than is required to perform the processing , with no value added such as looking for, reaching for, stacking part etc. (wasteful walking)
6. Correction of Defects and Rework

7. Waiting and idle time: Waiting for information, people, next process step, tools, part and materials can have a major impact on lead-time and costs.

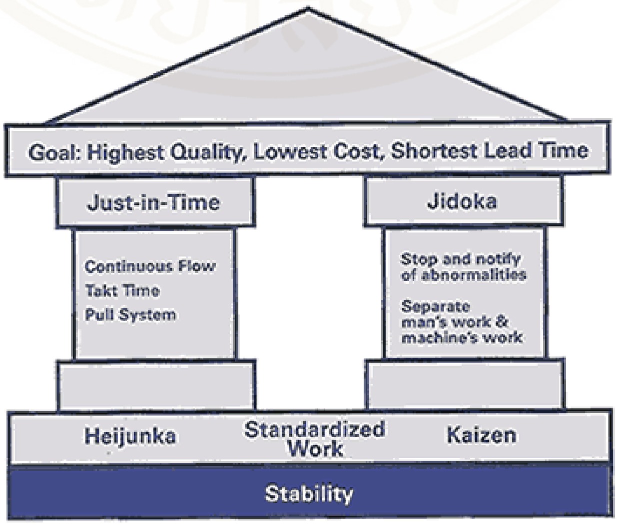
By eliminating both defective products and the wasteful practices, Toyota succeeded in improving both productivity and work efficiency.

**Basic Principles of the Toyota Production System**

The core of the Toyota Production System is the concept of eliminating waste while maintaining efficiency. TPS has a series of basic principles that explain how this is achieved. The right process will produce the right results.

1. Just-in-Time
2. Use the "pull" system to avoid overproduction
3. Heijunka: Leveling out or smoothing the workload
4. Jidoka: stop to fix problems, to get quality right from the first time.
5. Standardized works are the foundation for continuous improvement and employee empowerment to bring problems to the surface.
6. Use visual control so no problems are hidden
7. Use only reliable, thoroughly tested technology that serves your people and the process.

**Figure 2.3 Toyota Production System's House**



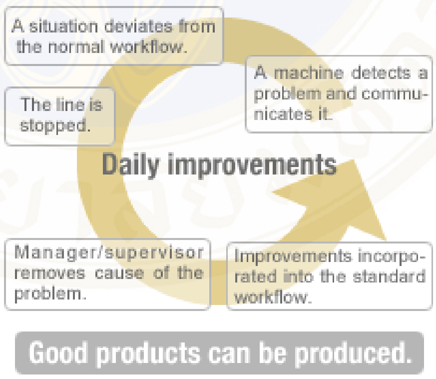

Toyota Production System "House"

The Toyota Production System (TPS) was built on two main pillars: "Jidoka" and "Just-in-Time (J.I.T)", to efficiently and quickly produce a wide range of vehicles of sound quality that fully satisfy customer requirements with the lowest cost, shortest lead-time. Toyota, (2006)

**Jidoka:** Build in quality at the process - Automation with a human touch. Jidoka is one of the two main pillars of TPS. It involves the automatic detection of errors or defects during production and adopts "the decision to stop or slow down in order to fix problem immediately as they occur rather than pushing them downstream to be resolved later". This is a large difference between the effectiveness of Toyota and other companies who have tried to adopt Lean Manufacturing. Liker, J.K. (2004). There are two types of Jidoka:

- Manual line - it allows the operator to stop the line if something goes wrong.
- Automated line - it stops the line automatically when the machine detects a defect. It is called "automation with human intelligence".

**Figure 2.4 Jidoka**




The Jidoka quality control process uses four steps:

1. Detect the abnormality.
2. Stop machine, operation, line.
3. Fix or correct the immediate condition.
4. Investigate the root cause and install a countermeasure.

When an imperfection or defect is detected, interruption of the production forces immediate attention to the problem. It helps prevent producing or passing on defects, focuses attention on finding and understanding the root cause of a problem, ensuring that it never recurs. Operators have an opportunity for learning how to make things better to enhance productivity in the long run. That is the substance of Jidoka to make it possible to "build" quality for the first time at the production process as well as guaranteeing maximum product quality at all times. Jidoka therefore can be said to be a key element in the successful Lean Manufacturing implementation by Toyota.

When a machine is down, flags or light with an alarm are used to signal for help to solve a quality problem. Liker, J.K. (2004) This interruption may cause slowed production, but by fixing a problem earlier could avoid the spread of bad outputs and wasting of resources.

**Just-in-Time (J.I.T.) system** was built upon four basic principles:

1. The Pull System
2. Continuous Flow Processing
3. Heijunka: Level out or smooth the workload
4. TAKT time

The Just-In-Time (J.I.T.) production system means making only "what is needed, when it is needed, and in the amount needed!" according to the production plan and customer order. It is truly the customer who is 'pulling' the production system. In order to deliver a vehicle ordered by a customer as quickly as possible, the vehicle must be efficiently built within the shortest possible time.

The Just-in-Time (J.I.T.) inventory system is the principle of having parts ready just as they are needed for the next process in a short period of time, rather than maintaining inventories across an assembly plant and in warehouses.

A low inventory level is a key outcome of the TPS. Not only are the direct cost savings greater from having less capital tied up in inventory, but it also supports the possibility work intelligently and eliminate waste and inconsistencies so that maintaining an unreasonable large inventory no longer needed. This results in improved productivity and adaptability.

**Figure 2.5 Hidden Problems behind Inventory**


By reducing the work in-process inventory in the system, there is no buffer to cover up the production problems that arise. This is a source of continuous productivity improvement. Shingo, S. (1984), Ohno, T. (1988), Krafcik (1988).

**Continuous flow** is a key element of "Just-in-Time J.I.T." pillar. Achieving one-piece flow helps manufacturers achieve true just-in-time manufacturing. That is, the right parts can be made available when they are needed in the quantity they are needed. Ideally, one-piece flow means that parts are moved through operations by step-to-step with no work-in-process (WIP) in between either one piece, or a small batch at a time. This system works best in combination with a cellular layout in which all necessary equipment is located in the sequence which it is used. Dolcemascolo, D. (2006) Creating continuous process flow could also bring problems to the surface.

Shortening the process flow from raw materials to finished goods leads to the lowest cost and shortest delivery time. Creating flow exposes inefficiencies that demand immediate diagnosis and correction. If not, the flow will be interrupted. It is opposite to traditional business processes that usually have capacity to hide inefficiencies without notice.

**Heijunka** is another element of Just-in-Time. It refers to a "Production leveling" or "Production smoothing" technique for the scheduling of production activities in order to control inventory, eliminate waste, decrease lead time and produce a mix of products and in appropriate volumes as per customer demand.

Leveling out the schedule is a foundation for flow and pull systems and for minimizing inventory in the supply chain. Toyota keeps only some small inventory of finished goods to protect the production schedule from being upset by a sudden peak in demand. Liker, J.K., (2004) Heijunka does not produce products according to the actual flow of customer orders, which can fluctuate wildly. It takes total volume of orders in a period and levels them out, so the same amount and mix of items is produced with little variation in production day to day.

| | |
|---|---|
| Mass Production: | AAAAABBBCCDD |
| Lean Level Production: | AABCD AABCD |

To prevent fluctuations in production for serving the order, it is important to try to keep fluctuations in the final assembly line to zero. Unlike traditional manufacturing processes, which employ large batches for the assembly of products and a large inventory. The basis of Heijunka is to use small batches in the production assembly line so as to keep the fluctuation in the final assembly line negligible. The general idea is to produce intermediate goods at a constant rate, to allow further processing to be carried out at a constant and predictable time. Heijunka also levels out the demand on labor, equipment, and suppliers.

From the book “Machine that changed the world”, by the late 1950s, Ohno, T. found out from experiments that it actually cost less per part to make small batches than run off enormous lots. Making small batches eliminated the carrying cost of huge inventories of finished parts that the mass-production system required.

Moreover, TPS also have other important elements that were used to support the main principles as per the following:

**5 “S” program** is the foundation and primary drive for success of workplace optimization. 5 “S” program comprises a series of activities for eliminating waste that contribute to errors, defects, and injuries in the workplace. It is an effective approach for continuous improvement in the organization. The 5 “S” name stands for five Japanese words- Seiri, Seiton, Seiso, Seiketsu and Shitsuke. Osada, (1991).

1. Sort or Separate (Seiri = arrange สะสาง) is sorting out between necessary and unnecessary items and disposing of unnecessary items. The idea of Seiri is to keep only the necessary items in the workplace at a convenient location.

2. Straighten (Seiton = orderliness สะดวก) means “A place for every thing and every thing in its place.” It is to make the arrangement of necessary items in good order so that they can be easily picked up for use and put away after use.

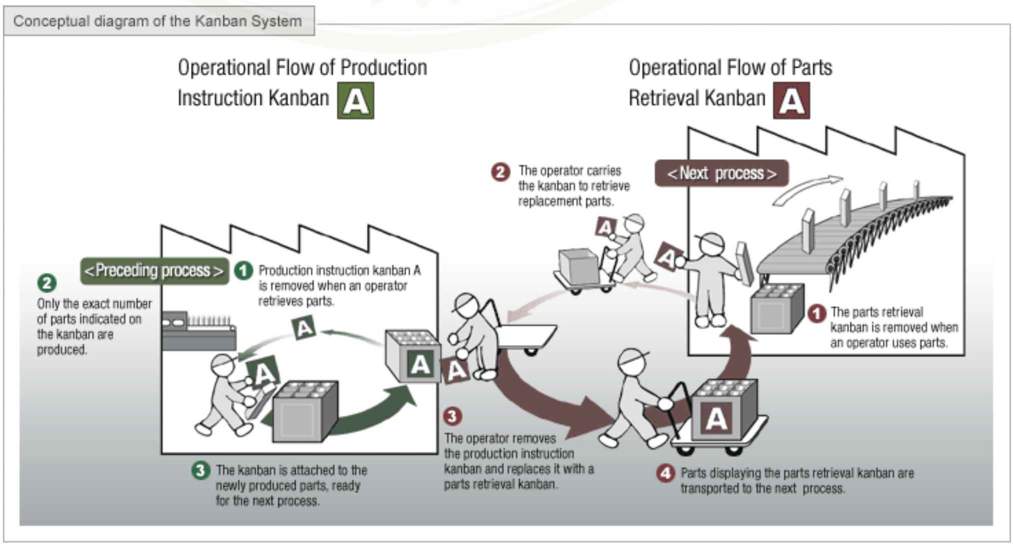
3. Shine (Seiso = สะอาด) is the cleaning process which acts as a form of inspection that exposes abnormal and pre-failure conditions that could hurt quality or cause machine failure.

4. Standardize (Seiketsu = สร้างมาตรฐาน) means creating rules. Develop systems and procedures to maintain and monitor the first three S’s (Seiri, Seiton & Seiso).

5. Sustain (Shitsuke = สร้างนิสัย) means Self discipline for maintaining the stabilized workplace. Continuous training and 5 “S” habits should be used to replace bad habits with good ones. This process helps people to become disciplined. Liker, J.K., (2004)

**The Kanban system** is another useful element of just-in-time system. It means “visible sign” for scheduling and controlling production that replaces what has been taken/ used by the following process. Kanban is simple from of production control.

**Figure 2.6 Kanban System**



Monden, Y. (1993) and Suzaki, K. (1987) claimed that kanban works as an information system. There are two kinds of kanban (the production instruction kanban and the parts retrieval kanban). The kanban card is attached to the parts or work-in process. It contains product-related information such as the product name, code, component name, the station location and the destination station, etc.

Toyota employed kanban cards in their production processes, when a process goes to the preceding process to retrieve parts; it uses a kanban to communicate what parts have been used and to order replacement items. Rules of Kanban are “Defects are never sent to the next process, produce only the amount taken, no production or movement without a Kanban.” Monden,Y. (1993) Fewer and more quickly resolved interruptions to the flow with reduced waiting times means that the Kanban could increase the productivity by using the same resources.

It only allows for minimal inventories as a safety stock to reduce paper work and easily adjusts to changes in market demand. It also reduces the burden on operators, ease of identification of parts, its location and status.

**Standardized Work**: The Toyota Production System organizes all jobs around human motion and creates an efficient production sequence to minimize waste. Work organized in such a way is called standardized work. It consists of three elements: TAKT-time, Working Sequence, and Standard In-Process Stock.

**TAKT time** (derived from the German word Taktzeit) can be defined as the maximum cycle time per unit allowed to produce a product in order to meet demand. Takt time sets the pace for industrial manufacturing lines. In automobile manufacturing, cars are assembled on a line, and are moved on to the next station after a certain time - the takt time. Therefore, the cycle time needed to complete work on each station has to be less than the takt time in order for the product to be completed within the allotted time. Anthony, L. (1999).

The TAKT Time can be calculated using the following formula given here.

$$\text{TAKT time} = \frac{\text{Net Time Available for production (Ta)}}{\text{Customer demand in unit (Td)}}$$

where

T = TAKT time, e.g. [minutes of work / a unit produced]

$T_a$ = Net time available to work, e.g. [minutes of work / day]

$T_d$ = Time demand (customer demand), e.g. [units required / day]

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.).

For an example, there are 8 hours of work a day for 5 days a week. For a week, there is a demand of 100 Pieces. Then the calculation will be as follows.

$$\text{TAKT time} = \frac{\text{8 hrs./day x 5 days x 60 minutes/hr.}}{\text{100 Pieces}} = \text{24 minutes/piece}$$

This could be interpreted that there was maximum of 24 minutes allowed to produce a piece of work to meet the demand.

**Working Sequence** refers to the sequence of operations in a single process, which leads a floor worker to produce quality goods efficiently and in a manner which reduces overburden and minimizes the threat of injury or illness.

**Standard In-Process Stock** is the minimum quantity of parts always on hand for processing on and between sub-processes. It allows the worker to do his job continuously in a set sequence of sub-processes, repeating the same operation over and over in the same order. Toyota Motor, (2006).

## 2.2 Application of Toyota Production System to the other industries

Toyota has been able to sustain a strategic competitive advantage from the Toyota Production System from a process innovation and intervention, as measured by quality, reliability, productivity, cost reduction, sales and market share growth and market capitalization. The principles of the Toyota Production System have been used worldwide by many companies and organizations for both private and public in different sectors other than the automotive industry. Different authors have different opinions; Womack, J.P., Jones, D.T., & Roos, D. (1990) believed that TPS or lean principles and practices can be applied to any organization or industry but the outcome may not guaranteed and depends highly on their understanding and effort.

According to a survey done by Lucansky, P., Potapchuk, L., Burke,R. (2002) conducted with 45 companies in six industries, research shows that over 70% of all transactions to apply Toyota Production System (TPS) or lean manufacturing failed to deliver the desired results, while almost 50% of all their transformations failed equally. The companies that were successful in transformation, have realized benefits of reducing cycle time by 95%, improving quality by 300- 400%, reducing space utilization by 50%, improving customer service 100% and reducing unit cost by 30%.

There are two case studies of local manufacturers in Thailand that had also implemented TPS following 4 steps, as in this paper, in their factories.

The first one is Chai Wattana Leather tanning company ltd. located in Samutprakarn, producing leather related products, car cushions for the domestic and export markets. The result was highly satisfactory, since it could reduce the lead-time from 3.75 days to 1 day, account for 73.33%, reduce the defects from 10 to 1-2 pieces a day, decrease the inventory of both work-in-process (WIP) and finished products from 80-100 to 33 car sets while increasing the productivity form 0.91 to 1.33 car sets/ man-day, account for 46.15%, decreased the working space from 324 to 252 sq.m. or 22.22%, reduced the overtime from 18 to 6 hours per week.

The second company is producing Aluminum and Zinc alloy casting products such as retainers, BRKT, cover upper. It is located in Pathum Thani province. It could reduce the lead-time from 13 to 4 days, accounts for -70%, increase the productivity form 36.35 to 85,84 pieces/ man-hour, account for 136%, while reducing inventory from 5 to 1.5 days, reducing manpower from 11 to 6 persons, account for -45%, reduce moving distance from 113 to 35 meters, account for -69%.

There are several foreign articles written about the benefits and success in applying the Toyota Production System (TPS) to different industries as per the following:

Many mold makers have experienced losing orders because of long lead-time. Lead-time is all of the time accumulated from customer order to the time of receiving cash. Reducing lead-time is a major benefit of any lean transformation.

In order to eliminate non-value added or wastes, improve the lead-time to satisfy the customer. Mold makers carefully studied about the lead-time and removed as much non-value-added time from the process as possible. As the result, the lead-time was decreased from 33 to 22 hours. Flinchbaugh, J. (2002)

TPS or lean principle was also applied to the retail business to speed up the operation in Starbucks stores. Employees usually move and reach for things that were never in the same place in making a drink. Starbucks can reduce the time by changing the order of assembly or moving items closer together where the drinks are made to save time by eliminating unnecessary motion.

Another bottleneck at Starbuck stores is carrying baked goods from one end of the shop, where they were delivered to the displaying shelf. This new method could cut off the store's drive-through time by an average of 2 to 23 seconds. Between September 2008 and June 2009, Starbucks had experienced a 10% increase in transactions, boosted traffic by keeps people from leaving stores. Cost cutting could help Starbucks to achieve better than expected profits. Even, Starbucks had faced some resistance to the program; some employees complained "They're trying to turn workers to robots.

Not only the private sector likes to adopt TPS, a local government in Spain had also followed the improvement initiatives from TPS to support their continuous process and service improvements to the public. There was empirical evidence show that it had a direct effect on improving their process, management system and quality of public services provided by local councils in Spain. Manuel, F., Smith, T. & Su Mi Dahlgaard-Park. (2009).

TPS has been successfully used in manufacturing companies for decades. It also makes great improvements in many healthcare institutions as per the following. What do the production of cars and the care of patients have in common? In both cases, the goal is to deliver high-quality, error-free results. Lean or TPS is a proven strategy for providing safe, improved and cost-effective patient care.

In 2003, The Jewish Healthcare Foundation based in Pittsburgh, Pennsylvania introduced TPS in improving the Papanicolaou test quality and reducing medical errors. After the TPS intervention, the percentage of Papanicolaou tests lacking a transformation zone component was decreased from 9.9% to 4.7% ($P$ = .001). The percentage of Papanicolaou tests with a diagnosis of atypical squamous cells of undetermined significantly decreased from 7.8% to 3.9% ($P$ = .007). The frequency of error per correlating cytologic-histologic specimen pair decreased from 9.52% to 7.84%.

Beginning in late 2005, Bolton Hospitals NHS trust in Great Manchester had tried to apply TPS or lean principles across their hospitals as a whole to some hospitals world-wide such as Virginia Mason in Seattle, Flinders in Adelaide and Thedacare in Wisconsin. TPS was adapted and developed to suit a healthcare culture. Over a period of nine months, the improvement was impressive: 42% reduction in paper work, better multidisciplinary team work, reduction in time taken to get patients from 2.3 to 1.7 days (account for -38%), faster recovery and lower demand for service care, total length of stay reduced by 33%, mortality reduced by 36% resulting in a relative risk adjusted mortality rate of 105.5. Fillingham, D. (2007).

A Healthcare service provider, named Heartland Regional Medical Center in Marion, IL under "Community Health Systems (CHS) in the United States. They had used TPS for a process innovation and intervention technique for this hospital to improve the performance in quality, safety, cost reduction and survive accreditation audits.

Another project was done by the Quality Assurance and Regulatory Compliance Department at Heartland Regional Medical Center, had used TPS to improve coordination, communication, integration of the individual departments into one coherent whole. Spear, S. (2004). It also improved the safety in using medication and reduced risk of infections or harm from fall. Collins, K.F., Muthusamy, S.K. (2007).

There were patient complaints about the slow speed of turnaround time. Patients desired a faster turnaround time for chemistry tests in the hospital. Thus, Clinical chemistry laboratory strived to improve the service speed for all patients. A study done by Person, T., Zaleski, S. & Frerichs, J. (2006), demonstrated that redesigning the pre-analytic processes to incorporate the elements of TPS and lean production can significantly decrease the turnaround time in chemistry tests without additional resources required. Redesigning pre-analytic processes only had fewer steps: eliminating wasteful activities and delays as well as applying one-piece or continuous flow process.

By doing these activities, the laboratory reported 80% of chemistry tests in less than an hour for 11 consecutive months. TPS rules imposed a discipline in processing that resulted in consistency of output and quality.

# CHAPTER III
# METHODOLOGY

The case study approach was adopted in this research by observing the experience and learning from PMK-Central Glass Company ltd (PMC). PMK-Central Glass Company ltd. (PMC) was selected as a representative of a local automotive glass manufacturer, because this company is considered to be one of the top glass manufacturers in Thailand and Asia Pacific. They were really committed to carrying out the Toyota Production System project and willing to share their information and time for this academic research.

In order to develop business operations and production, PMK-Central Glass Company ltd. (PMC) had applied Toyota Production System (TPS) project since January 2010 with Automotive Human Resource Development Project (AHRDP) in its factory in Bangpong district. The company got training, and great consulting support from the experts of Toyota Motor Corp., Thailand on how to implement the TPS program. This project took a total of four months and was completed in April 2010.

The researcher visited the PMC factory in Ban-Pong to observe the real situation before and after TPS activities, collected the secondary data and supporting documents in order to understand their activities during each step of TPS implementation.

Objectives for Implementing Toyota Production System into PMC were the following:

1. To increase the speed of their production and operation or reduce the lead time.
2. To increase productivity without any compromise in quality.
3. To reduce waste (muda), reduce costs by ensuring that resources were used efficiently.
4. To reduce the inventories both in finished goods and work in process (WIP)
5. To develop human resource.

PMC had set the targets as per the following:

| | | |
|---|---|---|
| 1. | Reduce lead time by | 30 % |
| 2. | Increase productivity by | 30 % |
| 3. | Reduce work-in-process (WIP) by | 30 % |
| 4. | Reduce glass moving distance by | 30 % |
| 5. | Reduce manpower by | 20 % |

Toyota Production System (TPS) project has 4 steps as per the following:

Step I: Worksite Control
Step II: Continuous flow/ Process improvement
Step III: Standardized work
Step IV: Pull system

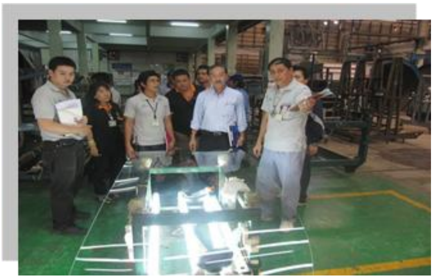
**Table 3.1 PMC's Schedule for Implementing the Toyota Production System**

| PMC Diamond Glass | TPS Activity Phase # 10 | Planned | Checked | Approved |
|---|---|---|---|---|
| | กำหนดการทั้งหมดของกิจกรรม | คุณสุพจน์ | คุณชาตรี | คุณฤตมัย |

| No. | ITEM | Jan - 10 | | | | | Feb - 10 | | | | | Mar - 10 | | | | | Apr - 10 | | | | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | |
| 1 | Orientation + Texbook I Lecture TPS Concept | | 6 | | | | | | | | | | | | | | | | | | | 19 PMC Working Days |
| 2 | Texbook II Lecture Worksite Control | | 6 | | | | | | | | | | | | | | | | | | | |
| 3 | Kick off Meeting at SMEs Dojo | | 7 | | | | | | | | | | | | | | | | | | | |
| 4 | Worksite Control Activity | | 8 | | | 27 | | | | | | | | | | | | | | | | |
| 5 | Texbook II Lecture & Simulation Continuous Flow | | | | | 28 | | | | | | | | | | | | | | | | 19 PMC Working Days |
| 6 | Continuous Flow Activity | | | | | 29 | | | 19 | | | | | | | | | | | | | |
| 7 | Texbook II Lecture & Simulation Standardized Work | | | | | | | | | 20 | | | | | | | | | | | | 21 PMC Working Days |
| 8 | Standardized Work Activity | | | | | | | | | 23 | | | | 16 | | | | | | | | |
| 9 | Texbook II Lecture & Simulation Pull System | | | | | | | | | | | | | 17 | | | | | | | | 21 PMC Working Days |
| 10 | Pull System Activity | | | | | | | | | | | | | 18 | | | | 9 | | | | |
| 11 | Summary & Final Report | | | | | | | | | | | | | | | | | 10 | | 25 | | 14 PMC Working Days |
| 12 | Final Report Presentation | | | | | | | | | | | | | | | | | | | | 26-30 | |








# CHAPTER IV
# TOYOTA PRODUCTION SYSTEM’S IMPLEMENTATION AND RESULTS

All manufacturing is under pressure from customers to cut lead time, including PMC. Not only must businesses compete based on product quality, cost, pricing, nowadays, businesses must compete based on speed as well. Reducing lead time is one of the most important factors in competing with competitors and in achieving a world-class operation. Lead time could be divided in to 3 components:

- Information lead time refers to the time for processing the information from the customer’s order to customer receipt.
- Process lead time refers to the production time from glass material at the first stage to completion at the last stage.
- Stock lead-time refers to the time waiting in queue to be processed.

Before applying the TPS project, PMC took 257 hours or totally around 32 days from customer’s order to product delivery, which was considered to be very slow and inefficient. Looking at the largest lead time from table or figure 4.1, 53 hour spent in customer service was the information lead time while 83 hours spent in TFA division was the stock lead time, not process lead time or the actual production time.

**Table 4.1 Lead-time spending in each process before TPS** unit: hour

| | Lead time<br>Process | Information<br>Lead time | Process<br>lead time | Stock<br>lead time | hours |
|---|---|---|---|---|---|
| 1 | Cimcut | 8 | 0.08 | 0 | 8.08 |
| 2 | Screen | 8 | 0.11 | 10.87 | 18.97 |
| 3 | Blind | 8 | 0.02 | 11.67 | 19.69 |
| 4 | TFA | 10 | 0.91 | 72.17 | 83.07 |
| 5 | Film | 8 | 2.20 | 15.56 | 25.76 |
| 6 | Auto Clave | 4 | 3.00 | 14.58 | 21.58 |
| 7 | QA& Packing | 8 | 0.13 | 0.89 | 9.02 |
| 8 | Warehouse | 3.50 | 4 | 0 | 7.50 |
| 9 | Delivery | 2.25 | 4 | 0 | 6.25 |
| 10 | Production plan | 3.20 | 0 | 0 | 3.20 |
| 11 | Customer service | 53.80 | 0 | 0 | 53.80 |
| | Total lead time | 116.75 | 14.45 | 125.73 | 256.93 |
| | Proportion | 45.44% | 5.62% | 48.94% | 100% |
| | | | | days | **32.12** |

**Figure 4.1 Lead-time spending in each process before TPS** unit: hour

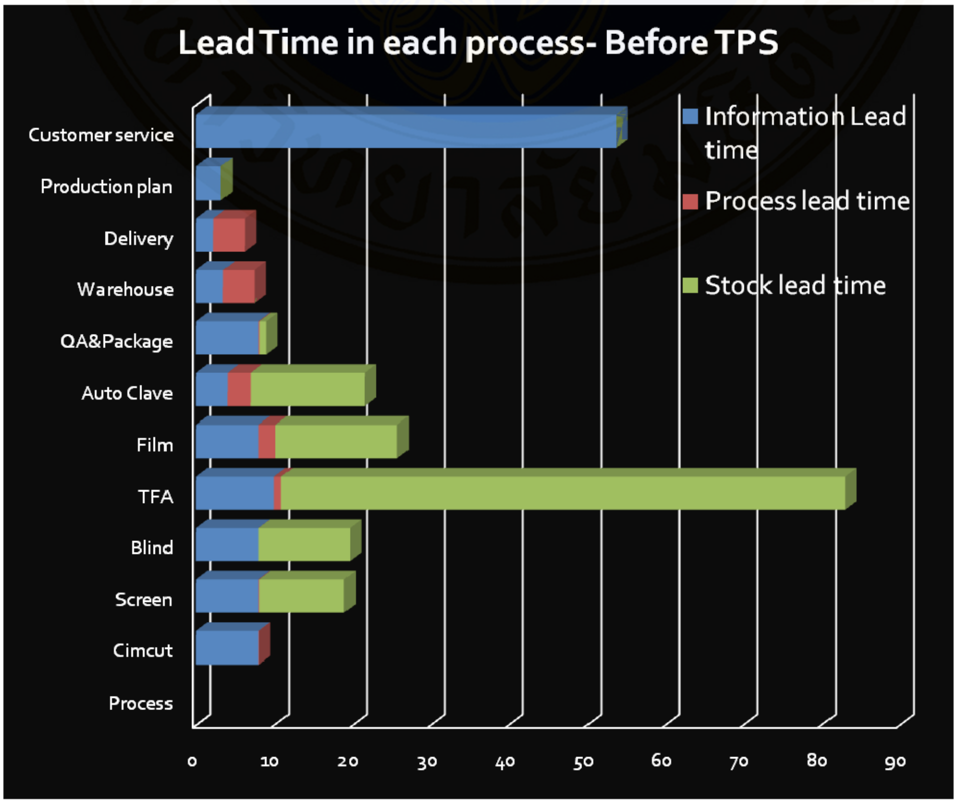


**Table 4.2 Components of the Lead-time** before TPS

| Lead time | days | Proportion |
|---|---|---|
| Information lead time | 14.59 | 45.44% |
| Process lead-time | 1.81 | 5.62% |
| Stock lead-time | 15.72 | 48.93% |
| Total Lead time | 32.12 | 100% |

Similar to what usually happens with most manufacturing, less than 10% of PMC's the total lead time or 5.52% was actually spent in **the process lead time** or manufacturing the product.

The largest part of lead time, which accounted for almost 50% of the total lead time, was **the stock lead time** or the waiting time to be processed esp. at TFA division due to the unmatched problem between production order and production capacity, waiting for the glass ordered from the supplier, time for moving glass from one division to the next, searching time for the needed glass in the inventory as well as in the production line, since there was no proper system to control the production and order.

Following by the information lead time, which accounted for 45% of total lead time, was **the information processing time** e.g. delay in production order, waiting for machine set up when start up or changing the product category, waiting for needed materials from store, information process to order materials, waiting for management approval to order supplier, etc. Moreover, PMC took 2 to 3 days to respond and confirm the delivery to each destination after receiving customer's order, therefore the information lead time was extremely long in customer service division.

All this idle time added no value and caused unnecessary customer waiting or delay that PMC must eliminate by applying the TPS project.

PMC had implemented the TPS project by doing four steps as per following:

**Step I: Worksite Control** "Use Visual Control, so no problem is hidden."

Worksite control is focusing on doing the "Visual Control", which is a starting point of the Toyota Production System (TPS) or lean manufacturing principle. Visual Control means any communication device used in the work place that tells at a glance how work has been done and whether it is deviating from standard.

Controlling an activity or production process is made easier or more effective by deliberately using visual signals in making things visible. Visual management charts must allow for communication and sharing. These signals can be in many forms from different color-coding paint, labels to a visual display or board.

The main purpose of visual control is to organize the working area so that everyone either employees or visitors can tell what is going on in the process and know whether thing is being done as it should be or if there is a problem occurring. These factors should clearly be seen without the need for professional help in determining or explaining how things are running. Sharing information through visual signals, help production running smoothly and safely. Moreover, when things are visible, any problem is kept in the conscious mind. It also serves to ensure that everyone has a common view of what is happening.

The whole purpose behind implementing visual control techniques is to expose abnormalities in the production line that could ultimately end up costing the company money or create waste. When visual control is able to do a good job at helping employees to recognize these abnormalities, action can be taken to correct the problems, reduce manufacturing costs, reduce possible waste, shorten production lead time and thus keep the delivery due dates, reduce inventory, ensure a safe and comfortable working environment, and increase the company's profit.

With Visual control systems, all the main processes and locations are expected to be managed visually as well as create an atmosphere of production, which is self-regulating and self-explanatory. Employees are more comfortable, because they clearly understand what is expected of them and so will be the managers.

Many of the visual controls were used to eliminate the need for verbal communication (unnecessary communication). Instead needs and expectations are clearly displayed, eliminating the time often wasted in the confusion of miscommunication due to different methods of verbal communication.

Processes in Worksite Control steps: After a lecture and training course, the TPS team began the project by obtaining relevant information in order to understand the current problems and situations which need improvement. TPS trainers and PMC project team did survey and evaluated the whole factory regarding their operations and production process in order to identify which areas needed to be improved. By following a Worksite Control Check Sheet, TPS master trainers commented and suggested on which areas that needed to be improved. There were 493 findings. The action plan was designed. Persons in charge were designated to assist in implementing the actions. Finally, the TPS experts regularly visited the production line from time to time, in order to check the progress and give advice for further improvement to suit the business. PMC staffs were working closely with the TPS experts from Toyota.

According to AHRDP, Worksite control was classified into 7 areas of control as per the following:

1. General control: 2 “S” - Sorting, Straighten
2. Production control
3. Workforce control
4. Delivery control
5. Safety control
6. Machine and equipment control
7. Quality control: Build quality into process

**Table 4.3 Worksite Control Check Sheet**

| **Worksite Control Check Sheet** | |
|---|---|
| 1. 2 "S" methodology<br><br>Sort (Seiri สะสาง)<br><br>Straighten (Seiton สะดวก) | 1.1 Sort out between necessary things and unnecessary items from the workplace<br>1.2 Discard unnecessary items<br>1.3 Keep necessary things at the convenient location<br>1.4 Make the arrangement of necessary items in good order so that they can be easily picked up for use.<br>1.5 Make rule for keeping things in place |
| 2. Safety control | 2.1 Assure the defined Safety rules<br>2.2 Make Safety rules understandable<br>2.3 Follow Safety rules strictly<br>2.4 Eliminate any unsafe area |
| 3. Build Quality into the<br><br>Processes | 3.1 Understand the quality control or not<br><br>3.2 Design the methods for monitoring the process and control quality to the standard<br>3.3 Have tools for monitoring the quality<br>3.4 Proceed to monitor the quality<br>3.5 Set rules to cope with quality problems and follow the rules strictly<br>(Stop the production, Call person in charge, take the order for solving the problem) |
| 4. Machine and Equipment Control | 4.1 Have clear description of the machine's operation manual |
| 5. Production Control | 5.1 Have production plan or not<br>5.2 Record production level each hour<br>5.3 Record the reason for not reaching production plan<br>5.4 Investigate the root cause of not reaching the production plan |
| 6. Delivery control | 6.1 Set Staging and Delivery plan<br>6.2 Allocate area for packing and staging for convenience<br>6.3 Able to know the state of Staging and Delivery |
| 7. Workforce Control | 7.1 Plan for necessary amount of labor in each process<br>7.2 Show the number of laborers working daily<br>7.3 Design way to dual with missing laborers |

Source: Automotive Human Resource Development Program (AHRDP)

Following to the Worksite control check sheet, there were 493 areas that was identified by Toyota experts and required to be improved**.** 370 Out of 493 areas had been done during the TPS project in April 2010. All areas were improved per their advised 100% in May 2010.

**Table 4.4 Finding Results from Worksite Control Checking**

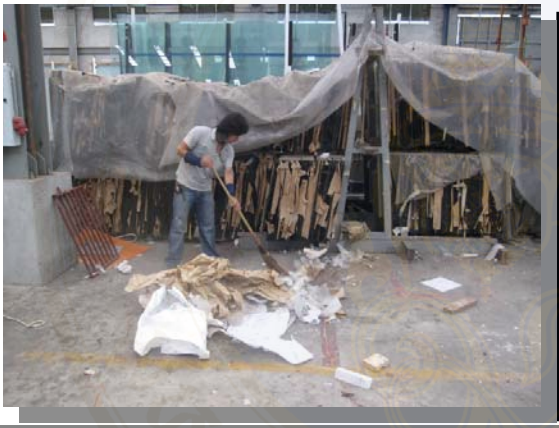
| Worksite Control | Items to be improved | Completed | % Completed |
|---|---|---|---|
| 1. 2 "S" (Sort, Straighten) | 305 | 266 | 87% |
| 2. Safety | 101 | 62 | 61% |
| 3. Build quality into the processes | 13 | 11 | 85% |
| 4. Operating machines | 34 | 9 | 26% |
| 5. Production control | 16 | 5 | 31% |
| 6. Delivery control | 17 | 10 | 59% |
| 7. Workforce management | 7 | 7 | 100% |
| Total | 493 | 370 | 75% |

Source: PMK-Central Glass Company ltd. (2010)

<u>The Major findings for Improvement following the Worksite Control Check Sheet</u>

**1. 2 "S" methodology - Sort and Straighten:**

PMC started the worksite control to become a visual factory by Sort and Straighten, especially at the storage of glass raw material and the inventory of the finished goods. PMC's staffs had cleaned up many areas in the factory, separated out between necessary and unnecessary items in the workplace and discarded of unnecessary items e.g. leftover glass and kept only necessary things e.g. new glass on order at convenient places and ready for use. Once things are kept in their place, it is more efficient to work and reach for things. Any problem could easily be detected, not hidden.

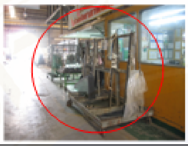
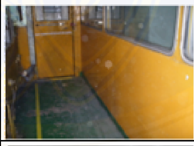



The following chart is an example of the actual check sheet according to 2 "S" methodology where PMC recorded their findings before and correction.

**Table 4.5 2"S" Check Sheet**

2 ส

| ข้อ | หัวข้อ | ข้อ | รายการ | ผู้รับผิดชอบ | กำหนดเสร็จ |
|---|---|---|---|---|---|
| 1 | สะสาง | 1 | เป็นและไม่จำเป็นออกจากกันหรือไม่ | | |
| | | 2 | งที่ไม่จำเป็นออกไปหรือไม่ | | |
| | | 3 | ที่และวางของที่ไม่จำเป็นหรือไม่ | | |
| 2 | สะดวก | 1 | ะดวกหยิบใช้สอยง่ายหรือไม่ | | |
| | | 2 | ว่ามีสิ่งใดวางไว้หรือไม่ | | |
| | | 3 | การวางและวางตามกฎนั้นหรือไม่ | | |

| | สถานตรวจพบจริง | รูปประกอบก่อนทำ | รูปประกอบหลังทำ | แนวทางแก้ไข | ผู้รับผิดชอบ | กำหนดเสร็จ | สถานะ |
|---|---|---|---|---|---|---|---|
| 1 | รถเข็นออกขวางทางเดิน |  |  | นำรถเข็นไปไว้ที่ตำแหน่งจอดรถ | คุณศักดิ์สม | 22/1/10 | |
| 2 | ไม่กล่องใส่จุ๊บยาง |  |  | หากล่องใส่ | คุณศักดิ์สม | 22/1/10 | |
| 3 | ไม่มีตำแหน่งการวางถัง |  |  | หาตำแหน่งถังใหม่และติดป้ายสถานะ | คุณศักดิ์สม | 22/1/10 | |
| 4 | มีเชือกวางไว้บนทางเดิน |  |  | เก็บเชือกให้เรียบร้อย | คุณศักดิ์สม | 19/1/53 | |
| 5 | มีบล็อคสกรีนขวางทางหน้าประตู |  |  | นำบล็อคสกรีนไปเก็บ | คุณศักดิ์สม | 22/1/10 | |
| 6 | ไม่มีตำแหน่งวางไม้ค้ำ |  |  | หาที่วางและติดป้าย | คุณศักดิ์สม | 19/1/53 | |
| 7 | อุปกรณ์ทำความสะอาดวางไม่เป็นระเบียบ |  |  | จัดให้เป็นระเบียบ | คุณศักดิ์สม | 19/1/53 | |
| 8 | เชือกบนรถไม่เป็นระเบียบ |  |  | เก็บเชือกให้เรียบร้อย | คุณศักดิ์สม | 22/1/10 | |

Source: PMK-Central Glass Company ltd. (2010)

1.1 Storage of glass material

Storage of glass material used to be disorganized. The new glass material was kept together at the same area with the leftover or residual glass. So it was difficult to find a needed piece of glass or tell the status of glass. A large area was required to store all these residual pieces of glass and new glass. Some glass was placed in the way of trolleys. It was not convenient to find and move things.

**Figure 4.2 Storage layout for glass material before TPS**

TPS created visual control in the storage of glass material. Storage layout was designed and displayed on the graphic chart for identifying the location for keeping the glass material according to the type and size. The new glass material was taken out of the leftover/ residual glass, classified and kept in order as in the designed layout.

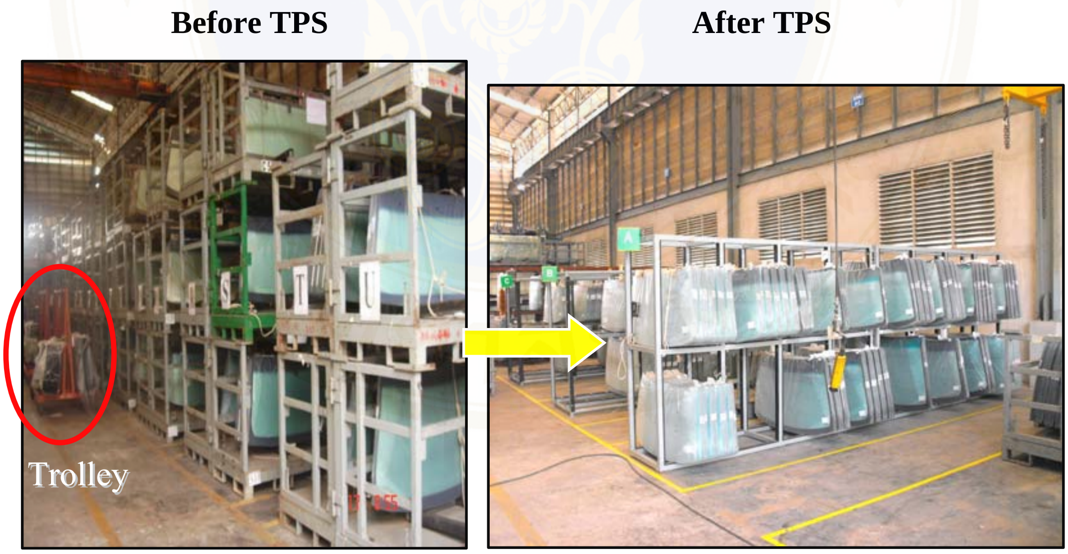
**Figure 4.3 Storage layout for glass material after TPS**

As a result, it could eliminate search time and is more convenient to find the needed glass material for production. The amount of glass material in the storage was easier to monitor and manage and less space was required to store the glass, opening more free space.

1.2 Warehouse of the finished products

At the warehouse, the original design of storage racks occupied a large space and it was difficult to do first–in first-out (FIFO) for taking glass that was produced earlier and placed inside as demonstrated in figure 4.3 before TPS. Moreover, some trolleys that are loaded with finished goods had not been put away into the storage rack, were parked in the hall.

**Figure 4.4 Warehouse of finished products**




Similar to the storage of glass raw material, TPS also did the visual control by developing an inventory board to display the quantity and location of the finished goods by product category. Moreover, the new storage shelf was designed and built for keeping the glass in order of type or specification and able to do first-in, first-out.

As a result, the number and location of the glass could be viewed and it was easier to check stock and find the needed piece of glass. Less space was required. The warehouse area could be decreased from 162 to 54 square meters. Moreover, less time was required to find the specific glass to be delivered to the customers.

**2. Production control**

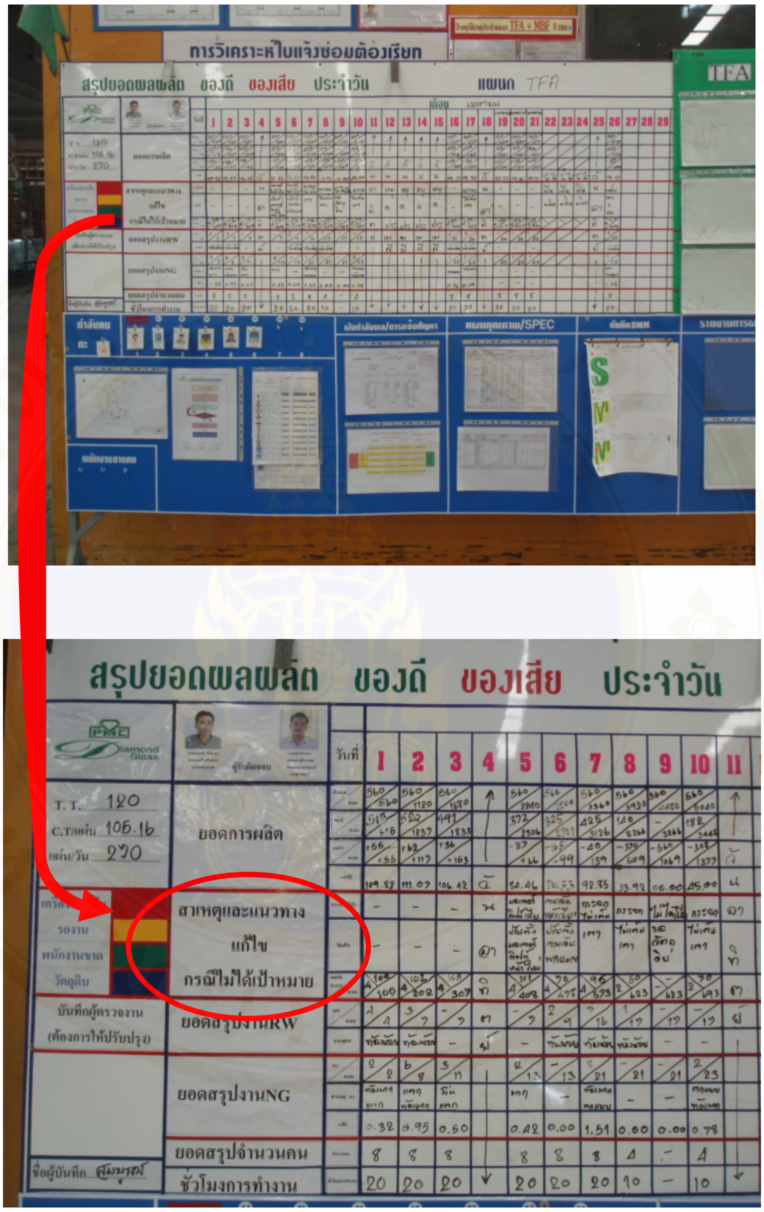
In order to control the production, originally each division in PMC's factory had a production board that recorded and displayed the level of production of glass and defects, but it was only on a daily basis. There was no record of the cause of defects or not reaching the production target and no record of level of manpower employed. There was also no solution or much concern about the problems. Thus, problem solving could be delayed for several days or weeks.

**Figure 4.5 Production Control Board before TPS**


From TPS's project, The Performance Control Board was improved to include the cause of defect, information about workforce and worker shortage management. Worker need to record the production results hourly and report if there was any problem immediately in order to find out the root cause and make correction.

According to the visual control concept, everything should be visualized. Not only the level of production hourly but also the reason for not reaching the production target must be recorded on the new Production Control Board as well as the solutions to the problems and data about workforce management. For TPS's principle, no problem is hidden.

**Figure 4.6 Production Control Board after TPS**




As a result, everybody could understand the production performance and problem at every division. When employees see the production plan and progress on this board, they would know their role and be able to proceed with what they need to do without waiting for verbal orders from their chief.

When things are well organized, visualized and put in order, it is easier to identify if there is any problem in the production, they tend to be solved faster, reduce repeated errors, defects, waste and total costs.

Supervisors and managers can simply notice and understand the status and performance of work in each division by looking at the visual sign and board. By knowing the actual real time status or problem of work, the supervisor or shop head could be more efficient in managing and controlling the production, time, labor and quality, planning for the next work and solving the problem at the line immediately.

Worker in each division would know and be able to proceed with their own work by looking at the production planning board, without waiting for the order from the head. This could shorter the lead time as the work is done in a more continuous manner.

### 3. Workforce Control

PMC originally had nothing for monitoring human resources or the workforce. There was no record of the worker skills and no target for developing those skills. It was difficult to manage the labor efficiently, especially when there was worker absenteeism or labor shortage.

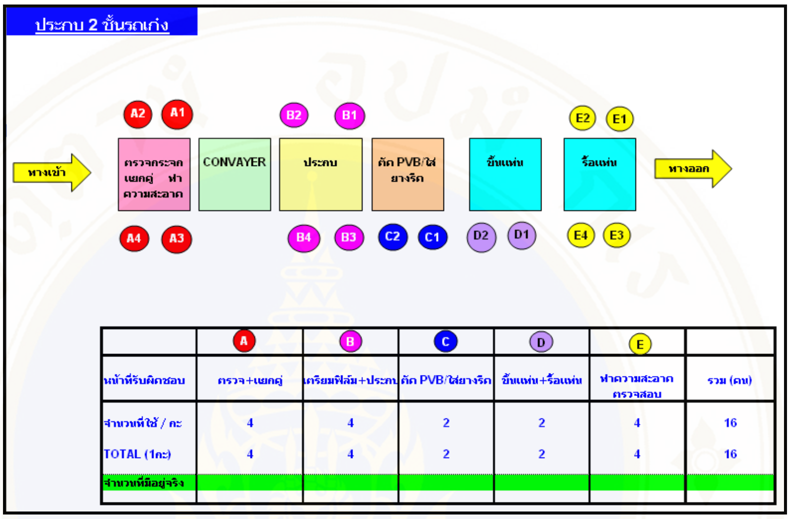
In order to visualize the workforce information, the Workforce Control board was created on the production control board for planning and displaying the worker's name and number in each division.

**Figure 4.7 Workforce Control Board after TPS**


Thus, supervisors would know the number of their staff who come on that day, so they could better manage their people and work more efficiently.

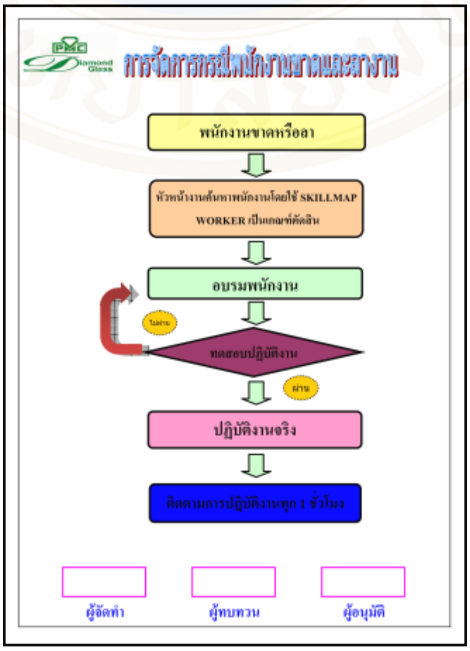
A workforce design for each division was created and posted on the board. It depicts the amount of worker required to perform the work at each stage as the example shows in figure 4.8.

**Figure 4.8 Workforce Design**




The procedure for replacing workers was also developed in a graphic chart, which is easy to understand and know on how to deal with the worker shortage.

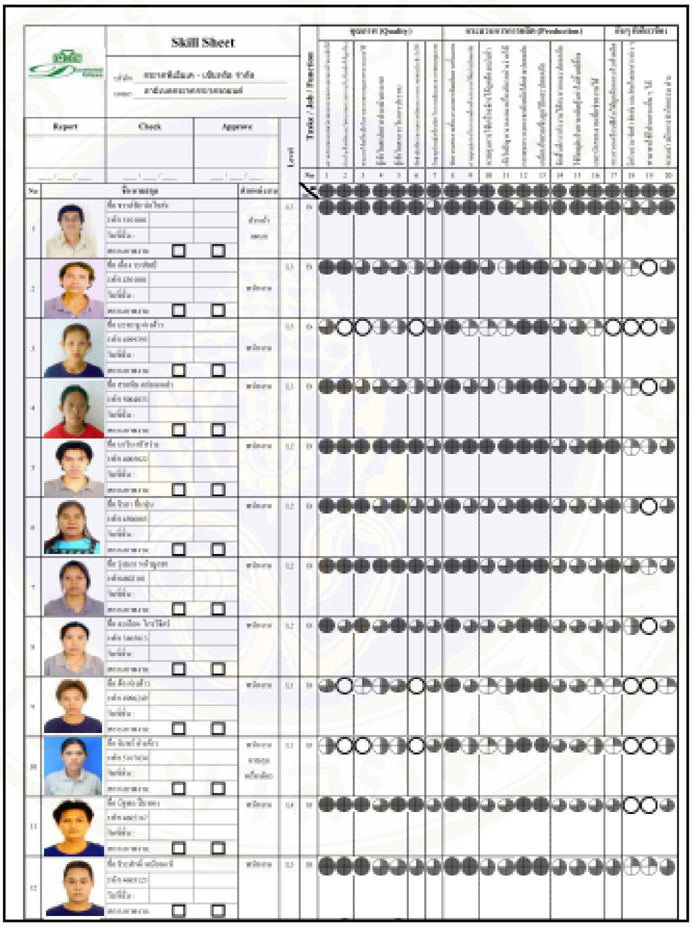
**Figure 4.9 Procedure for Worker Replacement**




Source: PMK-Central Glass Company ltd. (2010)

A Worker Skill Sheet was created to identify and display the skill of each worker, i.e. who has what skills. It is useful to know who haa what skills in order to manage their work and to train them efficiently. One worker can replace another position when needed.

**Figure 4.10 Worker's Skill Sheet**



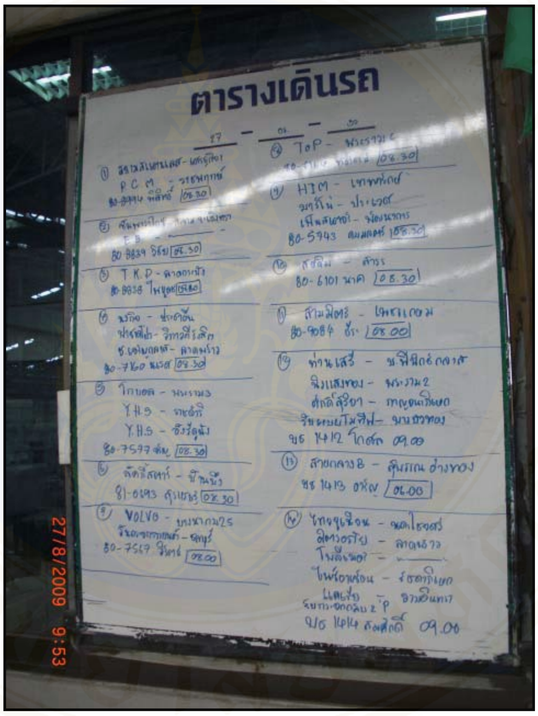

Source: PMK-Central Glass Company ltd. (2010)

Human resources or people are considered an important factor of production. Glass manufacturing is labor intensive, relying on people to perform the work and to transfer glass from one division to the next. Once information regarding people is displayed and visualized clearly. It becomes easier and more effective in managing their work force in each division.

**4. Delivery Control**

Similar to all other divisions in PMC's factory that has a displaying board for visual control. The delivery division also has a delivery board for planning the delivery schedules, but it was in an informal way, disorganized and did not shown enough detail. So it was difficult to know the delivery and loading progress and it was impossible to control delivery time and delivery schedule precisely.

**Figure 4.11 Delivery Schedule Board before TPS**




From the TPS project, the Delivery Control Board was formally developed for planning and showing the delivery schedule in detail, which are delivery time (in & out), customer's name, destination, truck id number, driver names as well as showing the preparation, loading status and time (from start process to finish loading or delay).

**Figure 4.12 Delivery Control Board after TPS**


**Delivery Dock** **Waiting Post for Delivery order**



Delivery control board and waiting post were used to control delivery of the goods to customers efficiently. As a result, everybody especially drivers, could easily understand their delivery trip assignment each day. While supervisors or management could know the delivery's status (loading, finished loading or delay) is under control and on time or not.

**5. Safety Control**

Accidents can happen at any time; even though no one wants or expects them. The cost of not providing safeguards a risky process. It is essential to take extra steps to establish and maintain safe systems and practice. Prevention is the best possible working environment for the health and safety of everyone.

5.1 Warning of Dangerous zones

There are some areas in PMC's factory that are dangerous and require caution, were no warning signs or colors indicate any danger zone as shown in the picture below. With the TPS project, those danger zones were painted so as to be noticed and workers made aware of them.

**Figure 4.13 Safety Conditions**

**Before TPS** **After TPS**

5.2 Safety rules and regulations.

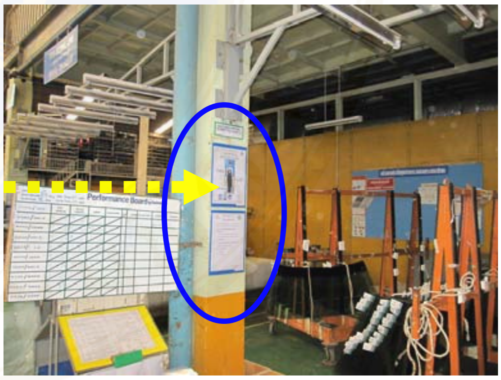
In PMC's factory, there were safety rules and relations on the board, but they were not updated and not noticeable. There was high risk of accidents and it was dangerous for workers. After the TPS project, the safety rules and regulation for each division were revised to give more details e.g. requirement to wear safety glove, head and foot protection, boot, hat, etc.

**Figure 4.14 Safety Instruction**

**Before TPS** **After TPS**


Safety instruction, rules and warning signs were always posted, where it is visible to educate people.

**Before TPS** **After TPS**



**Before TPS** **After TPS**

**6. Machines and Equipment Control**

Machinery and equipment are useful; they can facilitate the work to be easier and faster. But they are inherently dangerous, even when well designed. An extra level of effort is needed to keep operators free of injury. It is important that operators use them correctly and has adequate knowledge on them. At PMC, the manual for machinery and equipment is available, but it was too complicated and quite difficult for worker to understand. The board for operation instruction was also not visible, not updated and there were not machine checklists at the production line.

**Figure 4.15 Operating Instruction before TPS**


Source: PMK-Central Glass Company ltd. (2010)

After the TPS project, the operating instructions and safety concerns were revised and posted beside machinery and equipments such as elevators, forklift trucks, etc., where they were easy to see and prevent inappropriate use of the equipments. The standard of work in utilizing machinery and equipments increased. The condition of machine could be visually understood. Machine break down problems could be eliminated by preventive maintenance.

Moreover, PMC's employees were encouraged to be concerned and followed safety rule. There was a lower chance of accident or injury. Thus, safer working environment was promoted. There is lower possibility of accidents and injury and a lower rate of workers missing for medical treatment.

**Figure 4.16 Operating Instruction after TPS**


Source: PMK-Central Glass Company ltd. (2010)

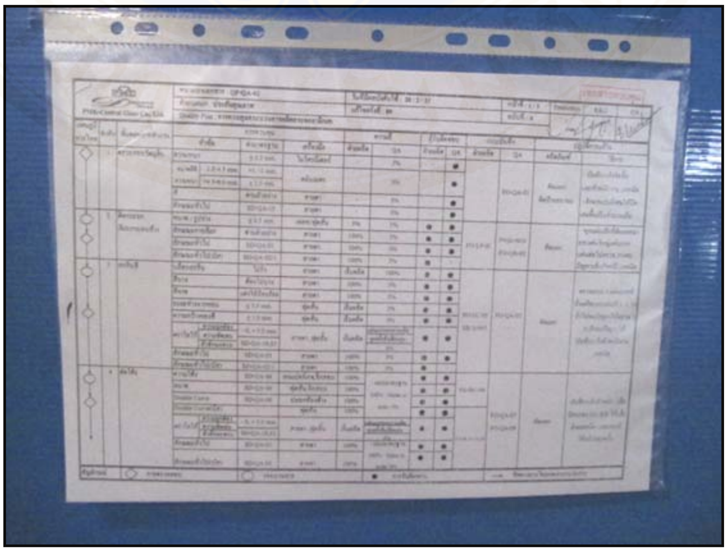
7. **Quality Standard:** Building a standard of quality into the process

Originally, for quality assurance, PMC's product specification documents were not ready for use. There was no standard on what was to be monitored and no procedure for handling any out of spec. or quality problem.

**Figure 4.17 Product Specification before TPS**

With the TPS project, the quality plan and quality assurance (QA) was revised to be more specific about the product specification and the criteria for standard quality.

**Figure 4.18 Product Specification after TPS**



One of the Toyota way's principles "Jidoka" is to build quality during the process by the ability to stop the production line to fix the problems, to get the quality right for the first time. Jidoka helps prevent the passing of defects, identify and correct problems. PMC has also developed a guideline for dealing with their product's quality problem. They promoted a new culture and practice called "STOP >> INFORM >> WAIT".

STOP means to stop the production, once any error or defect is detected.
INFORM means to inform the supervisor and person in charge.
WAIT means to wait for the problem solving decision.

**Figure 4.19 Jidoka/ Stopping guideline after TPS**


Problems were classified into four categories as per the following. Each category would have different person to take care and solve the problem.

1. Problem related to the product quality
2. Problem related to the machine break down
3. Problem related to the production process
4. Problem related to the production plan

Continuously solving the root problem would drive organization learning. With a quality plan and quality assurance, employees are better at acknowledging the product's quality standard in order to ensure that glass products meet and pass the criteria.

With the new practice, employees know who they need to contact and inform in case of any problem occurring. For different problems, employees need to contact different departments to solve the problem. Employees and related parties would go and see the problems first on hand in order to understand the situation thoroughly and be able to correct it in a timely manner. In practice, PMC rarely stop the production line, if the problem could still be handled or be under control.

For visual control, PMC adopted the alarming light for showing the status of production by different color as the following.

**Figure 4.20 Production's Status Light**


| | | |
|---|---|---|
| Red | means | Machine is out of service |
| Orange | = | Waiting for the next batch |
| Green | = | Production is running |
| Blue | = | Monthly Preventive Maintenance |
| Black | = | Waiting for parts |

Using the alarm light to inform about the current status of production, whether the production is running normally or if there is any delay or they are waiting for something or a machine is broken down and have called for attention.

In doing Worksite Control, PMC has been using many visual controls in their factory where applicable. A display board, sign, colors were adopted in all divisions to include more detail for showing the work status and performance as per the following examples:

- Performance board for production level -monthly, daily and hourly
- Delivery Control Board
- Loading Board
- Inventory Board both for displaying the information of glass production
- Workforce Control Board

**Inventory Board** **Loading Board**



Thus TPS's Visual Control was a very powerful element in improving the production capability and control, but they did not require a large capital investment. Therefore, it was considered to be very cost effective and efficient.

**Step II : Continuous Flow**

Most business processes are 90% waste and 10% value-added work. Continuous flow is the objective of Lean manufacturing or TPS to have materials flowing constantly through the factory to meet customer demand with a minimum level of work in process (WIP) inventories.

Continuous flow is usually referred to as the design of one piece flow, following the TPS principle. Create continuous flow wherever applicable in the core manufacturing and operating processes that bring problems to the surface and eliminate idle time and waste.

In the Continuous flow, using the material flow from raw material to finished goods, PMC focused on rearranging the production layout in order to find ways to shorten the distance or the flow of glass as much as possible and to speed up time and labor requirements.

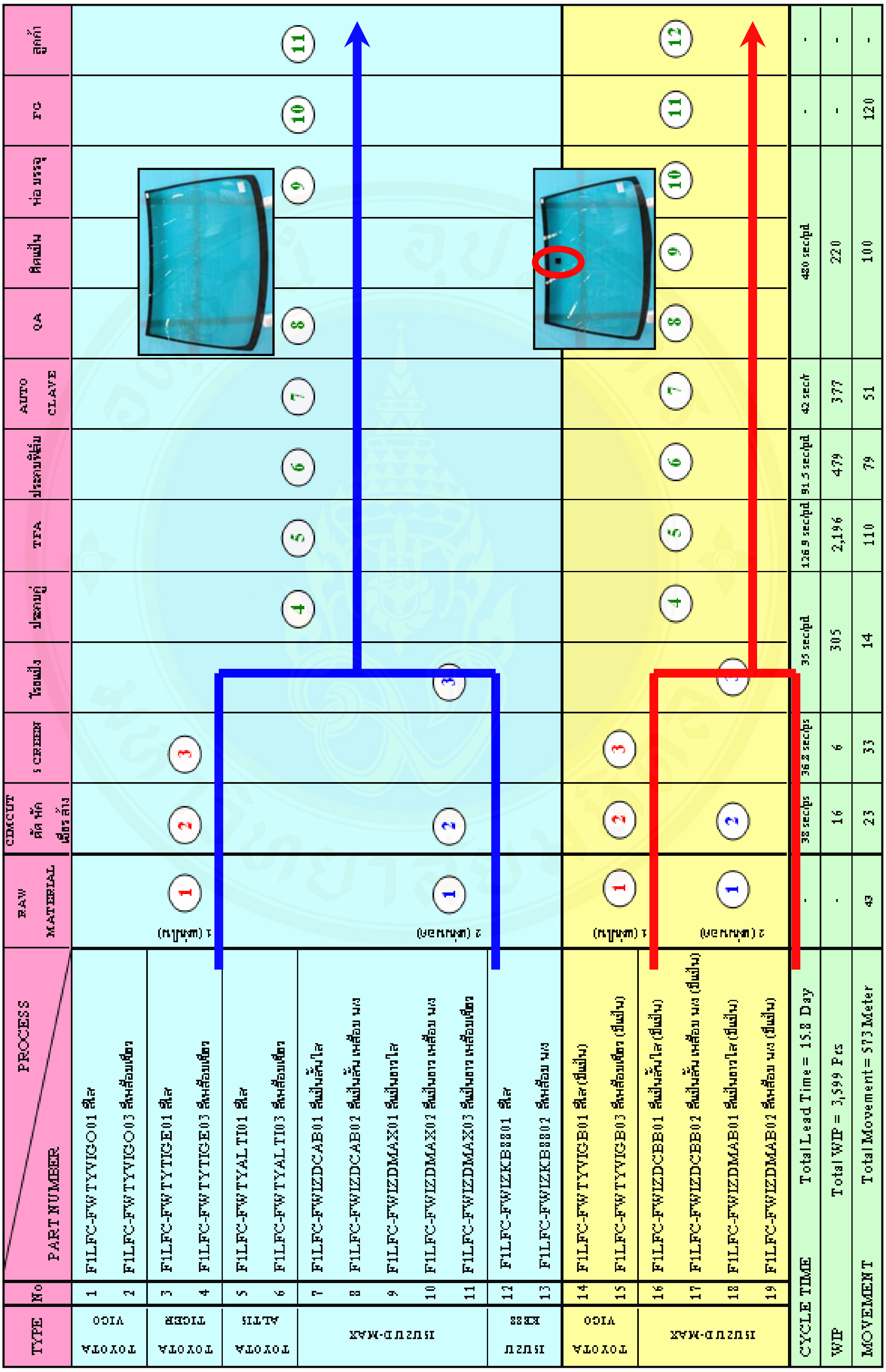
According to PMC's Material Flow Chart, there are 10 steps in PMC's glass manufacturing process, starting from raw material to finished goods. Four areas in this material flow could be identified to be adjusted in order to shorten the process flow as per the following:

1. From the storage of glass material to Cimcut division
2. From Screen drying machine to Powder division
3. JIG Quality Assurance area in between Glass Bending TFA division to Laminate division
4. Moving Quality Assurance next to Auto clave division

All these layout adjustments were done without moving any machines, because it was too costly and not reasonable to resettle machinery.

The following diagram is the PMC's Material Flow Chart, which starts from raw material to finished products.

**Figure 4.21 PMC's Material Flow Chart**

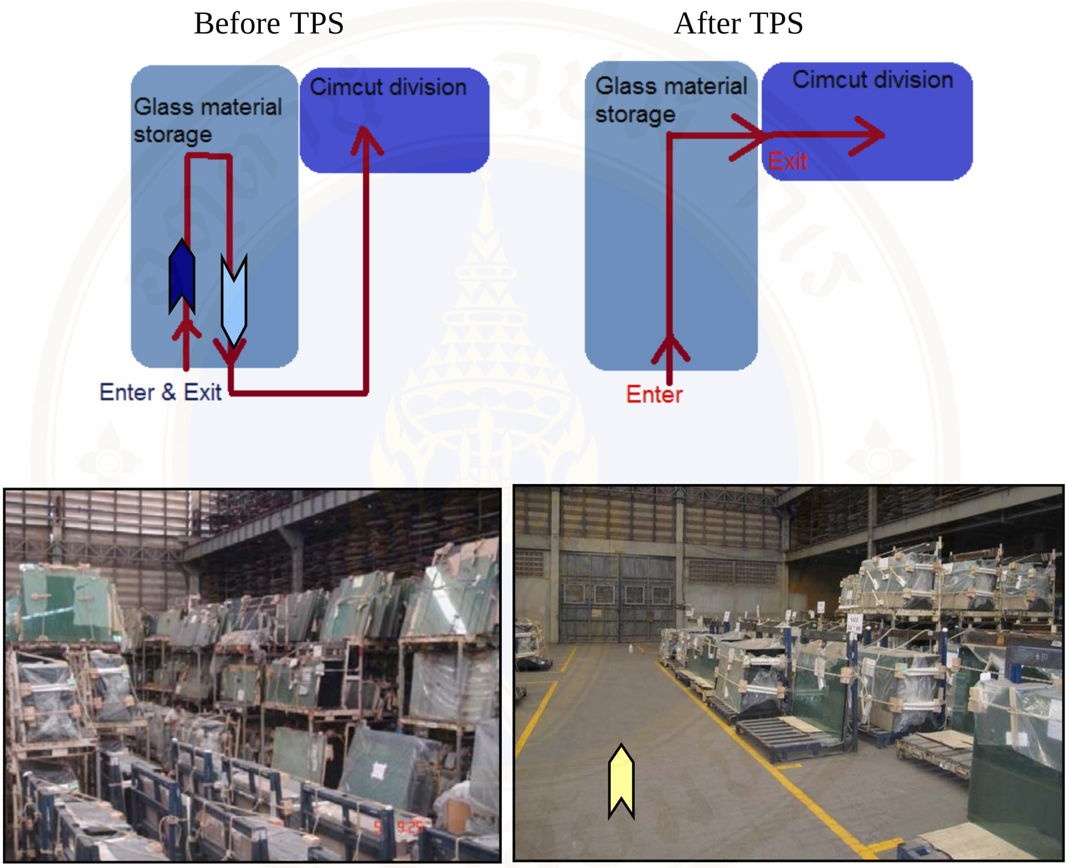



Source: PMK-Central Glass Company ltd. (2010)

Improving the production layout

1. From the glass material storage to Cimcut division

**Figure 4.22 Route for Moving Glass from Glass Storage to Cimcut Division**



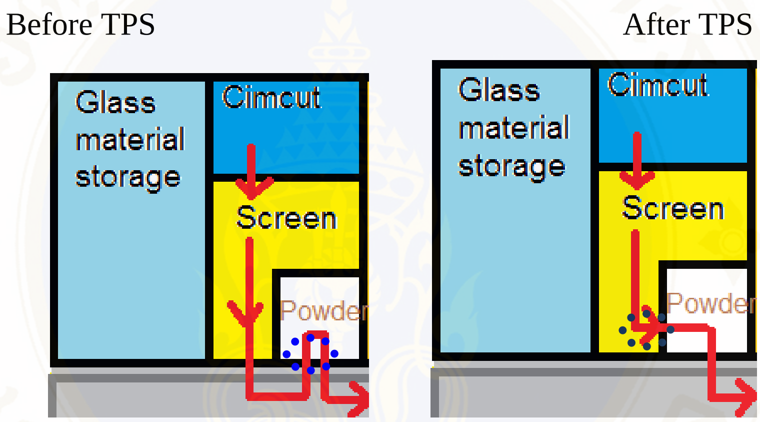

Originally, Glass material storage had only the same entrance and exit. Glass material needed to be carried both entering and exiting through the same gate. Therefore, the distance of moving glass material to the next step at Cimcut division was roundabout and unnecessarily far. Some glass material was placed in the inappropriate area and order e.g. in the way of a trolley. It was difficult to find needed glass material for production.

In order to smooth the flow of work by shortening the distances for moving the glass, PMC made a new exit that is directly connected to the Cimcut division, as well as rearranged the glass material storage area. Glass is now stored and classified by type, size and labeled with the details of glass material, using First in – First out (FIFO) concept.

Moving glass along a production line requires trolleys, a labor force, time, which are all incur costs to the business. Minimizing the travelling distance of glass could reduce the costs to the business substantially, as well as increasing the speed and efficiently of work. The needed glass material could be found more easily and quickly.

2. From Screen drying machine to powder division

**Figure 4.23 Route for Moving Glass from Screen drying machine to Powder**




The Power division was required to be in a closed room to protect from dirt and dust. After screening, the glass must be carried by trolley for some distance to the next division (powder)'s door. The glass was carried up and down the trolley to machines by labor so the glass did not flow smoothly. It caused a high lead time and high risk of damaging the glass. Labor was required to move the trolleys and workers got tired.

For a continuous flow of work, PMC decided to punch a hole in the wall between the screening and power room in order to connect them and allow the glass to flow smoothly between these two divisions, see figure 4.23. A special rolling rack was devised to support the transferring of glass from screen machine direct to the power room as shown in figure 4.24.

**Figure 4.24 Punched hole in wall between the screening and power room**

**Figure 4.25 Rolling rack for supporting glass flow**

The glass now flows smoothly from screen machine to the power room, without the use of a trolley. The labor and time required in these processes decreased and shorten the lead time.

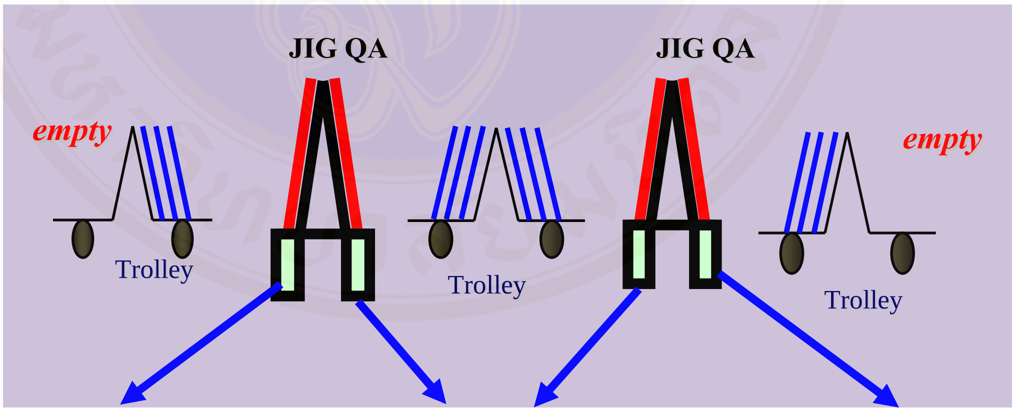
3. JIG Quality Assurance stand between Glass Bending (TFA) and Laminate division

After glass bending or TFA process, glass must be checked for quality assurance by using a JIG stand. The layout of JIG stands in the PMC factory was ineffective too roundabout, since it was an excessively long distance to move glass from TFA to the Laminate division. Moreover, as many as 9 trolleys were required to carry glass for JIG quality assurance. Some trolleys that were running were not fully utilized and were half empty.

To smoothen the flow of work, the layout of JIG stands was rearranged in a different direction. This new JIG layout could shorten the distance of glass flow from TFA to Laminate division as well as reduce the number of trolleys required from 9 to 6 and each trolley was fully utilized. Moreover, a smaller area was required for JIG quality assurance.

**Figure 4.26 Position of JIG quality assurance stands (JIG QA)**

**Before TPS**




**After TPS**

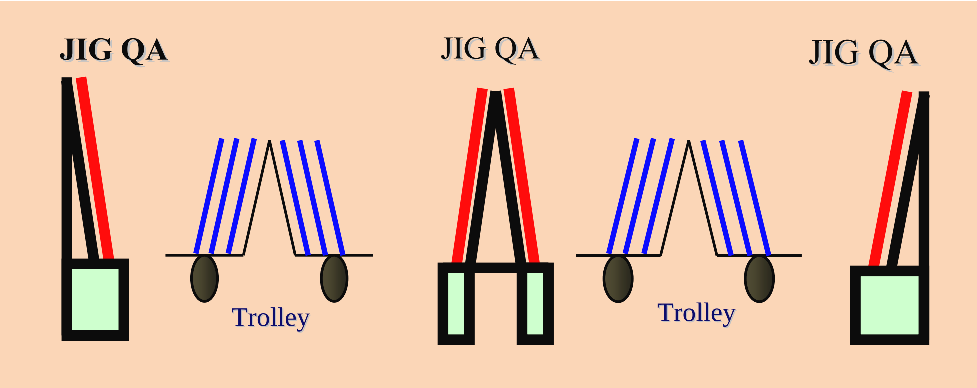
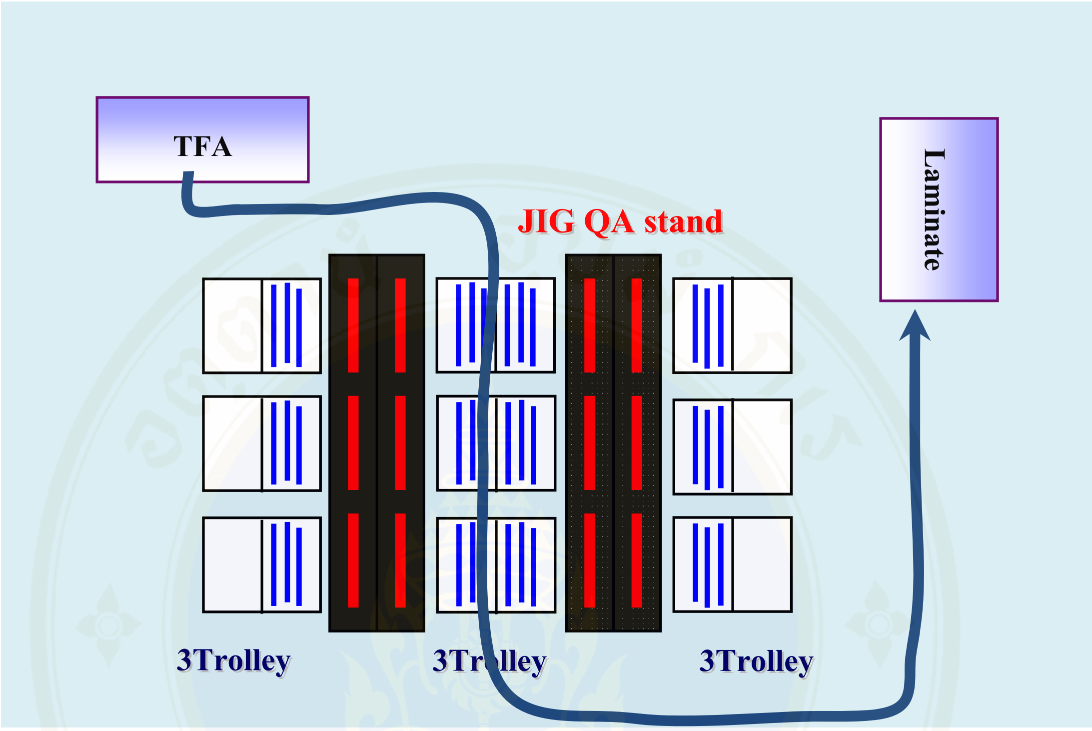


**Figure 4.27 Layout of JIG quality assurance stands**

**Before TPS**




**After TPS**

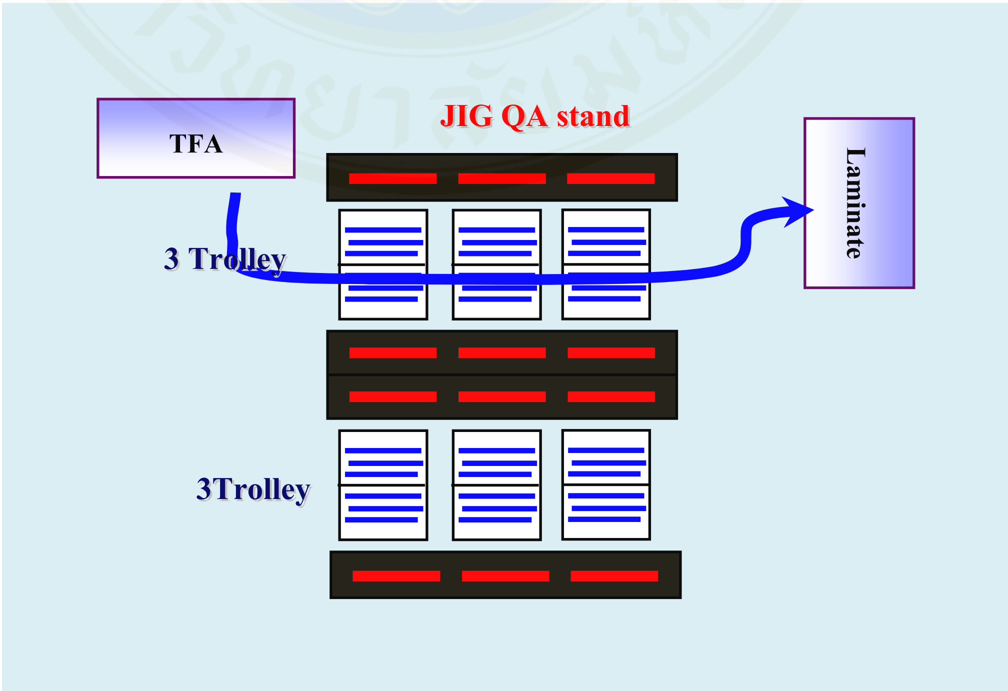



**Figure 4.28 The direction for moving glass from TFA to Laminate division**

**Before TPS**

**After TPS**


4. From Auto clave to the Quality assurance and Packaging division of the finished goods

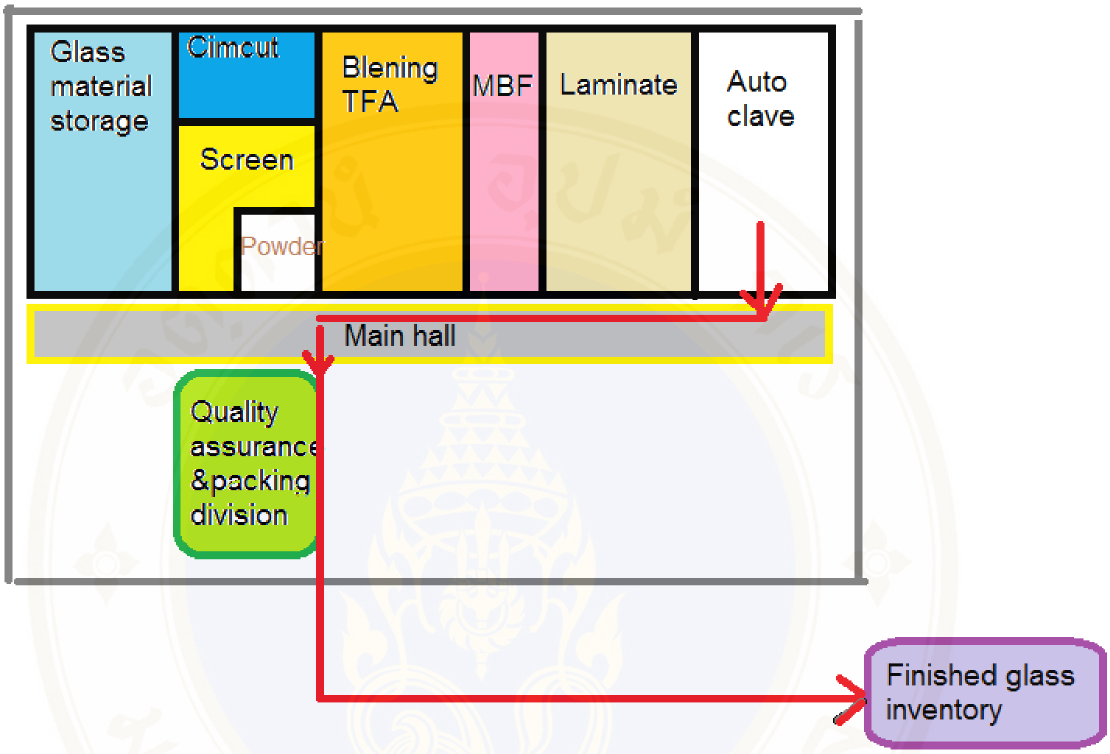
After passing the Auto clave division, glass must pass Quality assurance (QA) & Packing division, before being ready to be sold. However, PMC's Quality assurance and packaging division of the finished goods was located far away from the production line (Auto clave). It took an unnecessarily long distance to move finished goods from Auto clave to Quality assurance & Packaging division and then to the finished inventory.

**Figure 4.29 Quality assurance division & Packaging division**


Since there was no heavy machine or equipment in the Quality assurance and Packaging division, it was easy to relocate this division to be adjacent to the Auto clave division. Now, the finished glass moves the shortest possible distance and it is more convenient, from Auto clave to Quality assurance & packaging division, then to the inventory. The layout of Quality assurance & packaging division was rearranged and reduced excessive checking. Therefore, the lead time required is decreased.

**Figure 4.30 Moving Quality Assurance next to Auto clave division**

**Before TPS**




**After TPS**

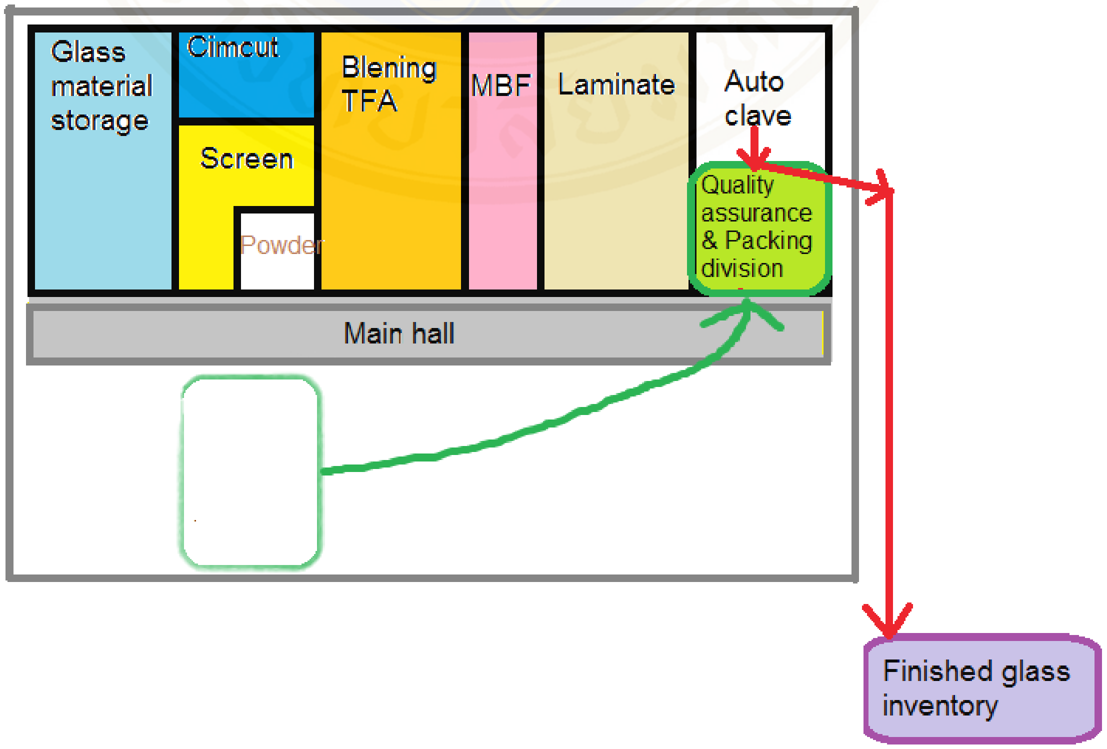
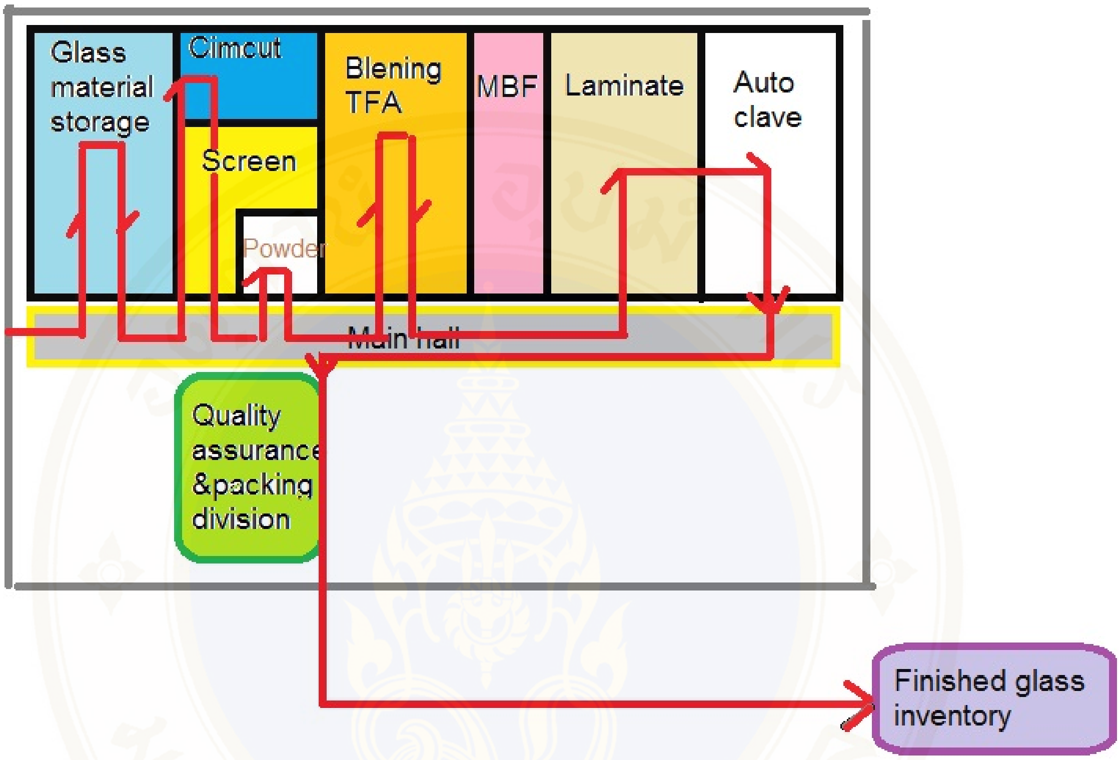


**Figure 4.31 Total Route for Moving Glass in PMC's Factory**

**Before TPS**




**After TPS**

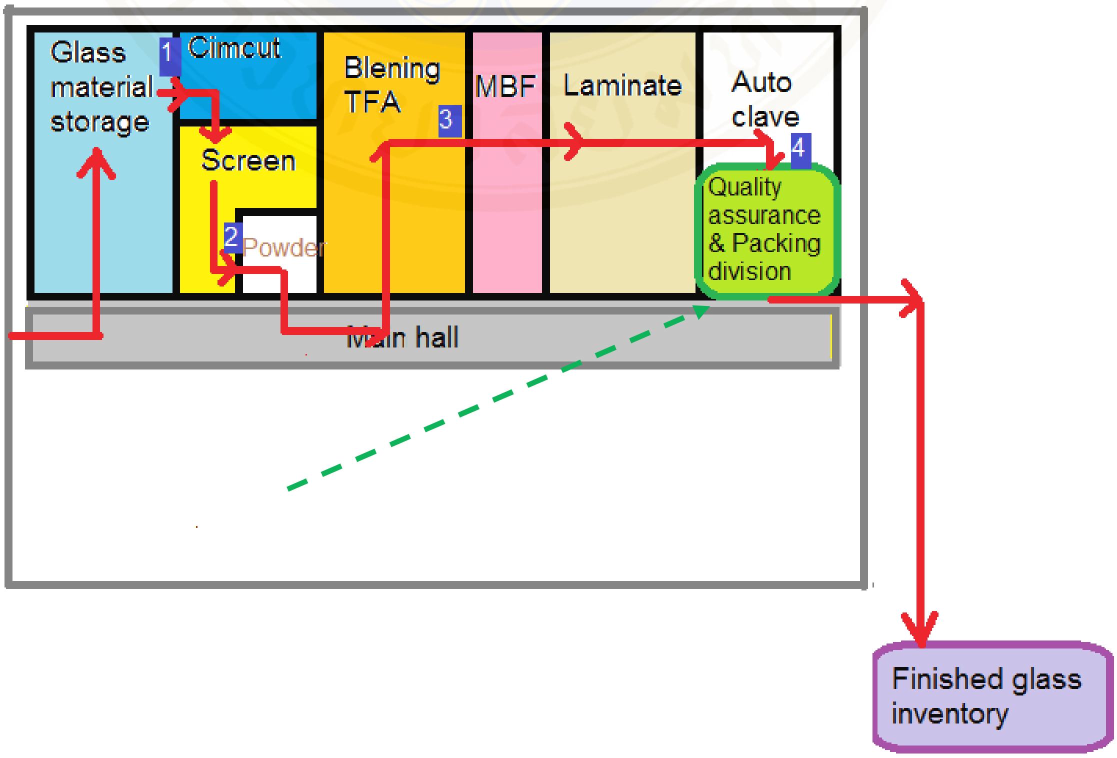


**Table 4.6 Summary of Continuous Flow Results**

| **Material Flow** (from raw material to finished goods) | | Before TPS | After TPS | % Diff. | Target Reduction |
|---|---|---|---|---|---|
| Total lead time | day | 15.8 | 12.9 | -18.35% | -50% |
| Total work-in-process | piece | 3,599 | 3,127 | -13.11% | -30% |
| Total glass movement | meter | 573 | 390 | -31.94% | |

The previous demonstration pictures show the whole process flow of glass work from being a raw material to being finished goods before and after TPS project. With the TPS project, there were 4 areas in the production layout that were changed. As a result, PMC could successfully shorten their process flow. Total distance of glass movement from the storage of glass material to become finished goods in the production process decreased significantly from 573 to 390 meters, which accounted for -31.93%, approximately reaching the target of -30%.

As a result of implementing Step II: Continuous Process Flow, total lead time of production decreased from 15.8 to 12.9 days or accounted for -18.35 %, which is below the target of 50%. Therefore PMC need to try harder to continue the TPS program in order to achieve a shorter lead time.

The total work in process decreased from 3,599 to 3,127 pieces, accounted for 13%. Moreover, there was 164 sq.m. of free spaces after implementing TPS program.

**Step III: Standard Work**

A standardized task is the foundation of Kaizen/ TPS (continuous improvement and employee empowerment). The production would emphasize Safety, Quality and Cost efficiency. TPS organizes all human movement around the processes by creating an efficient production sequence and work layout. Work sequence and work layout are defined to minimize human variation and unnecessary walking or movement. These could get rid of excessive labor, while maintaining quality and reducing defects.

The goal is to achieve a cycle time, which is capable of meeting the takt time requirements and reduce the quality problem frequently caused by human variation in the process and work load imbalances. PMC had set targets to increase the productivity by 30% and to reduce the workforce 20% by increasing the work efficiency and applying multi-task functions.

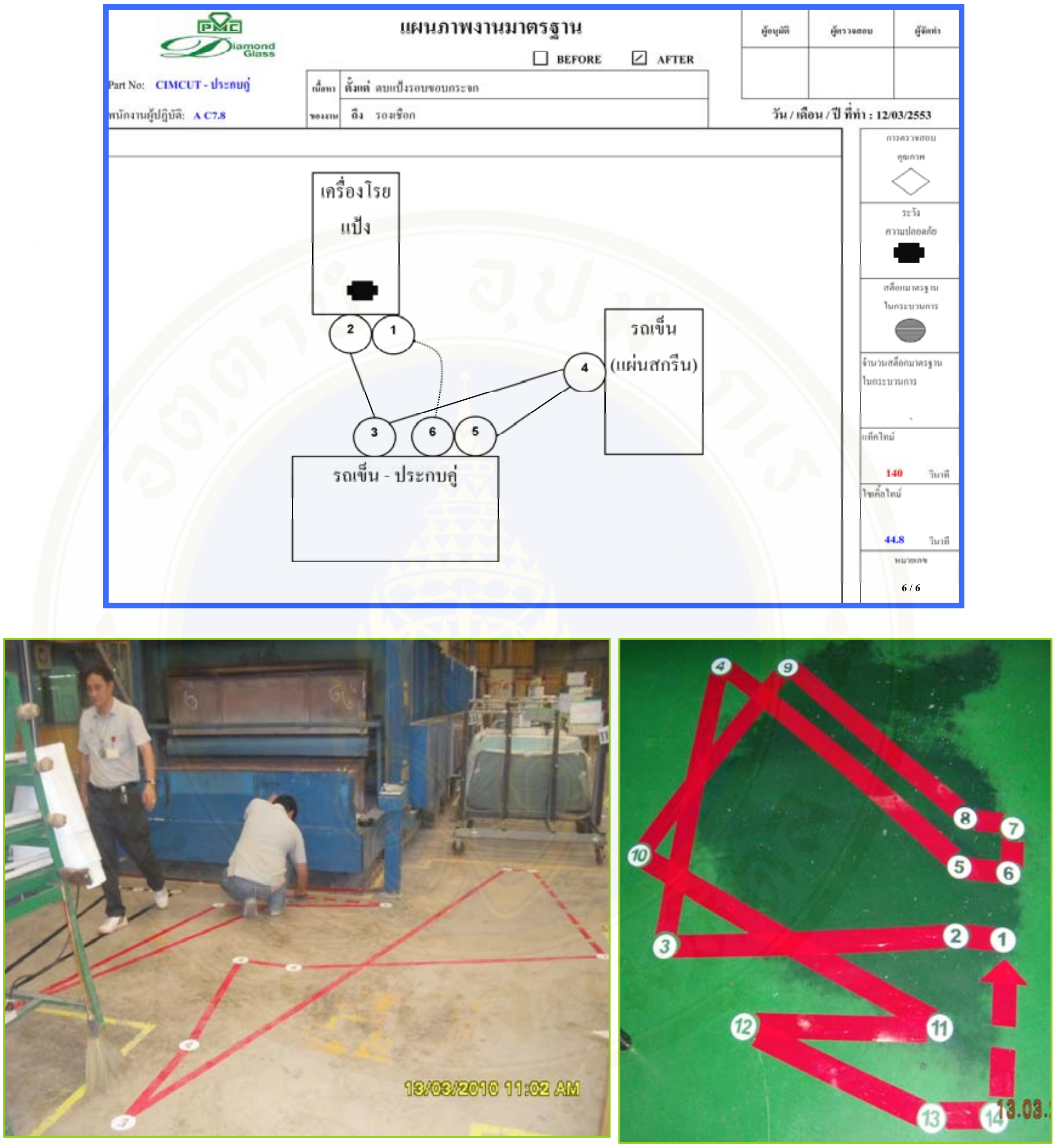
PMC has implemented step III: Standard Work as followings;

1. Design the work sequence and work layout indicating the operators' movement
2. Recording and calculating the cycle time of each division
3. Calculating the takt time -maximum time per unit allowed to produce a product
4. Drawing the Yamazumi chart.
5. All tasks of each worker were described in the work sequence and that workers must follow step by step.

Originally, PMC did not have a work standard. Their workers' motion was disorganized. The work sequence could be different each time. Process variations create costly quality problems, including wasting resources and time for rework and correction. As a result, that each output may deviate from the standard criteria or take longer time to complete. Standardized work would try to find the best method for completing each work and make everyone perform that work in the uniform way all the time.

PMC has tried to do standard work and started by clearly designing the work sequence, rearranging the work layout and marking each step of work on the plant floor in order to visualize control by directing the worker movements and being able to control the working/ cycle time. The below diagram is an example of the Work Sequence and Work Layout of the Cimcut division. The numbers indicate the sequence of work step 1, 2, 3 and so on.

**Figure 4.32 Work Sequence and Work Layout**




The time taken in doing the work for each step was recorded into a Time Check Sheet table several times to find the cycle time needed to process a piece of glass in all divisions from the Cimcut to Quality assurance and packaging divisions. An example here in figure 4.32 is in the Cimcut division, the cycle time is 44.88 seconds and takt time is 140 seconds or 2.33 minutes. Takt time is the maximum cycle time per unit allowed in producing a product in order to meet demand. Thus, PMC's cycle is less than the takt time by 95.12 seconds or 1.585 minutes.

**Table 4.7 Time Recording Sheet in Cimcut division**

BEFORE ☐ AFTER ☑ — แบบฟอร์มตารางจับเวลา

| Process | CIMCUT - ประกบคู่ | | | | | | | | | | | วันที่ | 12-มี.ค.-53 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model | หน้า 2 ชั้นเก๋ง ติดแป้น | รอบที่ | | | | | | | | | | ผู้บันทึกเวลา | | | |
| | | | | | | | | | | | | ผู้ปฏิบัติ | | | |
| ลำดับ | รายละเอียดงานที่ทำ | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | 10th | น้อยสุด | มากสุด | ส่วนต่าง | เวลาเฉลี่ย |
| 1 | ตบแป้งรอบขอบกระจก | 11.92 | 17.64 | 17.45 | 16.56 | 14.83 | 15.96 | 12.87 | 15.80 | 14.38 | 13.00 | 11.92 | 17.64 | 5.72 | 15.04 |
| 2 | ยกกระจก(โรยแป้ง) | 6.00 | 5.43 | 4.95 | 5.93 | 4.89 | 3.96 | 4.63 | 5.55 | 5.34 | 4.38 | 3.96 | 6.00 | 2.04 | 5.11 |
| | เดิน | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 1.00 |
| 3 | วางกระจกบนรถเข็น | 1.25 | 1.56 | 1.76 | 1.86 | 1.55 | 1.84 | 1.24 | 1.98 | 1.87 | 1.54 | 1.24 | 1.98 | 0.74 | 1.64 |
| | เดิน | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 0.00 | 2.00 |
| 4 | ยกกระจก (สกรีน) | 6.36 | 4.30 | 4.56 | 4.20 | 4.83 | 5.60 | 5.87 | 5.66 | 5.00 | 4.98 | 4.20 | 6.36 | 2.16 | 5.14 |
| | เดิน | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 0.00 | 2.00 |
| 5 | วางกระจก(สกรีน) ประกบคู่บนรถเข็น | 1.46 | 1.54 | 1.88 | 1.98 | 1.78 | 1.56 | 1.89 | 1.65 | 1.55 | 1.91 | 1.46 | 1.98 | 0.52 | 1.72 |
| 6 | รองเชือก | 4.83 | 4.24 | 4.82 | 4.98 | 3.96 | 4.01 | 4.70 | 4.88 | 4.56 | 4.32 | 3.96 | 4.98 | 1.02 | 4.53 |
| | เดินกลับ | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 1.00 |
| | รอเครื่องจักรทำงาน | 8.75 | 8.75 | 8.75 | 8.75 | 8.75 | 8.75 | 8.75 | 8.75 | 8.75 | 8.75 | 8.75 | 8.75 | 0.00 | 8.75 |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| Total | | 46.57 | 49.46 | 50.17 | 50.26 | 46.59 | 47.68 | 45.95 | 50.27 | 47.45 | 44.88 | 44.88 | 50.27 | 5.39 | 47.93 |

Source: PMK-Central Glass Company ltd. (2010)

Cycle time

Then PMC established the Process Time Analysis table to show a series or sequences of work, including time required.

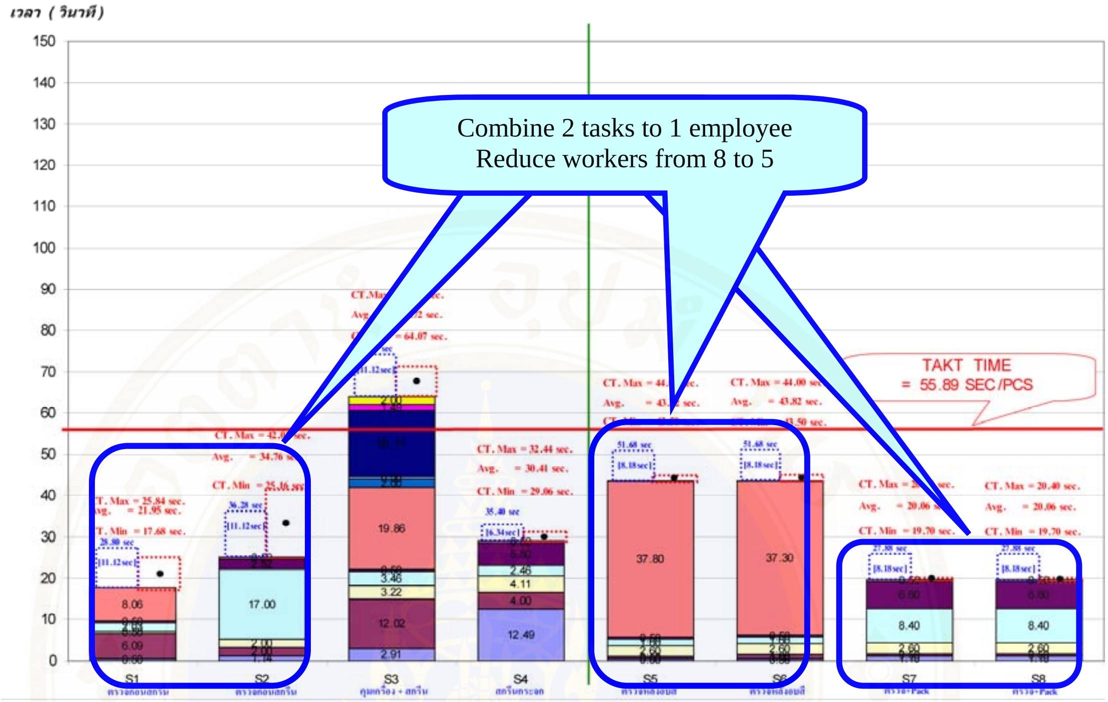
**Table 4.8 Process Time Analysis Table**


Source: PMK-Central Glass Company ltd. (2010)

Cycle time = 262.37 Second
Takt time = 55.89 Second

A Yamazumi chart is a stacked bar chart that shows the balance of cycle time workloads between the numbers of operators in an assembly line. Toyota had been using Yamazumi chart as a work balance chart to visually present the work content or a series of works and facilitate the work balance and the isolation and elimination of non-value added work content.

**Figure 4.33 Yamazumi Chart**




Source: PMK-Central Glass Company ltd. (2010)

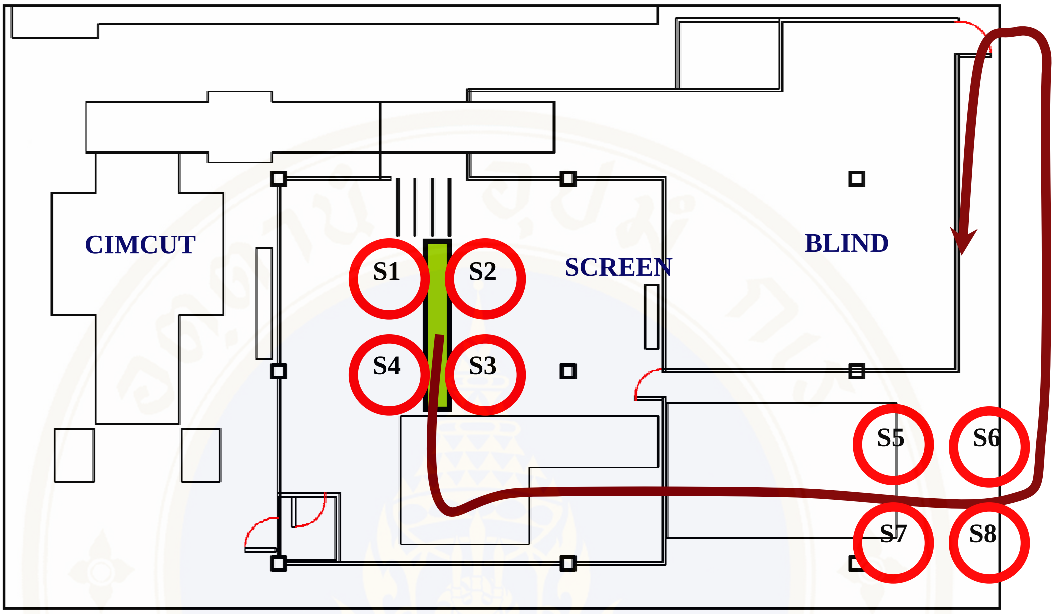
PMC applied the Yamazumi chart to analyse their workforce in each division to balance the workload of each worker, combine some tasks in order to minimize the number of worker. For an illustration, the Screen division previously had 8 persons, the Yamuzami chart could allow the management to review the work time in detail and combine some tasks to 1 employee in order to reduce the number of employees required from 8 to 5 persons, while still be able to perform all the work within the takt time. The same activity was also done in other divisions and got the following results.

- Cimcut division could reduce the number of employees from 7 to 4 persons.
- Glass blending (TFA) could reduce the employees from 7 to 5 persons.
- Laminate could reduce the employees from 16 to 10 persons.

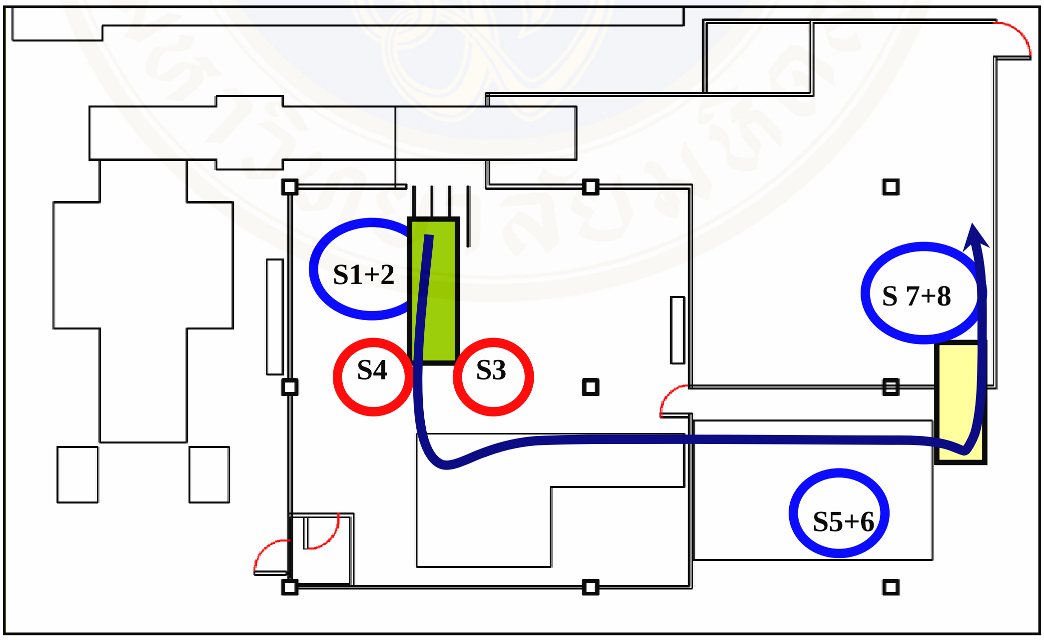
Some tasks could be combined to be done by an employee in order to reduce the number of employees required. The diagrams here demonstrate the screen division. After the TPS project, task 1 and 2, task 5 and 6, task 7 and 8 were combined into. As mentioned earlier, the employees in this division could be reduced from 8 to 5 persons and still were able to perform at the same level and speed of work flow.

**Figure 4.34 Task and Worker Layout**

**Before TPS**




**After TPS**




Source: PMK-Central Glass Company ltd. (2010)

**Step IV: Pull Systems**

Because traditional manufacturing used the "Push" concept in making large batches of product and "pushing" them to the downstream operation whether they were ready for them or not, Push system often produced products that were not sold. It was so called "overproduction." This was considered to be one of MUDA or "7 Waste" according to the TPS principle.

In order to eliminate the overproduction problem, TPS or Lean Manufacturing would prefer Pull Systems, which started at the opposite end. The production processes were based on customer demand. Customer orders drived production schedules based on actual demand and consumption rather than on forecasting. Once a customer placeed an order, it would trigger the last process signals to the upstream process to produce a product. Each upstream process received the signal or order from the downstream process that it needs a product, all the way up toward the supplier of raw material.

A pull system regulated the flow of resources in a manufacturing process by replacing only what has been consumed and only what was immediately deliverable. As a result, the production became increasingly lean, eliminating an excess inventory of raw materials, an in process inventory and finished goods.

The pull system would not produce to inventory, as TPS or Lean manufacturing concepts claimed that inventory was one of the largest wastes in a company. An excessive inventory could also hide production problems. Only some safety stock was required as a buffer for demand and supply variations serving at the required service level to avoid stock-out. A pull system would produce only the exact quantity withdrawn by the subsequent process, eliminating overproduction. The pull system would not hold excessive stocks of raw material, work-in-process and finished goods.

Since there was a wide variety of specification for automotive glass according to the size, model and brand of vehicle e.g. Isuzu, Toyota Hilux Vigo, Honda, Mitsubishi etc. , PMC has become more effective by changing from the Push to the Pull system, taking a customer's order as the key or the starting point to trigger the production process backward. The main purpose of Pull system was to prevent overproduction.

PMC has production planning division that makes sales forecasts based on its previous sales record in order to estimate the proper production level reflecting the market condition. Once glass products were taken out of inventory for delivering to customer, then the planning division would order the production in order to reproduce those goods to replenish in the inventory. Only some safety stock was allowed as a buffer for demand and supply fluctuations serving the required service level to avoid stock-out.

Pull System Targets for Improvement:

- To reduce Information Lead Time by 30 %
- To reduce Process Lead Time by 30 %
- To reduce Stock Lead Time by 30%

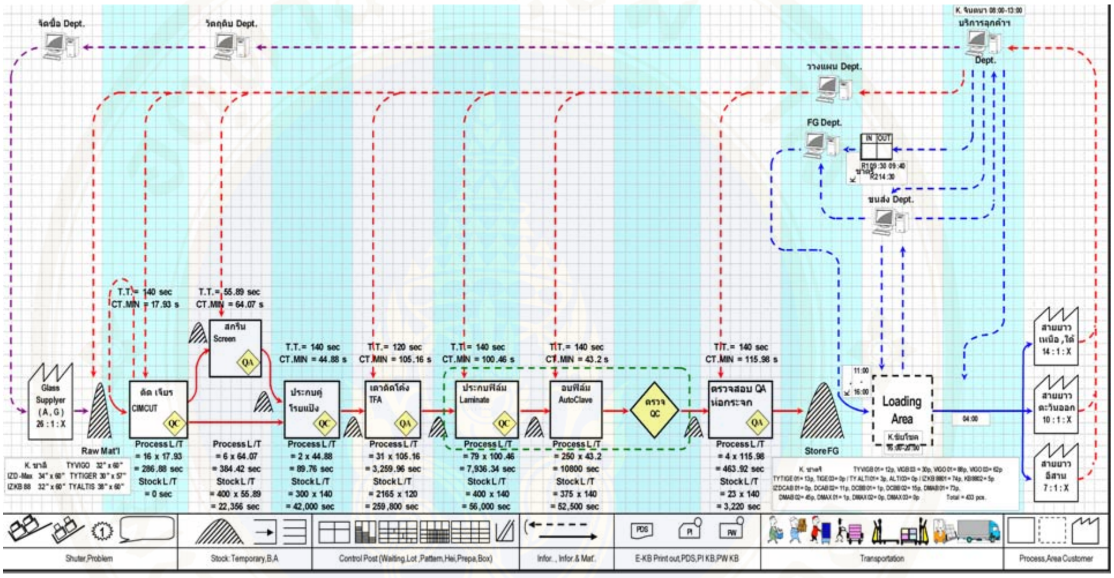
There were several tools used in the Pull System, which were advised by Automotive Human Resource Development Program (AHRDP).

1. Material and Information Flow Chart
2. Stagnation list
3. Kanban
4. Progressive plot
5. Waiting Post and delivery control board

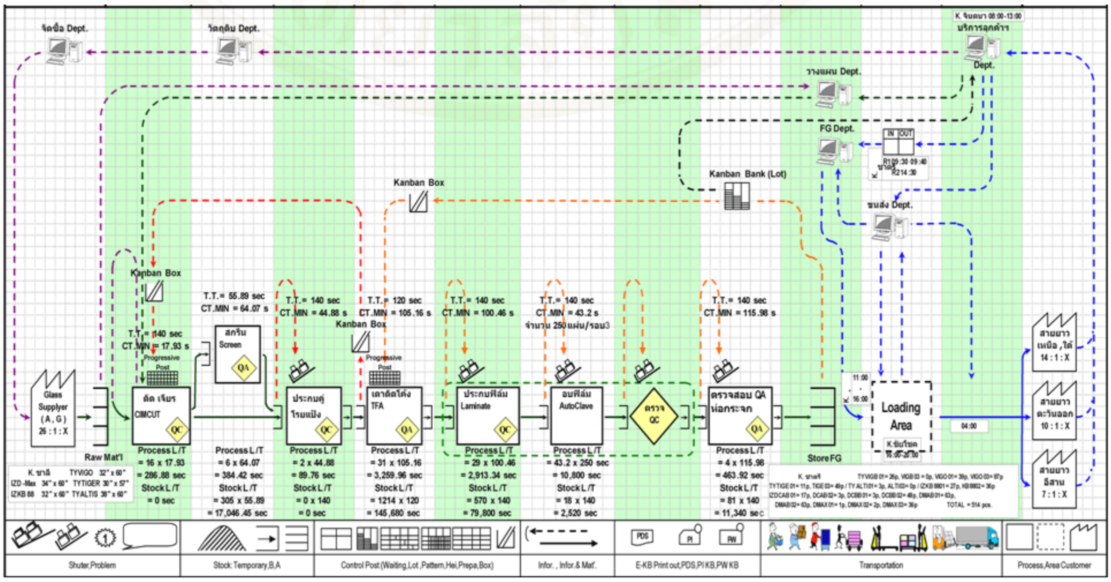
1. A Material and Information Flow Chart was used to analyze and illustrate material and information flows and showed the relationship between internal departments and sub-systems throughout PMC's factory. The time for each step was measured and recorded on the chart.

**Figure 4.35 Materials and Information Flow Chart**

**Before TPS**



**After TPS**



2. Stagnation list: The operation and production process was reviewed to identify the cause of delays and solutions recommended. PMC could identify 31 points that cause work delays and then need to be improved in terms of information processing and waiting in order to reduce the lead time.

**Table 4.9 Stagnation list**

| No. | Stagnation Item | Dept. | สัญลักษณ์การหยุดนิ่ง | Actual | | เหตุผลที่ทำให้เกิดการรอ | คิดว่าจะทำอย่างไร | เงื่อนไข | ความต้องการ | ผลการนำไปทำอย่างไร |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ชนิดข้อมูล | [illegible] | Reason | Ideal System | Limit Condition | Target System | Countermeasure |
| 1 | บริการลูกค้า | บริการ ฯ | | INFO | 86,400.00 | การรับข้อมูลจากลูกค้าแจ้งกลับ2-3วันเพื่อตัดยอดการผลิตสินค้า สายเหนือ อีสาน ใต้ ตะวันออก | ติดตามORDER จากลูกค้าให้เร็วขึ้นโดยการกำหนดการส่งสินค้าตามสายที่แน่นอน | ▲ | 19,800.00 | ตัดรายการโดยใช้เวลาวันที่ขึ้นสินค้าเป็นเกณฑ์ในการกำหนดวันเวลาการรับคำสั่งซื้อ |
| 2 | บริการลูกค้า | บริการ ฯ | | INFO | 10,800.00 | ทำรายการPICKSLIP ในระบบ ORACLE นาน เหนือ ใต้ อีสาน ตะวันออก | สร้างมาตรฐานการทำงานให้เจ้าหน้าที่ปฏิบัติตาม | ● | 5,400.00 | ทำPICKSLIP ตามที่ได้กำหนดไว้ให้ทันเวลารอบการส่งให้ทางคลังFGและขนส่ง |
| 3 | คลังสินค้าสำเร็จรูป ( FG ) | FG | | INFO | 1,800.00 | จัดทำสรุปรายการยอดขึ้นสินค้า กระจกรถยนต์ | จัดทำรายการพร้อมการหาอุปกรณ์การแพ็ค | ● | 1,380.00 | จัดทำรายการพร้อมการหาอุปกรณ์การแพ็ค |
| 4 | คลังสินค้าสำเร็จรูป ( FG ) | FG | | Stock | 14,400.00 | จัดจ่ายสินค้าตามรายการที่ PICKSLIP 4 ชม | ควบคุมการทำงานการจัดคลังให้สามารถหาสินค้าง่ายขึ้น | ▲ | 7,200.00 | จัดพื้นที่จัดเก็บให้สามารถมองด้วยสายตาได้ง่ายนำรุ่นที่ขายดีไว้หน้าเพื่อหยิบง่ายขึ้น |
| 5 | คลังสินค้าสำเร็จรูป ( FG ) | วางแผน | | INFO | 7,200.00 | รอยิงบาร์โค้ด รวมทุกสาย | ให้ยิงบาร์โค้ดตามหลังการจ่ายสินค้าของคลัง | ● | 3,600.00 | ทำงานควบคู่กับคลังในการจ่ายสินค้าเพื่อเวลาในการยิงบาร์โค้ดเสร็จพร้อมกับการจ่ายสินค้า |
| 6 | ขนส่ง | ขนส่ง | | Stock | 14,400.00 | แพ็คกระจกขึ้นงานสาย 4 ชม | ควบคุมการแพ็คสินค้าสร้างมาตรฐานการทำงาน | ▲ | 7,200.00 | ควบคุมการทำงานตามมาตรฐานที่สร้างไว้กำหนดรุ่นที่สามารถแพ็ครวมกันได้ช่วยลดเวลาการทำงานได้ |
| 7 | ขนส่ง | ขนส่ง | | INFO | 4,500.00 | ปริ้นบิลและเซ็นชื่อ ใช้เวลา75 นาที | กำหนดการทำงานใหม่ให้สอดคล้องการทำงาน | ● | 2,280.00 | ให้ทำงานควบคู่กันในเรื่องเอกสารปริ้นบิลและเซ็นต์บิลเพื่อลดเวลาการรอ |
| 8 | บริการลูกค้า | บริการ ฯ | | INFO | 7,200.00 | ต้องทำรายการแยกบิลตามแต่ละจังหวัดตามร้านค้าที่ส่ง เหนือ ใต้ อีสาน ตะวันออก | ทำรายการสรุปร้านค้าตามรอบการส่งของ | ● | 3,600.00 | จัดแยกตามรายการที่สรุปไว้เพื่อง่ายต่อการคัด |
| 9 | บริการลูกค้า | บริการ ฯ | | INFO | 14,400.00 | การเปิดเช็คข้อมูลสต็อกเพื่อเปิดใบสั่งผลิตก่อนเปิดใบสั่งผลิต รวม | เปิดตรวจสอบในช่วงเวลาที่สะดวก ไม่ติดการต้อนรับลูกค้า | ▲ | 7,200.00 | ให้ตรวจเช็คช่วงเวลาเย็นหลังเวลา15:00น เนื่องจากลูกค้ามีน้อยลง |
| 10 | บริการลูกค้า | บริการ ฯ | | INFO | 28,800.00 | เปิดใบสั่งผลิตล่าช้าเกิดจากการทำงานหลายหน้าทำให้เกิดการหยุดกระบวนการชั่วคราว รวม | เปิดใบสั่งผลิตในช่วงเวลาที่สะดวก ไม่ติดการต้อนรับลูกค้า | ▲ | 7,200.00 | ให้เปิดใบสั่งผลิตช่วงเวลาเย็นหลังเวลา 15:00น เนื่องจากลูกค้ามีน้อยลง |
| 11 | บริการลูกค้า | บริการ ฯ | | INFO | 28,800.00 | รอระดับจัดการเซ็นต์อนุมัติเพื่อส่งเข้าโรงงาน | แจ้งให้ระดับจัดการทราบงานล่วงหน้าเพื่อปลีกเวลาเซ็นต์อนุมัติก่อน | ● | 600.00 | ให้แทรกรายการเพื่อลดเวลาการรอที่ล่าช้า |
| 12 | บริการลูกค้า | บริการ ฯ | | INFO | 7,200.00 | บริการลูกค้าย้ายไปพื้นตรวจสอบและส่งให้ฝ่ายวางแผนใช้เวลามาก รวม | ทำมาตรฐานการตรวจสอบตามสเปกเพื่อลดเวลาการทำงาน | ▲ | 3,600.00 | ตรวจสอบให้เร็วขึ้นและให้ส่งทันทีไม่ต้องรอรอบเวลาการส่ง 10:00 และ 15:00 |
| 13 | วางแผนการผลิต | วางแผน | | INFO | 7,200.00 | รอรอบการถ่ายเอกสาร | ทำรายการจองเครื่องถ่ายเพื่อสำรองงานที่มีเข้ามาลดเวลาในการรอ | ● | 600.00 | ให้แทรกตามรายการที่ได้แจ้งจองไว้ล่วงหน้าเพื่อทำให้งานไม่ติดขัด |
| 14 | ฝ่ายผลิตกระจกรถยนต์ | CIMCUT | | Stock | 1,800.00 | รอยกกระจกขึ้นแท่นเพื่อทำการโหลดเข้าเครื่องตัด | ยกเลิกการใช้รอยกใช้เครนแทน | ● | 0.00 | ยกเลิกการใช้รอยกเปลี่ยนมาใช้เครนแทนลดเวลาการรอลง |
| 15 | ฝ่ายผลิตกระจกรถยนต์ | CIMCUT | | INFO | 900.00 | รอเปลี่ยนรุ่นการผลิต | SETUP ก่อนที่จะหมดรุ่นการผลิต | ● | 480.00 | ใกล้หมดรุ่นให้พนักงานคุมเครื่องเข้าไปทำการ SETUP เพื่อเตรียมตัดรุ่นต่อไป |
| 16 | ฝ่ายผลิตกระจกรถยนต์ | สกรีน | | Stock | 22,356.00 | STOCK ก่อนสกรีนรอผลิต 400 แผ่น | วางแผนการทำงานให้เหมาะสมกับหน้างาน | ● | 5,589.00 | ตั้งเป้าหมายกระจกรอผลิตให้เพียงพอต่อรอบการผลิต |
| 17 | ฝ่ายผลิตกระจกรถยนต์ | สกรีน | | Stock | 1,800.00 | รอกระจกแผ่นในมาให้สกรีนเพื่อส่งให้ประกบคู่ใยแป้ง | วางแผนการทำงานให้เหมาะสมกับหน้างาน | ● | 600.00 | ใกล้หมดรุ่นให้พนักงานเตรียมผลิตรุ่นอื่นๆ ต่อเพื่อลดระยะเวลาการรอ |
| 18 | ฝ่ายผลิตกระจกรถยนต์ | สกรีน | | INFO | 900.00 | รอเปลี่ยนรุ่นการผลิต | เตรียมบล็อกสกรีนไว้ล่วงหน้า | ● | 600.00 | ลดเวลาการจัดเตรียมอุปกรณ์ทำให้ถึงเวลาสามารถดำเนินการได้ทันที |
| 19 | ฝ่ายผลิตกระจกรถยนต์ | สกรีน | | Stock | 16,767.00 | STOCK หลังสกรีนรอผลิต 300 แผ่น | วางแผนการทำงานให้เหมาะสมกับหน้างาน | ● | 5,589.00 | ตั้งเป้าหมายกระจกรอผลิตให้เพียงพอต่อรอบการผลิต |

Source: PMK-Central Glass Company ltd. (2010)

3. Kanban System

To implement TPS, PMC has adopted a visual pull signal, so called "Kanban." By sequentially connecting the orders of the withdrawal kanban and the production-ordering kanban, the sale of a product at the final production process becomes a trigger to produce the product and its parts at each production process. This is called "Pull System."

In PMC's warehouse, the production-ordering kanban was used to represent the number of the finished goods, categorizing product by type. With a customer's order, the finished goods were taken out of the warehouse to be delivered to the customer. The production-ordering kanban was also removed out of the kanban bank at the same time and used to place an order for the next production to replace the goods sold.

**Figure 4.36 Kanban Bank**


The purpose of Kanban is to achieve Just-in-time production, that is to produce only what is needed, when it is needed and by how much it is needed. By maintaining only the minimal inventory (safety stock), PMC could substantially help in reducing inventory as well as efficiently controlling and improving the production units.

**Figure 4.37 PI Kanban**

Production Instruction (PI) Kanban is used in ordering the production. A PI Kanban is always attached to each batch of glass while it passes through the production line. From the glass material the labeling of necessary information, including customer name, the name, specification, number code of the glass as well as the barcode in order to update the progress of production.

Kanban is very useful for demonstrating the progress and sequence of work. It can quickly identify and systematically queue the work in order, which one comes first or must be processed first, second, and so on, reducing the searching time and mistakes. So everyone knows the status of the glass and could continue to process them correctly in order until complete.

4. Progressive Post

For the TPS project, many progressive posts were built for each divisions to show their work progress work and to control production order by fixed time and to show whether production was on time or delayed.

**Figure 4.38 Progressive Post** in Autoclave division


| Auto Clave Division |
|---|
| 1. Waiting for Auto Clave |
| 2. Autoclaving |
| 3. Finished Auto Clave<br>Waiting for Quality assurance |

**Figure 4.39 Progressive Post** in Laminate division


**Figure 4.40 Progressive Post** in Cimcut division.

## Toyota Production System Project Results

The following tables showed lead time used on each process for comparison before and after the TPS project.

### Table 4.10 Lead-time spent on each process

**Before TPS** unit: hour

| | Lead time Process | Information Lead time | Process lead time | Stock lead time | hours |
|---|---|---|---|---|---|
| 1 | Cimcut | 8 | 0.08 | 0 | 8.08 |
| 2 | Screen | 8 | 0.11 | 10.87 | 18.97 |
| 3 | Blind | 8 | 0.02 | 11.67 | 19.69 |
| 4 | TFA | 10 | 0.91 | 72.17 | 83.07 |
| 5 | Film | 8 | 2.20 | 15.56 | 25.76 |
| 6 | Auto Clave | 4 | 3.00 | 14.58 | 21.58 |
| 7 | QA& Packing | 8 | 0.13 | 0.89 | 9.02 |
| 8 | Warehouse | 3.50 | 4 | 0 | 7.50 |
| 9 | Delivery | 2.25 | 4 | 0 | 6.25 |
| 10 | Production plan | 3.20 | 0 | 0 | 3.20 |
| 11 | Customer service | 53.80 | 0 | 0 | 53.80 |
| | Total lead time | 116.75 | 14.45 | 125.73 | 256.93 |
| | Proportion | 45.44% | 5.62% | 48.94% | 100% |
| | | | | days | **32.12** |

**After TPS** unit: hour

| | Lead time Process | Information Lead time | Process lead time | Stock lead time | hours |
|---|---|---|---|---|---|
| 1 | Cimcut | 8 | 0.08 | 0 | 8.08 |
| 2 | Screen | 8 | 0.11 | 4.74 | 12.84 |
| 3 | Blind | 8 | 0.02 | 0.00 | 8.02 |
| 4 | TFA | 10 | 0.91 | 40.47 | 51.37 |
| 5 | Film | 8 | 0.81 | 22.17 | 30.98 |
| 6 | Auto Clave | 4 | 3 | 0.70 | 7.70 |
| 7 | QA& Packing | 8 | 0.13 | 0.37 | 8.50 |
| 8 | Warehouse | 0.33 | 2 | 0 | 2.33 |
| 9 | Delivery | 2.13 | 3 | 0 | 5.13 |
| 10 | Production plan | 0.48 | 0 | 0 | 0.48 |
| 11 | Customer service | 17.17 | 0 | 0 | 17.17 |
| | Total lead time | 74.11 | 10 | 68.44 | 152.61 |
| | Proportion | 48.56% | 6.59% | 44.85% | 100% |
| | | | | days | **19.08** |

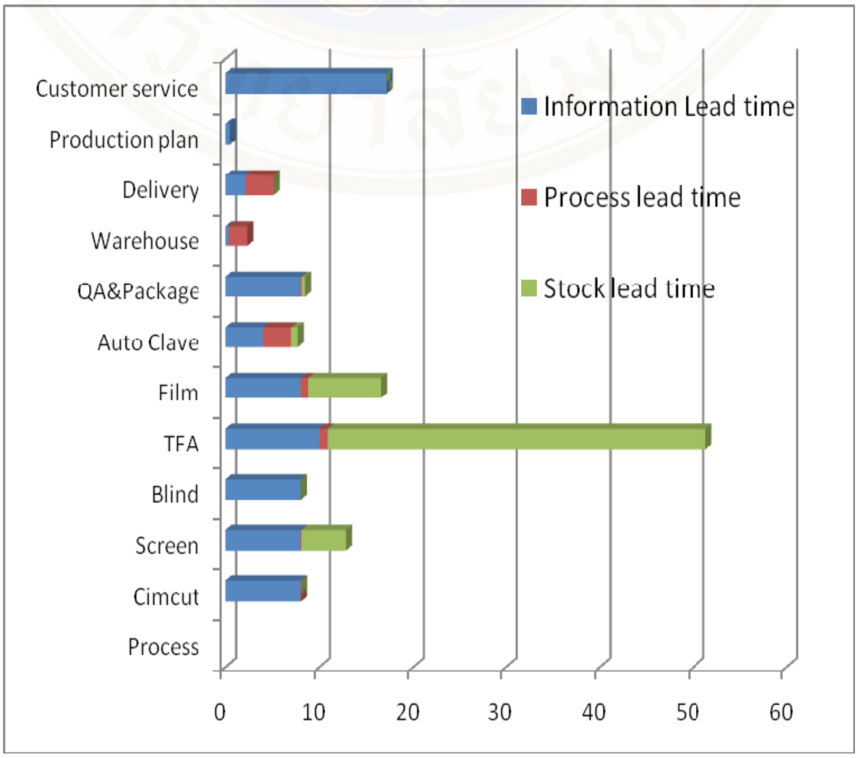
**Table 4.11 Summary of Lead-Time Changes**

| Lead time | unit | Before TPS | After TPS | Difference | % Diff. | Target |
|---|---|---|---|---|---|---|
| Information lead time | day | 14.59 | 9.26 | -5.33 | -36.52% | -30% |
| Process lead-time | day | 1.81 | 1.26 | -0.55 | -30.42% | -30% |
| Stock lead-time | day | 15.72 | 8.9 | -6.81 | -43.36% | -30% |
| Total Lead time | day | **32.12** | **19.08** | -12.69 | -39.54% | -30% |

PMC could reduce the total lead time from 32.12 days to 19 day or accounted for – 39.54% , greater than target of -30%. The process lead time decreased from1.8 to 1.26 days or accounted for -30.42 %.

From the Continuous flow, four major changes were done in the Screen, Blind, TFA, Auto clave division, could reduce the stock lead-time significantly from 15.72 to 8.9 days or account for -43%, seeing the green bar in figure 4.42 and 4.43. They were also the results of pull system, Just-in-time and the improvement in production planning and controlling to suit with the capacity of machinery that allowed smoothen production.

**Figure 4.41 Lead Time on each process after TPS**



The information lead time decreased from 14.59 to 9 days or accounted for -36.52%. These were the result of visual control, the Standardized work, preparing things ahead of time e.g. set-up machine, order materials and supplies, order production in advance, pre-order glass to be used.

**Figure 4.42 Comparison of Lead-Time** before and after TPS

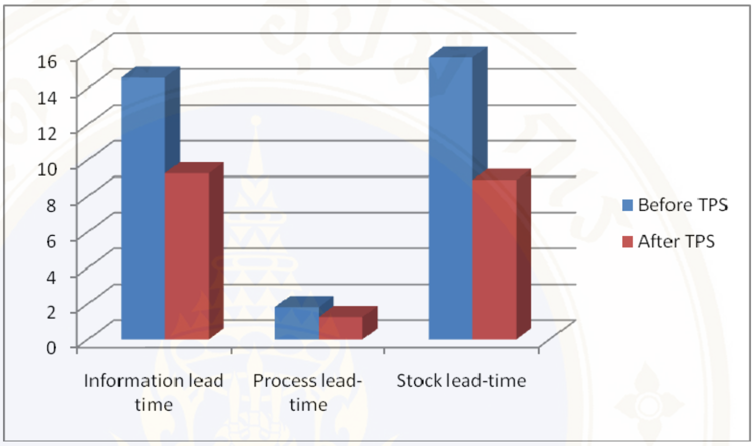



**Table 4.12 Summary of TPS Project Results**

| Items | unit | Before TPS | After TPS | Difference | % Diff. | Target |
|---|---|---|---|---|---|---|
| Productivity | piece/man hr. | 22.58 | 30.75 | 8 | 36% | 30% |
| Working area | sq.m. | 162 | 54 | -108 | -67% | - |
| Product movement | meter | 573 | 390 | -183 | -32% | -30% |
| Workforce | person | 43 | 35 | -8 | -19% | -20% |

As a result of applying TPS principles and seriously implementing many activities, not only reducing the lead time, but PMC could also achieve almost all of the targets, higher than expectations. Standardized work and managed their labor force more efficiently, PMC could possibly reduce the number of workers from 43 to 35 persons while maintain the quantity and quality of work, therefore the productivity per head would increase from 22.58 to 30.75 pieces per man hour or accounted for 36%.

Working area reduced from 162 to only 54 sq.m. or accounted for -67%. This was the benefit of visual control by cleaning up, getting rid of unnecessary items and rearranging things in the appropriate order and ready for use.

# CHAPTER V
# CONCLUSION

Within four months from January to April 2010, PMK-Central Glass Company ltd. had learned and actively implemented many activities following four steps according to TPS principles. This company had objectives to speed up its production and operations or reduce the lead-time to satisfying the customers as well as to efficiently use the resources in terms of capital (machines), labor's time, land (plant space), etc.

Firstly, Visual Worksite Control consisted of General Control- 2 "S" – Sort, Straighten - program, Production Control, Workforce Control, Delivery Control, Safety Control, Machine and Equipment Control and Quality Control, using several tools such as displaying board, sign, Kanban, etc. in order to organize, control the production and operation efficiently as well as being able to notice any abnormality and make timely correction.

Secondly, the company applied Continuous flow to smoothen the process. Four main areas in this factory had been modified, such as rearranging the glass storage and inventory, changing the position of JIG quality assurance stand, connecting one division to the next, moving Quality assurance and packaging division next to the production line, in order to shortening the distance for carrying glass through the production line as much as possible. It could reduce the distance for moving glass from 573 to 390 meters or accounted for -32%. Some equipment was also created to support the flow of glass from one division to the next to reduce the use of humans carrying the glass.

PMC's production line was allowed to be stopped "Jidoka", if problem or defect was detected to call the person in charge to correct the problem as soon as possible. No problem is hidden. The company aims on producing things right for the first time and do not allow any defect to pass to the next process, since it is more difficult to monitor and correct when it is late. All these changes in the factory help PMC to reduce lead time significantly in all three types of lead time from when a customer placing order to receiving the goods from 32.12 days to 19 days. Therefore, PMC could become more rapid response to the customers.

Thirdly, PMC has designed standardized work and utilized human resources more efficiently. By improving many things, the company expected to reduce defects and waste and reduce the number of workers required from 43 to 35 persons.

Fourth, PMC's production applied a "Pull system" and Just-in-time concept, which is to produce what is needed, when needed, to the amount that it is needed, do not overproduce and not over stock a large inventory that may not be used or sold. This company would produce according to customer orders with only some safety stock.

From the company's hard effort, their results were satisfactory. PMC could reduce its total lead-time from 32 to 19 days and increase the productivity from 22.58 to 30.75 pieces per man hour from standardized work, production control and many improvements following the TPS principles. With Continuous flow, they could reduce the distance of glass movement from 573 to 390 meters and reduce the plant area from 162 to 54 sq.m.

Not only the management team, but also all workers were the key elements in the successful implementation of TPS project. There was some resistance to change from workers, when the project was started. It was important to educate and encourage people to understand the benefits of these principles. It took some time for workers to learn, believe and commit that they could do it and that it would make their works easier and safer.

Not every company that tried to imitate Toyota's principles is guarantee for the success. Doing the TPS project was time consuming, tedious and required great effort to investigate, to find ways to improve things and finally to actually implement them. Some employees may not understand and be reluctant to follow the TPS practices. They may think that it was complicated and more onerous. Therefore, it is usually hard, when a TPS project is first started. Many things need be changed in the production layout to shorten the flow distance, to remove the stagnation points, etc. But after things settled down completely, people get used to the new system, thus works would definitely run smoother and faster.

It was important to have agreement and participation from all levels, especially from the front line employees who actually perform the job to follow what the

TPS's principles had established e.g. the standardized work, Kanban, new practices, etc. Management support was essential to reinforce their employees to commit themselves to follow the TPS project. The key to the success was to continuously carry-out the activities and continuous improvement, even after the TPS project finished. Since the benefit of TPS was in their best practice, not just physical capital.

In conclusion, PMC's experiences have demonstrated that the Toyota Production System could be applied to improve the performance of their business to satisfactory level. Industry or an organization need to make some adjustments to suit with their situation.

PMC paid much of their attention on improving operation and productivity; efficiently use the resources as well as reducing the lead time. But they have not put much attention on defect output, which was one of the 7 types of waste that should be considered and monitored in the TPS project. Unfortunately, PMC did not record the number of defects neither before nor after TPS project. So this paper has limited data to analyze and mention about this part.

Recommendation for further research would be to study the application of the TPS in different companies across various industries in order to compare in the areas that they may have in common to be successful or failed for the better understanding and adopting to suit with other organizations.


PMC
บริษัท กระจกพีเอ็มเค - เซ็นทรัล จำกัด (โรงงาน)
PMK - CENTRAL GLASS CO., LTD. (FACTORY)


Step#2 Continuous flow
TPS

# REFERENCES


Black, J., & Miller, D. (2008). The Toyota Way to Healthcare Excellence: Increase Efficiency and Improve Quality with Lean, *Leadership in Health Services*, 21(4), ACHE Management Series Book, May, 2008

Collins, K.F. & Muthusamy, S.K. (2007). Applying the Toyota Production System to a Healthcare Organization: A Case Study on a Rural Community Healthcare Provider, *Quality Management Journal*, Vol. 14, No. 4

Cooney, R. (2002). Is 'lean' a universal production system? Batch production in the automotive industry*", International Journal of Operation & Production Management*, 22(10), p.1130-47.

Dolcemascolo, D. (2006). *Improving the Extended Value Stream: Lean for the Entire Supply Chain*, Productivity Press.

Fillingham, D. (2007). Can lean save lives? *Leadership in Health Services*, 20(4), p. 231-241.

Flinchbaugh, J. (2002). "Lean Manufacturing in the Mold making Industry"

Hino, Satoshi (2005). *Inside the Mind of Toyota: Management Principles for Enduring Growth*. University Park, IL: Productivity Press. Retrieved from: http://www.productivitypress.com/productdetails.cfm SKU=3004.

Kasul, R.A., & Motwani, J.G. (1997). Successful Implementation of TPS in a manufacturing setting, *Industrial Management & Data Systems*, 97(7), p. 274-279.

Keys, J.B., & Miller, T.R. (2001). The Japanese management theory jungle, *The Academy of Management Review*, 9(2), p.244-56.

Krafcik, J.F. (1988). Triumph of the lean production system, *Slogan Management Review*, 30(1), p.41-51.

Liker, J.K. (2004). *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*, New York: McGraw-Hill.

Liker, J.K. & Meier, D. (2005). *The Toyota Way Field book: A Practical Guide for Implementing Toyota's 4Ps*. New York: McGraw-Hill.

Lucansky, P., Potapchuck L. & Burke R. (2002). Lean Transformation: A framework for Making the Transition to Lean, *PharmaChem*, no.11-12.

Manuel F. Suarez Barraza, Smith, T. & Su Mi Dahlgaard-Park (2009). Lean-Kaizen Public service: An empirical approach in Spanish local governments, *The TQM Journal*, 21(2), p.143-167

Miltenburg, J. (1989). Level Schedules for Mixed-Model Assembly Lines in Just-In Time Production Systems, *Management Science*, 35(2) , February, 1989: p.192-207.

Monden, Y. (1998). Toyota Production System: An Integrated Approach to just-in time, *Norcross: Industrial Engineering and Management Press*. 2nd ed. London: Chapman & Hall.

Ohno, T. (1995). *Toyota Production System: Beyond Large-scale Production*, Portland, OR.: University Park, ill.: Productivity Press.

Person, T., Zaleski, S. & Frerichs J. (2006). Improving Pre-analytic Processes Using The Principles of Lean Production (Toyota Production System), *American Society for Clincal Pathology*, 125: p.16-25.

Petterson, J. (2009). Defining lean and production: Some conceptual and practical issues, *The TQM Journal*, 21(2): p.127-142.

Robinson, A. (1990). *Modern* Approaches to Manufacturing Improvement, Portland, OR.: University Park, ill.: Productivity Press.

Shingo, S. (1984). *A Study of the Toyota Production System from an Industrial Engineering Viewpoint*, Japan Management Association, Tokyo.

Spear, S. (2005). Fixing healthcare from the inside today , *Harvard Business Review* (September 2005): p.78-91

Spear, S. & Bowen, H.K. (1999). Decoding the DNA of the Toyota Production System, *Harvard Business Review*, September 1999

Stephen S. Raab MD, Carey Andrew-JaJa MD, Jennifer L. Condel BS, SCT (ASCP) MT & David J. Dabbs MD. (2005). *Improving Papanicolaou test quality and reducing medical errors by using Toyota production system methods*, Departments of Pathology, University of Pittsburgh Medical Center: Pittsburgh: PA

Surendra M.G., Yousef A.Y.,Al-Turki & Ronald F.P. (1999). Flexible Kanban System. *International Journal of Operations & Production Management*, 19(10): p.1065-1093

Suzaki, K. (1985). The Application of Japanese Competitive Methods to U.S. Manufacturing. *Journal of Business Strategies*, 5(1): winter: p.10-19.

Toyota Motor Corporation, Operation Management Consulting Division. (1992). *The Toyota Production System.*

Toyota Motor Manufacturing, (2006). Kentucky. Retrieved from: http://www.toyotageorgetown.com/terms .asp

Womack, J.P., Jones, D.T., & Roos, D.(1990). *The Machine that Changed the World: The Story of Lean Production*. New York: Rawson Associates: Harper Collins. Retrieved from http://www.visual-control.net

# BIOGRAPHY

| | |
|---|---|
| **NAME** | Buranit Rattanachuen |
| **DATE OF BIRTH** | 3 April 1979 |
| **PLACE OF BIRTH** | Bangkok, Thailand |
| **INSTITUTIONS ATTENDED** | Thammasat University, 1997-2001<br>Bachelor degree of Economics<br>International Program<br>Hiroshima University, 2001-2003<br>Master degree of Environmental<br>Economics, International Program |
| **SCHOLARSHIP** | Monbusho Scholarship from Ministry of<br>Education, Japan |
| **POSITION& OFFICE** | Position : Customer service<br>Exxonmobil Company ltd.<br>54 Harintorn building, Sathorn north rd.<br>Bangruk district, Bangkok 10500,<br>Thailand<br>tel. 662-352-7044<br>e-mail: buranit123@gmail.com |
| **HOME ADDRESS** | 56 soi Taksin12/1, Taksin road, Bukkalo,<br>Thonburi district, Bangkok, Thailand<br>tel. 662-890-4714 |