WAREHOUSE DESIGN FOR A PLASTIC RESINS TRADING COMPANY

Mr. Nathapong Amarase

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering in Engineering Management
The Regional Centre for Manufacturing Systems Engineering
Faculty of Engineering
Chulalongkorn University
Academic Year 2001

ISBN 974-03-0748-5

การออกแบบคลังสินค้าสำหรับบริษัทค้าเม็ดพลาสติก

นายนัฐพงษ์ อมเรศ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาการจัดการทางวิศวกรรม ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2544

ISBN 974-03-0748-5

Thesis Title	Warehouse Design For A Plastic Resins Trading Company
By	Mr. Nathapong Amarase
Field of Study	Engineering Management
Thesis Advisor	Assistant Professor Dr. Rein Boondiskulchok

Accepted by the Faculty of Engineering, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

……. Dean of Faculty of Engineering

(Professor Somsak Panyakeow, D.Eng.)

THESIS COMMITTEE

……. Chairman

(Professor Sirichan Thongprasert, Ph.D.)

……. Thesis Advisor

(Assistant Professor Rein Boondiskulchok, D.Eng.)

……. Member

(Associate Professor Chuvej Chansa-ngavej, Ph. D.)

นาย นัฐพงษ์ อมเรศ: การออกแบบคลังสินค้าสำหรับบริษัทค้าเม็ดพลาสติก. (WAREHOUSE DESIGN FOR A PLASTIC RESINS TRADING COMPANY) อ.ที่ปรึกษา: ผศ. ดร. เหรียญ บุญดีสกุลโชค, 153 หน้า, ISBN 974-03-0748-5

ในปัจจุบัน อุตสาหกรรมพลาสติกมีแนวโน้มที่จะเจริญเติบโตสูงมากทำให้อุตสาหกรรมเม็ดพลาสติกซึ่งเป็นวัตถุดิบหลักของการผลิตผลิตภัณฑ์พลาสติกจะเจริญเติบโตตามไปด้วย วิทยานิพนธ์ฉบับนี้ เป็นการนำเสนอถึงการออกแบบคลังสินค้าสำหรับ บริษัท โพลีเมอร์ มาร์เก็ตติ้ง แอนด์ เทรดดิ้ง จำกัด ซึ่งเป็นบริษัทค้าเม็ดพลาสติก โดยมีวัตถุประสงค์ให้คลังสินค้าที่ออกแบบมานั้นสามารถรองรับยอดขาย 1000 ตันต่อเดือน ในอนาคตได้

ในเบื้องต้นของวิทยานิพนธ์ฉบับนี้ ได้ทำการศึกษาถึงทฤษฎีต่างๆ ที่เกี่ยวข้องกับการออกแบบคลังสินค้า รวมถึงลักษณะของเม็ดพลาสติกชนิดต่างๆ แล้วจึงทำการศึกษาตัวอย่างระบบคลังสินค้าของบริษัทค้าเม็ดพลาสติกบริษัทหนึ่ง จากนั้นจึงได้ทำการศึกษาและคาดการณ์ถึงความต้องการต่างๆ ที่จะใช้ในการออกแบบคลังสินค้า การออกแบบคลังสินค้า เริ่มต้นที่ การออกแบบขั้นตอนการปฏิบัติการต่างๆ ของคลังสินค้า ตั้งแต่ การรับสินค้า จนถึง การส่งสินค้า จากนั้นจึงทำการออกแบบ ถึงการใช้อุปกรณ์และบุคลากรต่างๆ ภายในคลังสินค้า สุดท้ายจึงทำการออกแบบลักษณะทางกายภาพของคลังสินค้าจากคลังสินค้าที่ได้ออกแบบมาพบว่าพื้นที่ภายในคลังสินค้ามีขนาด กว้าง 55 เมตร, ยาว 42.2 เมตร, และ สูง 6 เมตร ขณะที่ภายนอกคลังสินค้ามีขนาด กว้าง 57 เมตร และ ยาว 39 เมตร ซึ่งสามารถรองรับ ยอดขาย 1000 ตันต่อเดือน และ สามารถจัดเก็บสินค้าได้ 2100 ตัน

จากการประเมินการใช้งานคลังสินค้า โดยการสำรวจขั้นตอนการปฏิบัติการของคลังสินค้าที่ได้ออกแบบไปพบว่าการออกแบบเหมาะสมกับการปฏิบัติการในคลังสินค้า ขั้นตอนต่างๆ สามารถกระทำได้โดยไม่มีอุปสรรคใดๆ และ ระบบการจัดการสินค้าและลักษณะทางกายภาพของคลังสินค้า สามารถรองรับการปฏิบัติการได้ดี ในขณะที่การประเมินค่าใช้จ่าย พบว่า ค่าใช้จ่ายต่อหน่วยสำหรับยอดขาย 1000 ตันต่อเดือน ของคลังสินค้าที่ได้ออกแบบนี้ สูงกว่าค่าใช้จ่ายต่อหน่วยในปัจจุบันที่ได้ว่าจ้างบริษัทค้าเม็ดพลาสติกบริษัทหนึ่งจัดเก็บให้ อย่างไรก็ตามคลังสินค้าที่ได้ออกแบบนี้สามารถจัดเก็บสินค้าได้ถึง 2100 ตัน ซึ่งเมื่อเทียบค่าใช้จ่ายต่อหน่วยของการจัดเก็บสินค้า 2100 ตันแล้ว ค่าใช้จ่ายของคลังสินค้าที่ได้ออกแบบนี้ จะถูกกว่า ค่าใช้จ่ายต่อหน่วยจากการว่าจ้างบริษัทอื่นจัดเก็บ จึงสรุปได้ว่าคลังสินค้าที่ได้ออกแบบนี้สามารถนำไปใช้จัดเก็บสินค้าของบริษัทในอนาคตได้

ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต
สาขาวิชา การจัดการทางวิศวกรรม
ปีการศึกษา 2544

ลายมือชื่อนิสิต.....
ลายมือชื่ออาจารย์ที่ปรึกษา.....

4371605821: MAJOR ENGINEERING MANAGEMENT
KEY WORD: WAREHOUSE DESIGN / PLASTIC RESINS / TRADING COMPANY

NATHAPONG AMARASE: WAREHOUSE DESIGN FOR A PLASTIC RESINS TRADING COMPANY. THESIS ADVISOR: ASSISTANT PROFESSOR DR. REIN BOONDISKULCHOK, 153 pp. ISBN 974-03-0748-5

Nowadays, the plastic industry has a very high potential to grow up. So the plastic resins industry will be growing also. This thesis is conducted to design a new warehouse for Polymer Marketing and Trading Co., Ltd, the plastic resins trading company to cover 1000 tons per month sales expectation.

At the beginning of this thesis, the theory of warehouse design and the characteristics of each Plastics resins type were studied. Then the existing warehouse of a plastic resins trading company was studied as an example. And the requirements of warehouse design were studied and forecasted. The warehouse design started off with designing the operation procedure of the warehouse from receiving to shipping. Then the material handling equipments and material handling employees were designed. Lastly, the physical warehouse was designed. From the designed warehouse, the size inside the warehouse is 55 m wide, 42.2 m long, and 6 m high. While, the size outside the warehouse is 57 m wide and 39 m long. The designed warehouse can cover the 1000 tons per month sales expectation and can store 2100 tons of plastic resins.

From the warehouse validation by walking through the operational procedure design, it can be seen that the design is appropriate to the operation of the warehouse. The procedure of the operation can flow continuously without any obstacles. The material handling system and physical design can support the operational procedure design well. From cost evaluation, the cost per unit of the sales 1000 tons per month of using the designed warehouse is more than the cost of using the existing system. However, the designed warehouse can store 2100 tons of plastic resins. So the cost per unit of the inventory 2100 tons of using the designed warehouse is less than the cost of using the existing system. So the designed warehouse can be used for storing the plastic resins of the company in the future.

The Regional Center for Manufacturing System Engineering
Field of Study Engineering Management
Academic Year 2001

Student's Signature……..
Advisor's Signature……..

Acknowledgment

For my first appreciation, I would like to give thanks to Assistant Professor Dr. Rein Boondiskulchok, my Thesis Advisor for his invaluable suggestions through out my thesis.

Second, thank you Professor Dr. Sirichan Thongprasert and Associate Professor Dr. Chuvej Chansangavej for being the members of the examination committee and every suggestion.

Third, thank you Miss Anasaya Manyukong from TaP and Mr. Adirek Eiampornrat from IFCT for their information to my thesis.

Fourth, thank you all the professors from University of Warwick and Chulalongkorn University for their excellent teaching throughout the course.

Fifth, for all my friends and colleagues, especially Mr. Ratchatee Techapiesancharoenkij, thank you for your supports.

Last, I would like to give my thanks to my family that gives me the chances to study and work until I finish my thesis.

CONTENTS

PAGE

CONTENTS (Cont.)

PAGE

CONTENTS (Cont.)

PAGE

CONTENTS (Cont.)

PAGE

CONTENTS (Cont.)

PAGE

CONTENTS (Cont.)

PAGE

CONTENTS (Cont.)

PAGE

LIST OF FIGURES

PAGE

LIST OF FIGURES (Cont.)

PAGE

LIST OF TABLES

PAGE

LIST OF TABLES (Cont.)

PAGE

LIST OF TABLES (Cont.)

PAGE

CHAPTER 1

INTRODUCTION

1.1 Background of the Research

After the economic crisis of Thailand, in 1997, the purchasing powers in the domestic have decreased drastically. So many manufacturing companies that do not have enough capital to maintain the liquidity level have to be closed down.

Nowadays, the government tries to stimulate the economy by several ways. The way that is directly impact to all the industries is the government gives many supports for the small and medium enterprises (SME). By this way the new opened manufacturing companies will grow up very much in the future. One of the most interesting industries is the plastic industry.

The plastic industry, in the present time, has a very high potential to grow up. Many products such as containers, electric parts, auto parts, are now converting to use plastic as their materials more. The plastic consumption per capita of Thailand in 1999 was 28.4 kg/capita. It was still little compared with other countries in this region; Malaysia was 40.0, Singapore was 61.9, Japan was 66.6, South Korea was 69.2, and Taiwan was 136.0. (Thamnoo Vasrinont, 2001, No.2: 59-67) So the plastic industry can expand easily.

In the year 2000, Thailand had a growth of exporting the plastic products to the worldwide market for 38.52 % compared with the year 1999 (in $US). This shows that the future of the plastic products in Thailand is very promising.

The most important factor that relates to the plastic products is a raw material, plastic resins. More than 50 % of the cost of producing plastic products comes from plastic resins. So if the plastic products industry is growing, the plastic resins industry will be growing also.

Polymer Marketing and Trading Co., Ltd. (PM) was established in May 2000. It is a plastic resins trading company acting as a subagent of Thai Asia Plastic Co., Ltd. (TaP), which is an plastic resins' agent of Thai Petrochemical Industry Public Co., Ltd. (TPI). At this first year PM still does not have its own warehouse and

transportation trucks. TaP provides both the inventory store and trucks for PM and charges PM about 0.5 Baht per kilogram of the plastic resins. Nowadays, PM can sell plastic resins for the plastic product companies about 150 tons per month.

1.2 Statement of the Problem

PM has estimated the sales in the future about 1000 tons per month.

Nowadays, PM still uses the TaP's warehouse. But if the sales of PM increase as estimated, the present warehouse's capacities will not be enough to handle two companies' plastic resins. Moreover, the inventory management of TaP is not suitable for PM because the customers of the two companies are not the same. So PM must have a new warehouse and manage the inventory by itself.

1.3 Objective of the Research

The objective is to design a new warehouse for PM, the plastic resins trading company, to cover 1000 tons per month sales expectation.

1.4 Scope of the Research

The research is about designing a new warehouse by using a case of a plastic resins trading company, while the sale of 1000 tons per month. So it will start with analyzing the inventory storage and the inventory transaction to plan for the inventory level to design

1. Physical dimension, size of the warehouse (width, length, and height), and layout The size will be just enough for storing and operating the 1000tons per month sales. The layout will be designed for supporting effective operation. The physical dimension, size, and layout will be designed under the assumption that the company has a place (location) to build the warehouse already. The structure of the warehouse will also not be designed.

2. Material handling system (receiving, put-away, storage, order picking, sortation, and packing and shipping) with type and quantity for handling equipment The material handling system will be the system that support the

company to send the goods on time, convenient and safe with low operating cost for supporting the sales 1000 tons/month.

3. The operation design of the warehouse

The last part of this research is the design evaluation. The warehouse design in this research will evaluate by calculating directly the total logistic and warehouse cost.

1.5 Expected Results

The result of this research will be a new designed warehouse of the company that may be divided into two parts:

The physical design includes size, layout, selection of material handling system, and equipment type.

The operation design includes receiving, put-away, storage, order picking, sortation, and packing and shipping.

1.6 Research Procedure

1. Study the related literatures.
    - Theory of warehouse design
    - The characteristics of each Plastics resins type
2. Study the existing warehouse of a company to use as an example of the design.
3. Requirement analysis for example the plastic resins load, plastic resins qualification, the change of the price, etc.
4. Plan for the inventory level
5. Design the warehouse.
    - Design the warehouse operation
    - Physical design
6. Design evaluation

7. Conclusion and recommendation
8. Write up the thesis.
9. Examination

CHAPTER 2

RELATED LITERATURE STUDY

2.1 Warehousing

2.1.1 Definition of the Warehouse

Warehouse is defined as “the function of storing a variety of product types [stock-keeping units (SKUs)] that have a small or large quantity of storage units between the time that the product is manufactured by your facility (vendor) and the time that the product is required by your customer or workstation within your manufacturing facility.” (Mulcahy, 1994: 1.2)

2.1.2 Objective of the Warehouse

The activities in the warehouse must meet these objectives.

2.1.2.1 The space of the warehouse must be utilized maximally.

2.1.2.2 The equipment and employees of the warehouse must be utilized effectively.

2.1.2.3 The SKUs in the warehouse must be stored for accessing and controlling easily.

2.1.2.4 The SKUs in the warehouse must be handling effectively.

2.1.2.5 The operation expenses must be minimized as much as possible.

2.1.2.6 The warehouse must be protected in a good condition.

2.2 Warehouse Operation

2.2.1 Receiving

Receiving is the activities about the orderly receipt of all materials coming into the warehouse, the assurance that the quantity and quality of the materials are as ordered, and the disbursing of the materials to any function.

2.2.1.1 The procedures of good receiving activities (Tompkins and Smith, eds, 1988: 562)

1. Analyzing the documents for planning the receiving
    - Determining the dates of arrival for each type and quantity of the materials
    - Scheduling the carrier arrival
    - Using spotting information to control the incoming traffic
    - Preplanning the storage position
2. Unloading and clearing bills
3. Unpacking the materials as necessary
4. Identifying and sorting the receiving materials
5. Checking receipts against the packing slips and other documentation
6. Marking records of the unusual actions
7. Recording receipts on receiving slip
8. Noting the wrong materials
9. Disbursing materials to the appropriate location
10. Recording the receiving activities adequately and accurately

2.2.1.2 The principles of receiving (Tompkins et al., 1996: 396-400)

1. Some materials can let the vendor ship to the customer directly. The warehouse will save the time and cost to receive and ship fewer materials.
2. The information of the materials will be pre-received by using IT while the materials are being transported. Time can be reduced.
3. Cross-dock the materials as many as possible.
4. Put-away directly to the reserve locations for the “uncross-dockable” materials.
5. Stage the materials in the storage area.

6. Complete the necessary activities for efficient load and movement at the receiving area.
    - Prepackaging the materials
    - Labeling and tagging the packages
    - Cube and weigh for planning
7. Sort the materials for efficient put-away.
8. Combine put-away and retrieval activities.
9. Balance the use of resources at receiving by scheduling carriers and shifting time consuming receipts to off-peak hours.
10. Minimize walking by flowing the materials past workstations.

2.2.2 Put-away

Put-away is the transportation and placement of the materials in the storage.

2.2.3 Storage

Storage is the activities of the handling, protecting, and storing the materials until there is a demand.

2.2.3.1 The objectives of storage planning (Tompkins et al., 1996: 426)

1. Utilizing the space effectively.
2. Providing efficient materials handling.
3. Minimizing the storage cost.
4. Providing maximum flexibility.
5. Providing good housekeeping.

2.2.3.2 The principles of storage

1. “Popularity” is the storing method for minimizing the travel distance. The more popular materials will be stored in front, while the less popular materials will be stored in back. Travel distances may be minimized by storing popular materials in deep storage area and non-popular materials in shallow storage area.

2. “Similarity” is the storing method of storing the materials that are received and shipped together to be in the same area.
3. “Size” is about the method of storing to fit to the size of the materials.
4. “Characteristics” is the storing of the special materials characteristics.
    - Perishable materials
    - Oddly shaped and crushable materials
    - Hazardous materials
    - Security materials
    - Compatibility
5. “Space utilization”
    - Maximizing the space utilization and minimizing honeycombing by storing the materials at the proper height and depth.
    - Concerning the limitation of space by the truss, sprinkler and ceiling heights, floor loads, posts and columns, and safe stacking heights of material.
    - Concerning the accessibility in the warehouse.

2.2.3.3 The storage planning

1. The size of the warehouse must be planned by calculating the space in width, length, and height of the materials.
2. Considering the storage requirements of the warehouse about the material characteristics.
3. Identifying the storage location of the materials by concerning
    - The type, size, and weight of the materials and packaging
    - The inventory level of the materials
    - The inventory turnover of the materials

4. Considering the effect between the storing and the material handling system. Concerning the followings:
    - The material transport equipment must be suitable with the warehouse and the storage activities.
    - The storage system must be suitable with the equipments.
    - The storing must be planned to maximize the space utilization.
    - The materials transport must be easy and comfortable.
5. The storage location must minimize the travel distances in the warehouse.

2.2.3.4 The storage location

1. “Fixed Storage” is about storing the materials at the fixed location. The materials will be separated into groups. The same materials will be in the same group and stored in the same and fix location.
2. “Floating Slot or Random Storage” is about storing the materials by not fixing the location. The materials can be stored anywhere in the warehouse. This kind of storage location must be controlled and checked closely.
3. “Zoned Storage” is the space that is separated for storing the special materials.

2.2.3.5 Space planning and lay out

1. Studying the information of the space and the materials.
    - Quantity of materials
    - Warehouse policy
    - Issue Unit
    - Materials transport per time
    - Type of storage
    - Material handling method
    - Material handling equipment capability

2. Planning the storage of any materials groups.
3. Identifying the space for storage.
4. Analyzing the storage planning.
5. Designing the lay out by concerning
    - Materials size
    - Pallet size
    - Material handling equipment
    - Aisles for the equipments and employees
    - Pallets per stack
    - Location of the receiving and shipping area
    - Location of the aisles
    - Space for other service areas

2.2.4 Order Picking

Order picking is the process of retrieving the materials from the storage to meet the specific demand from the customers. So order picking is about the removing of the materials with low time and high efficiency.

2.2.4.1 The principles of order picking

1. Encourage and design the customer orders for full pallet load will help the works of picking and counting easier.
2. Try to bring the storage location to the picker for increasing the picking productivity and accuracy.
3. Eliminate and combine the order picking activities as much as possible. The activities are traveling, extracting, reaching, bending, documenting, sorting, packing, and searching. Eliminate the activities by:
    - Bringing the pick location to the picker can eliminate the traveling activity.

- Using automate information flow can eliminate the documenting activity.
- Presenting the materials at waist level can eliminate the reaching activity.
- Assigning one picker per order and one order per tour can eliminate the sorting activity.
- Bringing the pick location to the picker or taking the picker to the pick location can eliminate the searching activity.
- Using automated dispensing can eliminate extracting activity.
- Weigh counting or prepackaging in issue increments can eliminate counting activity.

Combine the activities by

- Stock-to-operator (STO) systems are used for combining traveling and extracting together. The systems are designed to keep order pickers extracting while the mechanical device travels around the storage location.
- Traveling and documenting can be combined by the order picker is free to document picking transactions, sort materials, or pack materials while the storage/retrieval machine is traveling around the storage location.
- The order picker can combine picking and sorting together if he/she completes more than one order.
- Picking, sorting, and packing can be combined when the ordered materials are small. So the order picker can pack while picking.

4. Increasing the orders per tour can reduce the travel distance and time. The followings are the several method of order picking.
   - Single order picking is the method that each order picker completes one order at a time. This method is appropriate for

the order that integrity but the order picker has to travel over a large portion of the warehouse.

- Batch picking is the method that each order picker response to retrieving a batch of orders during a picking tour. So the travel time per line item is reduced but the time to sort and the potential for picking errors increases.
- Zone picking is the method that each order picker is assigned to pick the materials in the assigned zone. The travel time can be saved by this method but the costs of sorting and errors will be high.

5. Establish the forward and reserve picking areas.
   - Determine the items to store in the forward picking area. The items should be the entire slow-moving items and some fast moving items.
   - Determine the quantities of each item to store in the forward picking area.
   - Plan the size for the storage in the forward picking area.
   - Identify the alternative storage methods.
   - Determine the operation methods within each storage alternative.
   - Estimate the costs and savings for each alternative system.
6. Assign the most popular items to the most easily accessed locations in the warehouse.
7. Balance picking activity across picking locations to reduce congestion.
8. Assign items that are likely to be requested together to the same or nearby locations.
9. Sequence picks location to reduce travel time.

10. Organize the picking documents to minimize search time and errors.
11. Design picking vehicles to minimize sorting time and errors and to enhance the pickers' comfort.
12. Eliminate paperwork from the order picking activity.

2.2.4.2 The picking document

The picker will receive the picking document that shows

- The sequence of order picking
- Item identification
- Item Location
- Item Quantity

2.2.5 Sortation

Sortation is done for sorting the batch picks into an individual order and accumulation of distributed picks into orders.

2.2.6 Packing and Shipping

Packing and shipping is the activity of checking orders for completeness, packaging in the appropriate shipping container, preparing shipping documents, weighing orders, accumulating orders, loading trucks.

2.2.6.1 The principles of shipping

1. Select cost and space effective handling units.
   - For loose cases, select the wood, plastic, metal, and nestable pallets.
   - For loose items, select totes and cardboard containers.
2. Minimize product damage.
   - Unitize and secure loose items in cartons or totes by using foam, peanuts, popcorn, bubble wrap, newsprint, and air packs.
   - Unitize and secure loose cases on pallets by using stretch wrapping, Velcro belts, and adhesive tacking.

- Unitize and secure loose pallets in outbound trailers by using foam pads and plywood.

3. Eliminate shipping staging, and direct-load outbound trailers.
4. Use storage racks to minimize floor space requirements for shipping staging.
5. Route on-site drivers through the site with minimum paperwork and time.

2.2.6.2 Consideration of shipping

1. Shipping materials characteristics, volume, and weight
2. Number of shipping position
3. Travel distances
4. Shipping type
5. Arriving day
6. Documents

2.3 Material Handling Equipment

Material handling equipment is divided as following. (Tompkins et al., 1996: 170-172)

2.3.1 Containers and Unitizing Equipment

2.3.1.1 Containers

1. Pallets
2. Skids and Skid Boxes
3. Tote Pans

2.3.1.2 Unitizers

1. Stretchwrap
2. Palletizers

2.3.2 Material Transport Equipment

2.3.2.1 Conveyors

1. Chute Conveyor
2. Belt Conveyor
   - Flat Belt Conveyor
   - Telescoping Belt Conveyor
   - Troughed Belt Conveyor
   - Magnetic Belt Conveyor
3. Roller Conveyor
4. Wheel Conveyor
5. Slat Conveyor
6. Chain Conveyor
7. Tow Line Conveyor
8. Trolley Conveyor
9. Power and Free Conveyor
10. Cart-on-Track Conveyor
11. Sorting Conveyor
    - Deflector
    - Push Diverter
    - Rake Puller
    - Moving Slat Conveyor
    - Pop-up Skewed Wheels
    - Pop-up Belts and Chains
    - Pop-up Rollers
    - Tilting Slat Conveyor
    - Tilt Tray Sorter

- Cross Belt Sorter
- Bombardier Sorter

2.3.2.2 Industrial Vehicles

1. Walking
   - Hand Truck and Hand Cart
   - Pallet Jack
   - Walkie Stacker
2. Riding
   - Pallet Truck
   - Platform Truck
   - Tractor Trailer
   - Counterbalanced Lift Truck
   - Straddle Carrier
   - Mobile Yard Crane
3. Automated
   - Automated Guided Vehicles
     - Unit Load Carrier
     - Small Load Carrier
     - Towing Vehicle
     - Assembly Vehicle
     - Storage/Retrieval Vehicle
   - Automated Electrified Monorail
   - Sorting Transfer Vehicle

2.3.2.3 Monorails, Hoists, and Cranes

1. Monorail
2. Hoist

3. Cranes
    - Jib Crane
    - Bridge Crane
    - Gantry Crane
    - Tower Crane
    - Stacker Crane

2.3.3 Storage and Retrieval Equipment

2.3.3.1 Unit Load Storage and Retrieval

1. Unit Load Storage Equipment
    - Block Stacking
    - Pallet Stacking Frame
    - Single-deep Selective Rack
    - Double-deep Rack
    - Drive-in Rack
    - Drive-thru Rack
    - Pallet Flow Rack
    - Push-back Rack
    - Mobile Rack
    - Cantilever Rack
2. Unit Load Retrieval Equipment
    - Walkie Stacker
    - Counterbalanced Lift Truck
    - Narrow Aisle Vehicles
        - Straddle Truck
        - Straddle Reach Truck
        - Sideloader Truck

- Turret Truck
- Hybrid Truck

- Automated Storage/Retrieval Machines

2.3.3.2 Small Load Storage and Retrieval Equipment

1. Operator-to-stock—Storage Equipment
   - Bin Shelving
   - Modular Storage Drawers in Cabinets
   - Carton Flow Rack
   - Mezzanine
   - Mobile Storage
2. Operator-to-stock—Retrieval Equipment
   - Picking Cart
   - Order Picker Truck
   - Person-aboard Automated Storage/Retrieval Machine
   - Robotic Retrieval
3. Stock-to-operator Equipment
   - Carousels
     - Horizontal Carousel
     - Vertical Carousel
     - Independent Rotating Rack
   - Miniload Automated Storage/Retrieval Machine
   - Vertical Lift Module
   - Automatic Dispenser

2.3.4 Factors of Equipment Consideration

2.3.4.1 Material factors

1. Type

2. Characteristics
3. Dimension
4. Weight
5. Receiving Method
6. Purchasing Document

2.3.4.2 Move factors

1. Quantity
2. Frequency
3. Starting point and objectives
4. Loading level
5. Unloading level
6. Distance
7. Aisles
8. Across
9. Space

2.3.4.3 Storage factors

1. Storage objectives
2. Materials quantity
3. Volume and capacity
4. Materials size
5. Materials weight
6. Changes

2.3.4.4 Price factors

1. Investment
2. First price
3. Operating price

4. Reinvestment
5. Space savings
6. Cost of capital
7. Depreciation policy

2.3.4.5 Other factors

1. Flexibility
2. Adjustment capability
3. Expansion
4. Future planning
5. Maintenance
6. Obsolescence
7. Capability

2.4 Warehouse Layout

2.4.1 Storage Area

Storage area must be planned for approaching from a quantitative viewpoint as apposed to a qualitative assessment of requirements. The planning of the storage area layout must do as following.

2.4.1.1 Define the storing materials

The materials must be defined about

1. Material description
2. Unit loads characteristics
   - Type of unit loads
   - Capacity
   - Size
   - Weight

3. Quantity of unit loads stored
4. Storage space
   - Method
   - Specs
   - Area
   - Height

2.4.1.2 Determine the storage philosophy

1. Fixed or assigned location storage is storing each stock-keeping unit in a specific location and no other SKU may be stored in that location, even though that location may be empty. If the fixed-location storage is used, a given SKU must be assigned sufficient space to store the maximum inventory level.
2. Random or floating location storage is storing each SKU in any available storage location not fix. Using random location storage, the quantity of items on hand at any time will be the average amount of each SKU.

2.4.1.3 Determine alternative storage method space requirements

The space requirements are related to the SKUs volume and the use-of-space characteristics. The 2 most important use-of-space characteristics are

1. Aisle allowance is the percentage of space occupied by aisles within a storage area. Aisles are in the storage area to allow accessibility to the materials storage.
2. Honeycombing allowance is the percentage of storage space lost because of ineffective use of the capacity of a storage area. Honeycombing occurs whenever a storage location is only partially filled with material and may occur horizontally and vertically.

2.4.2 Receiving and Shipping Area

This area is the most important functions of a warehouse. The transfer of the materials from the source to the warehouse and from the warehouse to the user occurs in here. The area must be large enough to receive and ship efficiently, safely, and accurately. The planning of the receiving and shipping area layout must do as following:

2.4.2.1 Define the receiving and shipping materials

The materials must be defined about

1. Material description
2. Unit loads
   - Type of unit loads
   - Capacity
   - Size
   - Weight
3. Size of shipment
4. Frequency of shipment
5. Transportation
   - Mode
   - Specs
6. Material handling
   - Method
   - Time

2.4.2.2 Determine dock requirements

1. How many docks are required?
   - Determining the receiving and shipping quantity and service time

2. How should the docks are configured?
    - 90° docks
    - 45° or finger docks

2.4.2.3 Determine maneuvering allowances inside the warehouse

1. Dock leveling area is varies according to the type of dock leveling device. The area is about 0.9-2.1 m measured from the dock face.
2. Dock maneuvering space is an aisle between the dock leveling and the receiving or shipping stage area.

2.4.2.4 Determine buffer and staging area requirements

1. Receiving buffer area is a depository for the materials unloaded from the suppliers' trucks. This area allows the unloading for fast receiving activities.
2. Shipping staging area is an accumulation point for the materials that comprise a shipment.

2.4.2.5 Determine related space requirements

1. Office space is for the office employees to work. The space is 11.25 m^2 for each employee.
2. Receiving hold area is for accumulating received material that has been rejected.
3. Trash disposal is the space for putting the trash waiting for disposal.
4. Empty pallet board storage is for storing the empty pallet board ready for receiving.
5. Employee's lounge is the area for the truck drivers and the employees to have rests. The space is 11.25 m^2 for the first employee, and an additional 2.25 for each additional employee.

2.4.3 Docks

2.4.3.1 Dock locations

1. Combination of receiving and shipping docks
2. Separateed receiving and shipping docks
3. Scattered receiving and shipping docks

2.4.3.2 Dock design

1. Flush dock
   - Cantilever flush dock
   - Vestibule flush dock
2. Open dock
   - Dock curtains or sliding panels
3. Enclosed dock
   - Side-entrance enclosed dock
   - Straight-in-entrance enclosed dock
   - Side-loading or finger dock
   - Drive-through-the facility dock
   - Staggered (saw tooth) dock
   - Pier dock
   - Freestanding dock (dock house)
   - Mobile yard ramp

2.4.3.3 Dock door design features

1. The width of the dock doors is 2.4-2.7 m to agree with the corresponding rear truck dimension 2.4-2.55 m.
2. The clear height of the dock doors is 2.4-3 m and at least one dock door is 4.2 m high for the tallest material handling equipment.

2.4.4 Aisles

Aisle is the access to the areas within the warehouse among the storage area, receiving area, and shipping area.

2.4.4.1 Factors of the aisles position

1. Type of the aisles
2. Material handling equipment in type, size, capacity, and turning
3. Size of SKU
4. Direction and accessibility
5. Inventory level
6. Column spacing
7. Service area
8. Lift and pathway

2.4.4.2 Type of aisles

1. Working aisle
   - Transportation aisle
   - Cross aisle
2. Personal aisle for the person to access to the warehouse or the doors.
3. Service aisle for accessing to the stacks to check the inventory
4. Bin aisle
5. Lift aisle for accessing to the lift
6. Other aisle for accessing to the utilities

2.4.4.3 The width of the aisle

1. The aisle between product-to-product for wide-aisle and narrow-aisle handling equipment is 0.15-0.3 m.
2. Nominally, the aisle width dimension is 0.15 m wider than the diagonal dimension of the pallet load.

3. The aisle between the shelves of a single-item pick is 0.9-1.05 m.
4. The pallet jack operation needs 2.4-2.7 m and the counterbalanced lift truck require 3.6-3.9 m width for two-way pallet truck traffic.
5. The main aisle that has intersecting to the storage and pick aisles needs 0.3 m width added.
6. All main vehicle traffic aisles allow two vehicles to pass each other.
7. The ramps, dock doors, and building doors must have clear height of the equipment plus 0.15 m.
8. All personal aisles have 1.05-1.2 m wide.

2.4.5 Stacks

Factors of stacking the materials are as following.

1. Unit load support device
2. Stack turnover
3. Stack weight
4. Floor condition
5. Material handling equipment (capacity and capability)

2.4.6 Truck Access Area

2.4.6.1 Truck traffic flow patterns

1. One-way pattern is at least 3.9 m wide and plus 1.2 m for an employee walkway.
2. Two-way pattern is at least 7.8 m wide plus 1.2 m for the employee walkway.

2.4.6.2 Delivery truck holding area

Delivery truck holding area is a buffer area for the truck before the receiving starts, or exits the warehouse.

1. Block concept
2. 45° angle concept

3. Back-to-back and side-to-side concept

2.4.6.3 Truck loading and maneuvering areas

1. The loading area is minimum 19.5 m long. The width is the overall width of the widest truck plus 0.9 m on each side of the truck. The area can decrease, if the shorter trucks are used.
2. The maneuvering area is a minimum of 21 m extending outward from the loading area for the counterclockwise vehicular traffic and 42 m for the clockwise vehicular traffic. The area can decrease, if the shorter trucks are used.

2.5 Material Characteristics

Polymer Marketing and Trading Co., Ltd. is a plastic resins trading company, so the material that the company keeps is the plastic resins.

The plastic resins that the company sells can be divided into two types by using chemical structure.

2.5.1 Non-Polar Polymers

Non-polar polymers are the plastic resins that cannot dissolve water in the air, which is the polar molecule substance. So this kind of plastic reins will not be moist when kept in the warehouse. The plastic resins in this type that the company sells are

2.5.1.1 Polypropylene (PP)

PP is the plastic resins used widely in the plastic industries. PP can be divided into three types: Homopolymer, Block copolymer, and Random copolymer. Homopolymer PP is the most widely used among PP products. This kind of plastic resins is translucent, high heat resistance, but has low impact strength. The price range of homopolymer PP is 20-30 Baht/kg. The followings are the kinds of PP that PM sells.

1. **PP Film** is the PP plastic resins that use for making film products such as plastic bags, food packaging, etc. There are a lot of grades of PP Film: 1126NK, 1126NN, and 1125NA of TPI brand; P600F and P601F of TPE brand; PD943 of HMC brand; FA8014 of TPC

brand; etc. PM sells this material about 21 % of overall sales or about 210 tons per month.

2. **PP Inject** is the PP plastic resins used for making plastic injection molding products such as households, closures, food containers, etc. There are a lot of grades of PP Inject: 1100NK, 1100NN, and 1100RC of TPI brand; P700J and P701J of TPE brand; 6331 of HMC brand; etc. PM sells this material about 20 % of overall sales or about 200 tons per month.

3. **PP Yarn** is the PP plastic resins used for making plastic yarn and monofilament products such as coarse textile for woven bags, tapes, sheets for files, etc. There are a lot of grades of PP Yarn: 1102H, 1102K, and 1102J of TPI brand; P400S, P401S and P401J of TPE brand; 6631 and 6531 of HMC brand; etc. PM sells this material about 14 % of overall sales or about 140 tons per month.

2.5.1.2 High-Density Polyethylene (HDPE)

HDPE is the plastic resins that is opaque, hard, and has high impact strength. HDPE can use for making many products. HDPE Film is used for making shopping bags, inner bags, printed bags, etc. These grades are GA3750 and GA3245 of TPI brand; H5640F and M4004F of TPE brand; 7000F of BPE brand; etc. HDPE Blow is used for making blow-molding products such as bottles, gallons, etc. These grades are GA2850, G2855, GM2860, and GM2865 of TPI brand; H5603B, H5840B, H6240B, and H6430BM of TPE brand; 8200B, 6200B, and 5200B of BPE brand. HDPE Inject is used for making household products, pallets, baskets, buckets, boxes, etc. These grades are V1160 and R1760 of TPI; H5818J, H6218J, H6105JU, and H6205JU of TPE brand; 1600J and 2208J of BPE brand; etc. HDPE Monofilament is used for making fishing nets, seines, ropes, etc. These grades are N3260 of TPI brand; H5690S and H5480S of TPE brand; 5000S of BPE brand; etc. PM sells HDPE about 14 % of overall sales or about 140 tons per month. The price range of HDPE is 25-35 Baht/kg.

2.5.1.3 Low-Density Polyethylene (LDPE)

LDPE is soft but high impact resistance. LDPE is used in 2 majors works. LDPE Film is used for making fruit bags, zip bags, shrink films, laminating films, etc. These grades are JJ4324, D2022, D2226, and II4330 of TPI brand; LD1905F, LD2130F, LD2150F, and LD2305F of TPE brand; F410-2 of TPC brand; LF525H of Mitsubishi brand; etc. LDPE Injection is used for making bottle covers, packaging covers, toys, plastic flowers, etc. These grades are S1018, ST1018, and SU1018 of TPI brand; LD1708J, LD1630J, and LD1450J of TPE brand; 7050 of TPC brand; 0405 of NUC brand; etc. PM sells LDPE about 5 % of overall sales or about 50 tons per month. The price range of LDPE is 30-35 Baht/kg.

2.5.1.4 General Purpose Polystyrene (GPPS)

GPPS is the plastic resins that is transparent but has low impact strength, so it is fragile. It is used in two purposes, injection and extrusion. GPPS Injection is used for making any transparent products such as boxes, toys, etc. These grades are GP150 of TPI brand, 656D of Dow brand, THF77 of HMT brand, 525/527-10 of Eternal brand, etc. GPPS extrusion is used for making foam sheets, thermoforming products, frames, etc. These grades are GP110 of TPI brand, 685D of Dow brand, THH102 of HMT brand, 555/500 of Eternal brand, etc. PM sells GPPS about 10 % of overall sales or about 100 tons per month. The price range of GPPS is 25-40 Baht/kg.

2.5.2 Polar Polymers

Polar polymers are the plastic resins that can dissolve water in the air, which is the polar molecule substance. So this kind of plastic reins will be moist easily when kept in the warehouse. This type of plastic resins must be dried before making any products. The plastic resins in this type that the company sells are

2.5.2.1 High Impact Polystyrene (HIPS)

HIPS is the polystyrene that added Butadiene to increase the impact strength of the GPPS plastic resins, but the plastic resins will not be transparent. HIPS is also used in the same purposes as GPPS, injection and extrusion. The grades of HIPS are HI650 and HI830 of TPI brand, 486B and 486M of Dow brand, H350 of HMT brand, 825 and 830/855 of Eternal brand,

etc. PM sells HIPS about 8 % of overall sales or about 80 tons per month. The price range of HIPS is 25-40 Baht/kg.

2.5.2.2 Acrylonitrile-Butadiene-Stryrene (ABS)

ABS is the polystyrene that is added width Acrylonitrile to increase gloss, heat resistance, chemical resistance, stiffness, and rigidity; and is added with Butadiene to increase impact strength. So ABS can be used in many fields of products such as toys, auto parts, electrical parts, households, etc. ABS that PM sells are the medium impact with high gloss ABS and high impact with high gloss ABS. The grades are MH-1 and GA800 of TPI brand, PA717C of Chimei, etc. PM sells ABS about 8 % of overall sales or about 80 tons per month. The price range of ABS is 40-50 Baht/kg.

Every grade of plastic resins from every supplier is packed in the 25 kg-plastic or paper sacks. The colors of the sacks show the type of plastic resins. The grades and lot numbers are printed on the each sack. The materials are sent to the company from the suppliers by using the trucks, which can load 14 tons of plastic resins. That means every truck loads 560 sacks of plastic resins.

2.6 Literature Survey

Warehouse is a very important operation part in any companies since the warehouse uses for stocking raw material, work in progress, and finished goods. So the warehouse operation impact directly to the costs and customer services. The warehouse management must be managed in the right way.

There are a lot of books and researches that wrote about warehouse management. Jenkins (1968) wrote the book about warehouse management. The book included the warehousing's role in modern business, when to use warehousing, where to locate warehouses, warehouse construction and finance, handling and storing materials, selection and use of equipment, warehousing's transportation functions, and effective ways to measure, evaluate, and control the basic functions of warehousing. Spechler (1975) also wrote a book about the warehouse management. The book covers the operation and physical management in the warehouse. His book emphasizes on reducing and controlling the physical distribution and inventory

carrying costs. Warman (1983) wrote a book about all the management activities in the warehouse by intending the practical work more than the theory of the warehouse management.

Pranee Kammarabootra (1979) used the information from many book to write her thesis about a guideline to warehouse management and a rouse for the interest of management to the important role of warehousing. She tried to point about the importance of the warehouse in any companies. Her thesis covered almost the management in the warehouse; those are the location, size, layout, storage area, stacking, stock location, material handling equipment, maintenance and safety, planning and control, organization, etc. She also recommended three management styles. 1.The warehouse organisation should have a definite job description, some decentralisation of management's duty, a strict rule, and a qualified people recruited. 2. The good working atmosphere should be created in the warehouse. 3. Safety and sufficient security against all risks should be provided. Then Pongpat Phetrungrueng (1996) wrote a thesis by trying to improve the efficiency of a warehouse, using the case of the air conditioner warehouse. This air conditioner warehouse is the receiving place of air conditioners from the suppliers to store and wait for delivering to the customers. The thesis started with studying the subject of warehousing analysis, packaging, management, material handling, motion and time study, and lay out. Then the problems were defined and analyzed. And the warehouse were improved and measured. Moreover, Tanan Kraikosol (2000) wrote a thesis about the inventory management by using the system of group ordering and a case of the construction materials' distributor. The thesis concerned about the inventory level of each material item, and used the purchasing method of EOQ to purchase the materials. After that the EOQ method is compared with the traditional method, it appeared that the EOQ method could reduce the costs not so many.

Beside the warehouse management, the warehouse planning and design is also important for operating or building a new warehouse. The warehouse that will be designed to use in the future must be planned about the operation, the material handling system, and the physical design in the appropriate way. There are many books and researches that wrote about the warehouse planning and design.

Mulcahy (1994) wrote a handbook of the warehouse distribution and operation. The book includes a lot of the planning and design criteria that involved the

warehouse such as operation, space layout, equipments, storage method, etc. While Mulcahy (1994) emphasized on the warehouse distribution and operation, Tompkins et al. (1996) wrote a book that emphasized more about facilities planning in both manufacturing plant and warehouse. The book is about the planning of the facilities, which is the physical part of the warehouse planning and design. They tried to tell about the choosing criteria of the material handling system and the design criteria of the plant layout.

One part of the thesis of Thong-moh Phungpai (1992) is about the improvement of the warehouse layout and operation. He discovered that one major problem of the air conditioner manufacturing, his case study, occurred in the warehouse. So he tried to increase the efficiency of the factory by changing something in the company, one of that was the warehouse operation and layout. Then, Numpon Tungsub (1995) wrote his thesis about improving the utility of the warehouse in the air conditioner assembling factory. He realized that the air conditioner has a lot of parts to assembly, so the storage position and the warehouse area are very important. Moreover, Supanee Kosonwattana and Jadesda Nuntanart (1999) did their senior project about improving the plant layout of a warehouse for the most efficiency in inventory system by using a case of Siam CPAC Block Co.,Ltd. They used the Systematic Layout Planning (SLP), and the Systematic Handling Analysis and Motion and Time Study to develop and improve the warehouse of their case study. Their project could improve the old Siam CPAC block's plant layout efficiency such as using inventory area completely, decreasing handling costs, reducing the operation time, etc.

There is a book that wrote about both warehouse management and warehouse planning and design. Tompkins and Smith (1988) were the editors of this book. They tried to collect the articles from many authors about the warehouse management and the warehouse planning and design criteria. The book became the handbook of the warehouse management.

The warehouse management, planning, and design are studied so many in the past by using several cases. However, the case of plastic resins trading company still has not been studied. So this research will study some parts of the existing warehouse management design some parts of a new warehouse by using a case of plastic resins trading company.

CHAPTER 3

EXISTING SYSTEM AND SITUATION STUDY

3.1 The Company

Polymer Marketing & Trading Co., Ltd. (PM) is a plastic resins trading company. Its customers are from the plastic industries. The company is a subagent of Thai Asia Plastic Co., Ltd. (TaP), which is an plastic resins' agent of Thai Petrochemical Industry Public Co., Ltd. (TPI).

PM was established in May 2000. The office is settled at Taksin Road, Bangkok. At the moment, the company still does not have its own inventory store and transportation trucks. TaP provides both the inventory store and trucks for PM and charges PM about 0.5 Baht per kilogram of the plastic resins.

3.2 The Company Organization

PM is a new company, so the organization of it is not complex. The organization is shown in Figure 3.1 below.

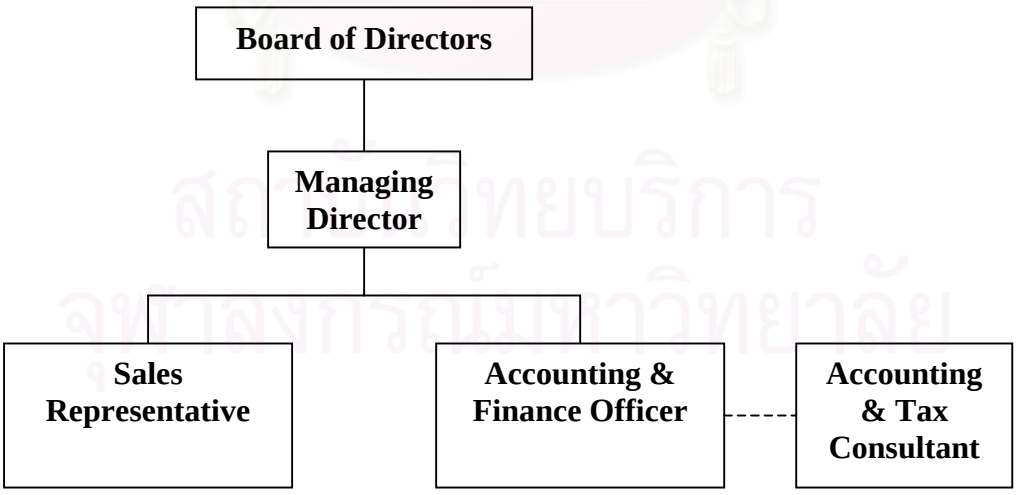


FIGURE 3.1 The Company Organization

3.2.1 Board of Directors

The board of directors consists of 4 members, who are the shareholders of the company. The board of directors is responsible for making the company policies.

3.2.2 Managing Director

Managing director is responsible for controlling all the implementation of the company's work, making the decision on purchasing the materials, and making the sales policies.

3.2.3 Sales Representative

Sales representative is responsible for reaching out to the customers, selling the products, and providing services to the customers. Nowadays, the company has only 1 sales representative.

3.2.4 Accounting & Finance Officer

The company has 1 accounting and finance officer to take care of the accounting and finance work.

3.2.5 Accounting & Tax Consultant

The accounting & finance officer will consult with an accounting & tax consultant, who is an expert in the account and tax work.

3.3 The Products and Sales

The products that PM sells are several types of plastic resins. Nowadays, the company is selling the plastic resins of TPI brand about 150 tons per month. Table 3-1 shows the sales in the last three months.

TABLE 3-1 The Sales in The Last Three Months (Tons)

Month-Year	PP Film	PP Inject	PP Yarn	HDPE	LDPE	GPPS	HIPS	ABS	Overall
Mar-01	28.000	29.400	21.000	22.500	6.800	14.300	13.500	10.900	146.400
Apr-01	33.000	30.350	21.000	19.875	7.550	16.700	11.350	12.200	152.025
May-01	35.000	29.800	21.000	20.600	8.100	14.900	11.800	12.950	154.150
Average	32.000	29.850	21.000	20.992	7.483	15.300	12.217	12.017	150.858

TABLE 3-2 The Percentage Sales in The Last Three Months (%)

Month-Year	PP Film	PP Inject	PP Yarn	HDPE	LDPE	GPPS	HIPS	ABS	Overall
Mar-01	19.126	20.082	14.344	15.369	4.645	9.768	9.221	7.445	100.000
Apr-01	21.707	19.964	13.814	13.074	4.966	10.985	7.466	8.025	100.000
May-01	22.705	19.332	13.623	13.364	5.255	9.666	7.655	8.401	100.000
Average	21.2	19.8	13.9	13.9	5.0	10.1	8.1	8.0	100.0

The price of each plastic resins type is collected and shown in Table 3-3.

TABLE 3-3 The Price of Each Plastic Resins Type (Baht/kg)

Month-Year	PP Film	PP Inject	PP Yarn	HDPE	LDPE	GPPS	HIPS	ABS
Mar-99	21.0	20.5	20.0	25.0	30.0	25.0	27.0	41.0
Apr-99	22.0	21.5	21.0	26.0	30.0	25.5	27.5	41.0
May-99	23.5	23.0	22.5	26.5	30.5	26.5	28.5	42.5
Jun-99	23.5	23.0	22.5	26.5	30.5	27.5	29.5	43.5
Jul-99	21.0	20.5	20.0	25.5	30.5	25.5	27.5	43.0
Aug-99	27.0	26.5	26.0	28.0	31.5	27.5	29.5	44.5
Sep-99	30.0	29.5	29.0	34.0	34.5	30.5	32.5	45.0
Oct-99	28.0	27.5	27.0	33.0	35.0	33.5	35.5	46.5
Nov-99	27.0	26.5	26.0	31.5	35.0	35.0	37.0	47.0
Dec-99	26.5	26.0	25.5	30.0	34.5	37.0	39.0	48.0
Jan-00	24.0	23.5	23.0	28.0	33.5	36.0	38.0	45.0
Feb-00	29.0	28.5	28.0	35.0	34.5	38.0	40.0	49.0
Mar-00	28.0	27.5	27.0	30.0	34.0	39.0	41.0	50.0
Apr-00	28.0	27.5	27.0	30.0	35.0	38.5	40.5	50.0
May-00	26.0	25.5	25.0	29.5	34.5	38.0	40.0	48.0
Jun-00	27.0	26.5	26.0	31.0	33.0	38.0	40.0	48.0
Jul-00	28.0	27.5	27.0	32.0	35.0	37.5	39.5	48.0
Aug-00	28.5	28.0	27.5	32.0	35.0	37.0	39.0	48.0
Sep-00	30.0	29.5	29.0	35.0	35.0	37.0	39.0	49.0
Oct-00	29.0	28.5	28.0	33.0	34.0	36.0	38.0	48.0
Nov-00	27.5	27.0	26.5	30.5	33.0	35.5	37.5	48.0
Dec-00	26.0	25.5	25.0	28.5	31.5	35.5	37.5	48.0
Jan-01	27.0	26.5	26.0	30.0	32.5	34.0	36.0	49.0
Feb-01	29.0	28.5	28.0	30.0	33.0	34.0	36.0	47.0
Mar-01	29.0	28.5	28.0	30.0	33.0	33.5	35.5	47.0
Apr-01	27.0	26.5	26.0	31.0	32.0	33.0	35.0	46.5
May-01	27.0	26.5	26.0	31.5	32.5	32.0	34.0	46.0

Table 3-4 shows the summary of the types, sales in the present time, price ranges, and grades of the plastic resins.

Table 3-4 The Types, Sales, Price Ranges, and Grades of the Products in a month

Products	Sales (Tons)	Price Range (Baht)	Grades
PP Film	32.0	20-30	1126 NK, 1126 NN, and 1125 NA
PP Inject	29.9	20-30	1100 NK, 1100 NN, and 1100 RC
PP Yarn	21.0	20-30	1102 H, 1102 K, and 1102 J
HDPE	21.0	25-35	GA2850 , G2855 , GM2860 , and GM2865
LDPE	7.5	30-35	JJ4324 , D2022 , D2226 , and II4330
GPPS	15.3	25-40	GP150 and GP110
HIPS	12.2	25-40	HI650 and HI830
ABS	12.0	40-50	MH-1 and GA800
Overall	**150 .9**		

The plastic resins of every brand are sold in the form of plastic resins sack. The weight of each plastic resins-stored sack is 25 kg. The size of the sack is about 0.4 m wide, 0.6 m long, and 0.2 m thick.

3.4 The Existing Physical Structure

Since PM still does not have its own warehouse, the existing physical structure is about the warehouse of TaP. TaP's warehouse is shown in Figure 3.2.

The warehouse of TaP can be divided into 2 parts.

3.4.1 Inside the Warehouse

The warehouse size is 50 m wide, 25 m long, and 10 m high. So the area inside the warehouse is 50*25 = 1,250 m^2. Inside the warehouse consists of the following:

3.4.1.1 The office

The office is located in the front part of the warehouse for the supervisors doing their works. The size of the office is 5 m wide and 5 m long. The area is 5*5 = 25 m^2.

3.4.1.2 The employees' lounge

The employees' lounge is also located next to the supervisor office in the front part of the warehouse. The employees can take a rest in the lounge

while do not have work. The size of the lounge is 5 m wide and 5 m long. The area is 5*5 = 25 m^2.

3.4.1.3 The storage area

The storage area is the area for storing the materials, keeping the empty pallet boards, and parking the lift trucks. The size is 50 m wide and 17 m long. The area is 50*17 = 850 m^2.

3.4.1.4 The parking and shipping area

The parking and shipping area is the area for parking the shipping trucks at night and shipping the materials during the daytime.

3.4.2 Outside the Warehouse

There is an area of 8 m wide and 50 m long outside the warehouse. TaP uses this area for the receiving operation.

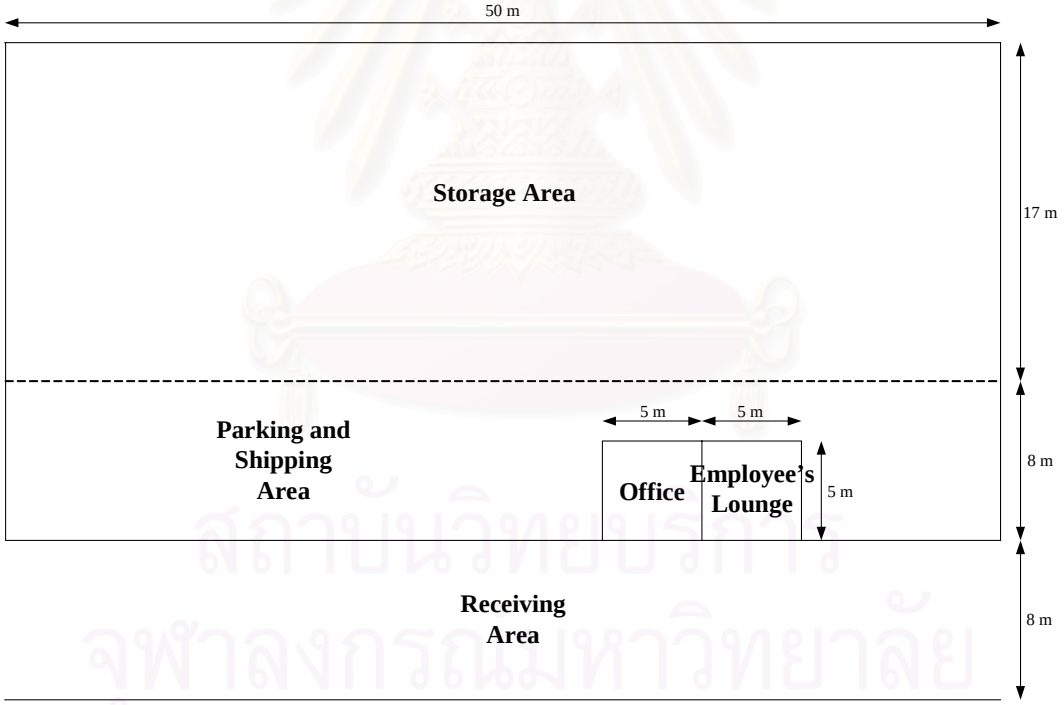


FIGURE 3.2 TaP's Warehouse

3.5 The Existing Operation Procedure

PM still does not have its own warehouse, so this is the study of TaP's existing operation procedure.

Nowadays, TaP has 2 supervisors and 40 workers to work in the warehouse.

3.5.1 Receiving

The receiving steps of the existing system are as following.

3.5.1.1 The supplier's trucks are driven into the receiving area.

Before 6.00am of each working day, supplier's trucks are driven into the receiving area. The space of receiving area is enough for only 4 trucks. If there are more than 4 trucks at the same time, the excess trucks must wait at the nearby area.

3.5.1.2 The doors are opened and the warehouse supervisor checks the invoice.

The warehouse doors are opened at 8.00am of the day. The truck drivers will give the invoices of their truck's goods to the warehouse supervisor. The supervisor will check the type, grade, and quantity of the material in the invoice of each truck by comparing with the purchased information. If the information is not the same as the invoice, the supervisor has to contact to the head office to confirm the information and return that wrong truck to the supplier. If the information is the same as the invoice, the workers will open the container door of that truck.

3.5.1.3 The workers unload the materials.

The lift trucks will lift the empty plastic pallet boards to each truck. The workers will put the 2 pallet boards right behind the back of each truck. Two workers will climb up into the container of the truck while other two workers are on the ground. The two workers on the truck will drop the sacks of plastic resins on to each pallet and the workers on the ground will separate the sacks on the pallet board.

The sacks sizes are about 0.4m wide and 0.6m long. The worker on the pallet board will separate 5 sacks in each layer, 3 sacks are cross and 2 sacks are straight, on the 1.0m * 1.2m pallet boards. The direction of the sacks will be separated alternate in the above layer. The sacks will be separated for 10 layers. The sack separate is shown in Figure 3.3.

When the materials are unloaded for about half of the container, other two workers will climb up into the container to help the first two workers dropthe plastic resins sacks. So each truck has 6 workers to unload the materials.

FIGURE 3.3 Sacks separate method (5 sacks in each layer)

From Warehouse of Thai Asia Plastic Co.,Ltd. (18 September 2001)

3.5.1.4 The supervisor and the workers check the quantity and the quality of the receiving materials.

The workers will check the quality of the materials by observing the sacks while unloading them. If any sacks are wet or broken, the workers will notify the supervisor. The supervisor will decide to accept or return the materials to the suppliers. The type, grade and quantity of the returned materials will be noted in the supplier's invoice.

The supervisor will check the quantity of the materials by counting the number of full pallet loads. Each pallet load has 50 sacks and each sack is 25 kg, therefore the total weight of each full load is 1250 kg. So the supervisor will know the weight of the received material by knowing the total number of full pallet loads.

3.5.1.5 The unloaded trucks exit the receiving area.

After the materials are all unloaded, the supervisor will sign the invoices and return the copies to the trucks drivers. The trucks drivers will drive the trucks out of the receiving area to park at the nearby area. The excess

trucks that have not been unloaded will be driven into the receiving area and the workers start the receiving activities again.

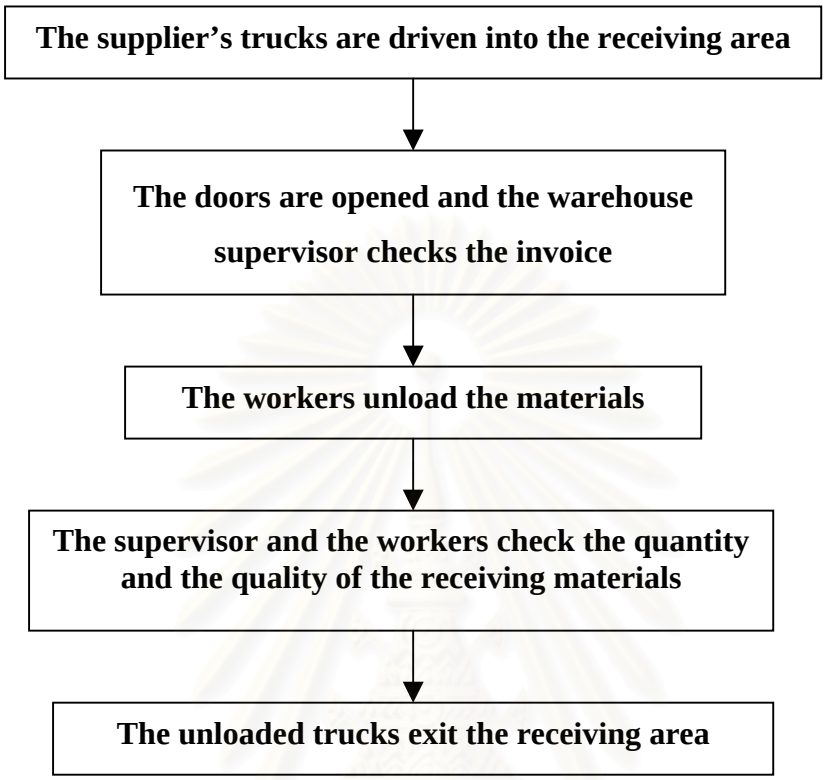


FIGURE 3.4 Flowchart of Receiving

3.5.2 Put-away

The Put-away steps of the existing system are as following.

3.5.2.1 The supervisor plans for the storing position and the cross-dock shipping material.

The supervisor will find the free space position to store the received materials by checking the storage area. First, the supervisor will look for the just-received materials that can cross-dock to ship immediately, so these materials do not have to be stored in the storage area. Then the supervisor will tell the lift truck driver whether the received materials must be kept in which position or lifted to the shipping truck for shipping.

3.5.2.2 The lift trucks lift the loaded pallet loads out of the unloading area.

The lift trucks will lift the loaded pallet loads out of the unloading area and put the loads aside the supplier's trucks. The workers will change the

empty pallet board to the unloading area and repeat the unloading steps described above.

3.5.2.3 The lift trucks lift the loaded pallet loads to the storage or shipping area.

The lift trucks lift the loaded pallet loads one by one from the side of the trucks into the storage or the shipping area.

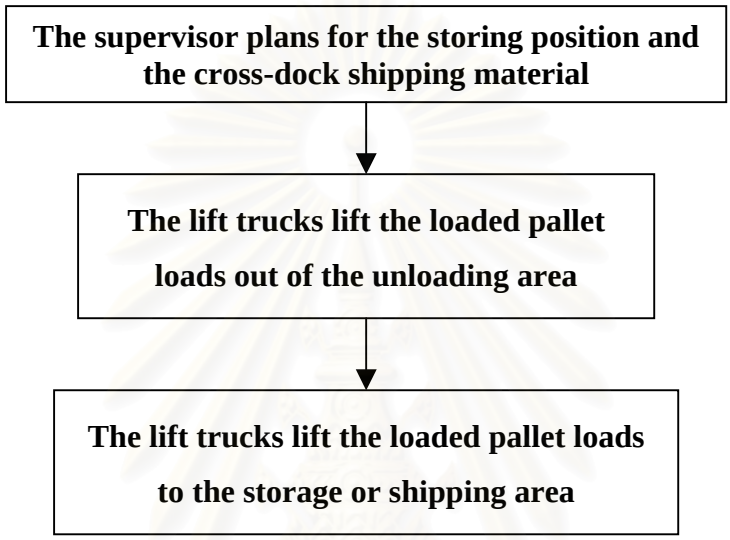


FIGURE 3.5 Flowchart of Put-away

3.5.3 Storage

TaP stores the materials by using the floor stack method, each stack loads 2 pallet loads. The materials are stored into rows. Each row stores the same grade of material. The new receiving materials will store in the new rows. So the grades of materials will not be stored in the fixed row. The storage steps of the existing system are as following.

3.5.3.1 The lift trucks lifts the loaded pallet loads to store in the row that the supervisor assigned.

The supervisor will assign the received materials to the empty rows. The same grade of plastic resins is to be stored in the same row.

3.5.3.2 The supervisor update the inventory level of the warehouse.

The supervisor will update the storing quantity in the inventory level book.

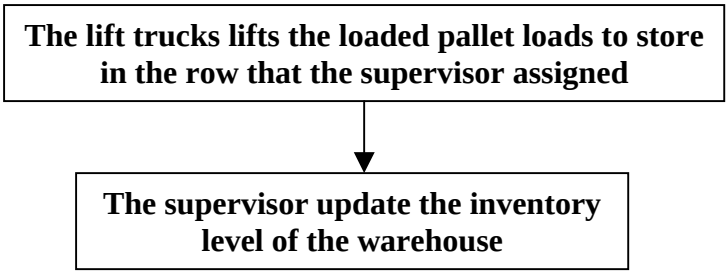


FIGURE 3.6 Flowchart of Storing

3.5.4 Order Picking

The order picking steps of the existing system are as following.

3.5.4.1 The supervisor plans for the customers orders.

After the supervisor receives the customer orders from the head office, she has to plan the sequence of sending the materials to the customers. The sequence and routing of sending must be planned first. Next, the order picking and shipping sequence will be planned. If the truck has to send the products to more than 1 customer, the plastic resin grades of the customer to whom the products will be sent the last must be loaded into the container of the truck first. This is because, when the lift truck carries the order picking grade of the last customer to the shipping area, the worker can separate this grade at the most inside of the truck. Consequently, the orders of the first customer should be picked last. The worker can separate this order in the most outside of the truck.

3.5.4.2 The supervisor observes the storage and assigns the order picking position to the lift trucks drivers.

The supervisor will look at the customer orders and go to the storage area to find the picking position. Then the supervisor will assign the lift truck drivers about the sequence of picking; the type, grade, and quantity of plastic resins; the picking position; and the assigned shipping truck.

3.5.4.3 The lift trucks pick the pallet loads to the shipping trucks.

This step will start when the shipping truck is at the parking and shipping area. The lift trucks will pick the pallet loads from the storage area following the supervisor's assignment to the shipping truck.

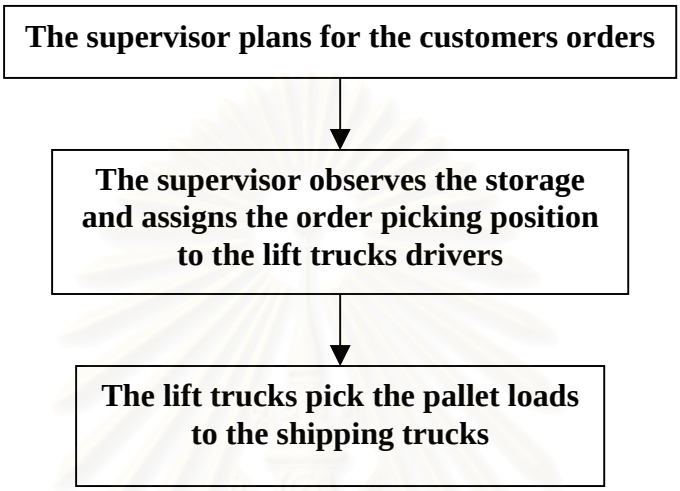


FIGURE 3.7 Flowchart of Order Picking

3.5.5 Shipping

The shipping steps of the existing system are as following.

3.5.5.1 The supervisor prints the sending invoice and give to the truck drivers.

The supervisor will print the invoice for the truck drivers to give to the customers. The invoice consists of the customer's name and address, type, grade, and quantity of the material orders.

3.5.5.2 The workers load the plastic resins sacks to the trucks.

After the lift trucks finish lifting the pallet loads to the shipping area, the workers load the plastic resins sacks into the trucks. Each truck will have 1 worker on the truck to separate the sacks and 1 worker outside the truck to send the sacks to the worker on the truck. A 4-wheeled truck can load 80 sacks and the 6-wheeled truck can load 200 sacks.

3.5.5.3 The trucks drivers check the sequence, quantity, and quality of the materials.

The trucks drivers that have been received the sending invoice will go to the shipping trucks area. The drivers will look after the loading of the workers and the sequence of the materials orders that the workers are loading, count the sacks, and check whether the sacks are broken or wet. If any sacks are broken or wet, the driver can tell the workers to replace those sacks.

3.5.5.4 The lift trucks lift the left pallet loads back to the picking position.

After the plastic resins sacks are loaded to the trucks, there are some pallet loads left with the plastic resins sacks. The lift trucks will lift these pallet loads back to the storage area at the position from where they are original lifted.

3.5.5.5 The supervisor updates the inventory level.

The supervisor will erase the type, grade, and quantity of the materials that have already been printed the invoice in the inventory level book. The information in the book will show only the inventory left in the warehouse.

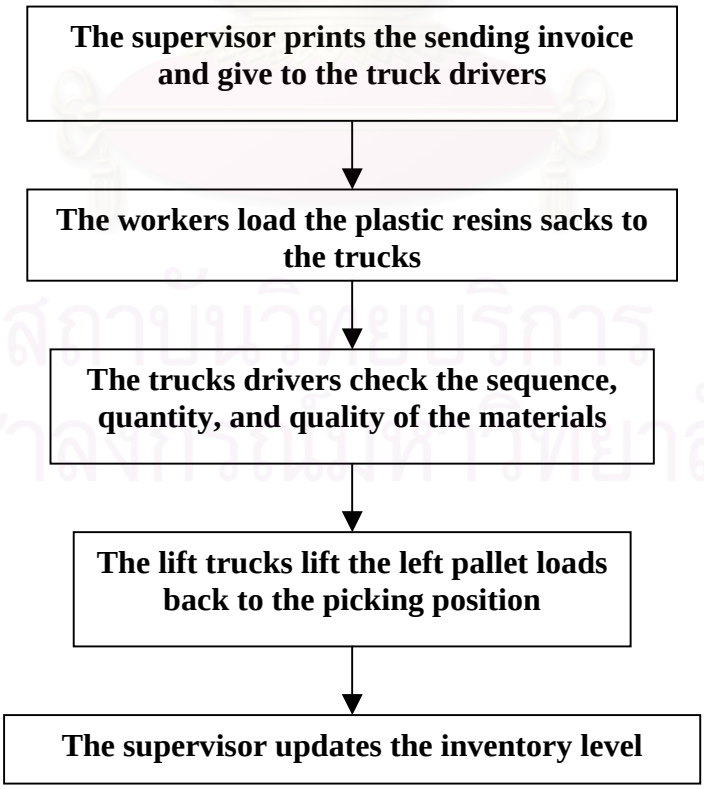


FIGURE 3.8 Flowchart of Shipping

3.6 The Projected Requirement and Forecasting

3.6.1 Sales Level

PM tries to increase its productivity by finding more suppliers to get more grades of materials and hiring more sales representatives to expand the markets.

PM has targeted the sales in the future at 1000 tons of plastic resins per month. The future sales of each plastic resins type are estimated by extrapolating the present sales as shown in Table3-2. The estimated sales are as following:

- PP Film is about 21 % of overall sales so the future sales of this type will be about 210 tons per month.
- PP Inject is about 20 % of overall sales so the future sales of this type will be about 200 tons per month.
- PP Yarn is about 14 % of overall sales so the future sales of this type will be about 140 tons per month.
- HDPE is about 14 % of overall sales so the future sales of this type will be about 140 tons per month.
- LDPE is about 5 % of overall sales so the future sales of this type will be about 50 tons per month.
- GPPS is about 10 % of overall sales so the future sales of this type will be about 100 tons per month.
- HIPS is about 8 % of overall sales so the future sales of this type will be about 80 tons per month.
- ABS is about 8 % of overall sales so the future sales of this type will be about 80 tons per month.

3.6.2 Inventory Level

The prices of the plastic resins always change. So the company has a policy that it will stock as many material as the quantity the budget allows when the goods are the cheapest. The space of the warehouse must be enough for the entire inventory, so it will be designed by using the maximum inventory level. The minimum price of each kind of goods can bring to the maximum inventory level. The price of each

plastic resins type is shown in Table 3-3 and the price range is shown in Table 3-4. The budget for stocking the inventory that the company set is 50 million Baht. So the inventory level of each plastic resins type is as following.

PP Film

- The sales will be 210 tons/month.
- The minimum price is 20 Baht/kg.
- So the cost is 210*20 = 4.2 million Baht/month.

PP Inject

- The sales will be 200 tons/month.
- The minimum price is 20 Baht/kg.
- So the cost is 200*20 = 4.0 million Baht/month.

PP Yarn

- The sales will be 140 tons/month.
- The minimum price is 20 Baht/kg.
- So the cost is 140*20 = 2.8 million Baht/month.

HDPE

- The sales will be 140 tons/month.
- The minimum price is 25 Baht/kg.
- So the cost is 140*25 = 3.5 million Baht/month.

LDPE

- The sales will be 50 tons/month.
- The minimum price is 30 Baht/kg.
- So the cost is 50*30 = 1.5 million Baht/month.

GPPS

- The sales will be 100 tons/month.
- The minimum price is 25 Baht/kg.

- So the cost is 100*25 = 2.5 million Baht/month.

HIPS

- The sales will be 80 tons/month.
- The minimum price is 25 Baht/kg.
- So the cost is 80*25 = 2.0 million Baht/month.

ABS

- The sales will be 80 tons/month.
- The minimum price is 40 Baht/kg.
- So the cost is 80*40 = 3.2 million Baht/month.

Overall costs of stocking = 23.7 million Baht/month

So with the budget of 50 million Baht, the company can stock the inventory about 2.1 months. The overall stocks are 2100 tons consisting of 441 tons of PP Film, 420 tons of PP Inject, 294 tons of PP yarn, 294 tons of HDPE, 105 tons of LDPE, 210 tons of GPPS, 168 tons of HIPS, and 168 tons of ABS.

3.6.3 Receiving Level

The sales estimation is 1000 tons per month, so the warehouse receives the plastic resins at least 1000 tons per month. However, PM can keep a maximum inventory at 2100 tons. So the company will receive 0 ton per month if the inventory is enough for the sales in that month, the company will receive 3100 tons per month if the company want to stock the inventory 2100 tons.

The average of 0 and 3100 tons per month is the quantity that the company will receive most frequently. So the design will use the number of 1550 tons per month as a receiving design criterion, which comes from the average of 0 and 3100 tons per month.

Using the safety factor 25% for the fluctuation of each day. So the warehouse has to receive 1550*1.25 = 1937.5 tons per month. The workdays in each month are about 25 days. So everyday the warehouse has to receive the plastic resins 1937.5/25 = 77.5 tons.

3.6.4 Suppliers' Trucks

The trucks from any suppliers are the 10-wheeled trucks. Each truck has a container that can load 14 tons or 560 sacks of plastic resins. The trucks size is 2.5m in width, 7.5m in length, and 3.8m in height. A 10-wheeled truck is allowed to drive in Bangkok from 10.00am to 3.00pm and 10.00pm to 6.00am.

The receiving level is 77.5 tons per day. So everyday PM has to receive the materials from 77.5/14 = 5.54 or 6 trucks.

FIGURE 3.9 10-wheeled truck

From Warehouse of Thai Asia Plastic Co.,Ltd. (18 September 2001)

3.6.5 Shipping Level

The sales estimation is 1000 tons per month. Use the safety factor 25% for the fluctuation of each day. So the warehouse has to ship 1000*1.25 = 1250 tons per month. The workdays in each month are about 25 days. So everyday the warehouse has to ship the plastic resins 1250/25 = 50 tons.

3.6.6 Shipping Trucks

There are two kinds of truck that used for shipping the materials.

3.6.6.1 "6-wheeled truck"

The truck size is about 2m wide and 5m long, and its height must not exceed 3.8m (following the truck regulation). This kind of a truck can load up to 5 tons or 200 sacks of plastic resins. The 6-wheeled trucks are allowed to drive in Bangkok from 9.00am to 4.00pm and 9.00pm to 6.00am. So in each

day the truck can be used for sending the plastic resins to the customers for about 3 trips: 9.00am-11.20am, 11.20am-2.40pm, and 2.40pm-4.00pm. So one 6-wheeled truck can ship 5*3 = 15 tons per day.

FIGURE 3.10 6-wheeled truck

From Warehouse of Thai Asia Plastic Co.,Ltd. (18 September 2001)

3.6.6.2 "4-wheeled truck" or pick-up truck

The truck size is about 1.8m wide and 5m long, by the height is about 2.5m. This kind of truck can load 2 tons or 80 sacks of plastic resins. The 4-wheeled trucks are allowed to drive in Bangkok all the day. So in each day the truck can be used for sending the plastic resins to the customers for about 5 trips: 8.30am-10.10am, 10.10am- 11.50am, 11.50am-1.30pm, 1.30pm-3.10pm, and 3.10pm-4.50pm. So one 4-wheeled truck can ship 2*5 = 10 tons per day.

PM has to use two 6-wheeled (15*2 = 30 tons) trucks and two 4-wheeled (10*2 = 20 tons) trucks to meet the 50 tons per day shipping level (30+20 = 50 tons).

FIGURE 3.11 4-wheeled truck

From Warehouse of Thai Asia Plastic Co.,Ltd. (18 September 2001)

3.7 Problems of Using TaP's Warehouse

3.7.1 Receiving Problems

3.7.1.1 From Figure 3.2, the receiving area is too small (only 8 m wide and 50 m long). So the receiving activities cannot be done conveniently. The supplier's trucks cannot park in a good direction and the traffic is bad. It is very difficult to do any activities if there are more than 4 trucks on any days.

3.7.1.2 The plastic pallet board size is 1.0m*1.2m that is big and heavy. So it is not appropriate to let the workers carry and put while changing them. The workers can spoil the pallet boards or hurt themselves.

3.7.1.3 The plastic resins sacks 50 sacks per pallet load or 1.25 tons are difficult to check and count.

3.7.2 Put-away Problems

3.7.2.1 The supervisor has to waste time to find a free space for storing the materials.

3.7.2.2 The supervisor tells the lift trucks drivers about the storing position without any instructions for them. So the lift truck drivers may sometime store the materials in a wrong position.

3.7.2.3 The lift trucks have to lift the loaded pallet loads out of the unloading area and put the pallet loads at the side of the supplier's trucks. The area is not spacious enough for staging and sorting the pallet loads before put-away to the storage area.

3.7.3 Storage Problems

3.7.3.1 The pallet length is 1.2m and need another 0.1m more for accessibility. With the warehouse width 50m, it can store 50/1.3 = 38.4 or about 38 rows. The pallet width is 1.0m, so each row can store 17 stacks of pallets along the 17m long of the storage area. Each stack loads 2 pallet loads. So the storage area can store 38*17*2 = 1292 pallet loads. The pallet loads 50 sacks, so there are 1292*50 = 64,600 sacks. Each sacks are 25 kg weight, so the warehouse can store 64,600*25 = 1,615,000 kg = 1615 tons. The TaP's warehouse storage will not be spacious enough for storing the future-estimated amount of 2100 tons of plastic resins of PM. The layout of TaP's warehouse is shown in Figure 3.2.

3.7.3.2 The warehouse stores the materials randomly without any position identification. So it is hard to memorize and find the position of the required grade. This causes less accuracy in storing and picking.

3.7.3.3 The 17 stacks long row is too long to store any materials. If the materials are not so popular (sell less), the honeycombing problem will happen easily.

3.7.3.4 There is no specific place to store the empty pallet boards and park the lift trucks. So after using them the workers will not know where to park the trucks or keep the boards.

3.7.4 Order Picking Problems

3.7.4.1 The supervisor has to waste time to find the position of order picking. First in First out cannot be used because the supervisor forget as to which row is first in and should be first out.

3.7.4.2 There are no picking instructions, so the mistakes can occur easily.

3.7.5 Shipping Problems

3.7.5.1 There is no sortation activity before the shipping trucks return to the shipping area. So time is wasted

3.7.5.2 The shipping area of the warehouse is not appropriate for the shipping activities because it is too big and obstructs the traffic to the receiving area.

CHAPTER 4

OPERATIONAL PROCEDURE DESIGN

4.1 Design Brief

A design brief is the part that collects information and problems from an existing system to make a brief or an introduction for an operational procedure design.

4.1.1 Receiving Design Brief

From the problem of using TaP's warehouse, the receiving area of TaP's warehouse is too small for receiving activities. So the receiving design will be designed to support the receiving level of 77.5 tons or 6 trucks per day that has already been forecasted in Chapter 3.

Pallet boards are big and heavy. It is not appropriate to let the workers manually remove the pallet boards during the receiving activity. The received sacks must be separated on the pallet boards so that it is easier to move and store the materials. So the receiving operation can use the lift trucks to move the pallet boards and pallet loads.

The 50 plastic resins sacks or 1.25 tons per pallet load are difficult to check and count. The separated quantity of the pallet loads will be designed for 1 ton or 40 sacks per pallet load.

4.1.2 Put-away Design Brief

The put-away of the TaP's warehouse wastes time because a supervisor has to find the free space for storing the materials. There is no instruction for the lift truck drivers. So the put-away design must sort the received materials before a put-away operation in the storage area. Moreover, the supervisor has to make the instruction for the lift truck drivers.

The put-away design has to minimize time of the put-away operation by cross-docking the received materials that can cross-dock to the shipping area, and combining put-away and order picking activities together.

4.1.3 Storage Design Brief

The storage of TaP's warehouse is not big enough for the projected inventory level. The storage procedure will be designed to support the inventory level of 2100 tons.

The TaP's warehouse storage stores the materials randomly without having any position identification. So it is hard to memorize and find the position of the required grade. The storage design will use "Fixed Storage" by storing the same material in the same group and fixing the location. And the design has to make the identification for the storage position.

Use "Popularity" by storing the more popular materials in the front section of the storage area with a deep storage and storing the less popular materials in the back section of the storage area with a shallow storage. Use "Similarity" by storing the same type of materials in the same area.

4.1.4 Order Picking Design Brief

The supervisor of TaP's warehouse has to waste time to find the position of order picking. The order picking design has to eliminate the material-searching activity by using the storage identification and a computer to identify the picking position. The supervisor of the order picking design has to sequence the order picking to minimize the travel time.

The TaP's warehouse order picking has no picking instruction so the supervisor of the design has to make the picking instruction for the lift trucks drivers to minimize materials-searching time and errors.

4.1.5 Sortation Design Brief

There is no sortation activity before the shipping trucks come back to the shipping area. So time is wasted. The sortation design will be made for the warehouse design. The sortation is designed given the conditions that each 6-wheeled truck stores 5 tons and each 4-wheeled truck stores 2 tons. The activities must be performed before the shipping trucks return from sending materials. After doing the sortation, the workers can load the plastic resins sacks to the trucks right after the trucks park in the shipping area. The supervisor has to make the sortation instruction for the workers.

4.1.6 Shipping Design Brief

The shipping area of the TaP's warehouse is not appropriate for the shipping activities because the shipping area is too big and obstructs the traffic to the receiving area. The shipping procedure will be designed to support the shipping level of 50 tons per day.

The customer's orders before the shipping day must be shipped at the early trips. The customer's orders on the shipping day must be shipped at the later trips.

4.2 Receiving Design

Receiving is the operation of managing the materials that are received from the suppliers. The receiving will be designed following the receiving design brief.

4.2.1 Steps of Receiving

4.2.1.1 The suppliers' trucks entry the warehouse area in the morning and are driven to the receiving docks area.

As forecasted in Chapter 3, there are about 6 supplier's trucks on each day. The trucks will entry the warehouse area before 6.00am of every working day because it is not allowed to drive a truck in Bangkok after 6.00am. The trucks are driven into the receiving dock area and moved backward to the dock doors. The receiving docks will be designed for receiving up to 6 trucks at the same time. If the trucks are more than 6 trucks at the same time, the excess trucks will be parked at the truck holding area.

4.2.1.2 The dock doors are opened at 8.00am. The truck drivers walk into the office and give the invoices to the supervisor.

The works will start at 8.00am of the day. The workers will open the dock doors at 8.00 am. The 6 truck drivers will walk to the warehouse office. Each truck driver will give the invoice of the shipped materials in his truck to the supervisor.

4.2.1.3 The supervisor checks the invoices.

Before the receiving day, The supervisor has received the information about the sending supplier, sending date, and type, grade and quantity of each

material from his/her head office. The supervisor will compare the invoices with the information from the head office. If the information is not the same, the supervisor has to connect to the head office to confirm the information and return that truck with incorrect-sent materials to the supplier.

4.2.1.4 The workers open the container doors and start to unload the plastic resin sacks.

If the information from the head office is the same as the invoices, the supervisor will go to the receiving area and ask the workers to open the container doors. The workers will start to unload the plastic resins sacks at about 8.05am.

The suppliers' trucks are 2.5 m wide. The standard pallet boards 1.0*1.2 m sizes are used for separating the plastic resins sacks. The used pallet boards will be shown in next part.

Each truck will unload 2.5/1.2 = 2.08 or 2 pallet boards at the same time.

From the calculation above, unloading 2 positions from each truck at the same time is just right for the truck's width.

The lift truck will lift the empty pallet boards to place right behind the back of the trucks at the unloading area by 2 pallet boards per truck to unload 2 position at the same time. Two workers will climb up into the container of the truck while other two workers are on the ground. The two workers on the truck will drop the sacks of plastic resins on to each pallet and the workers on the ground will separate the sacks on the pallet board.

When the materials are unloaded about half of the container, other two workers will climb up into the container of the trucks to help the first two workers drop the plastic resins sacks for reducing the receiving time. So each truck has 6 workers to unload the materials.

4.2.1.5 The workers under the trucks separate the plastic resins sacks on the pallet boards.

The workers will separate the sacks just enough on the pallet boards. The sacks are about 0.4 m wide, 0.6 m long, and 0.2 m thick. So the standard pallet boards with sizes of 1.0*1.2 m^2 are used by separating 5 sacks in each layer, 3 sacks are cross and 2 sacks are straight as shown in Figure 4.1.

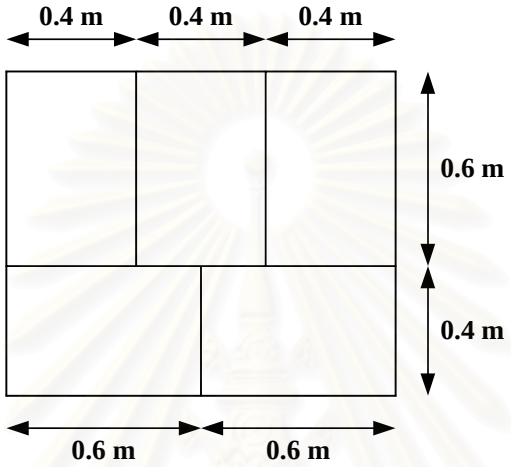


FIGURE 4.1 The Plastic Resins Sacks Separate Method

The workers will separate the plastic resins sacks to the height with which the plastic resins sacks will not fall down when stored in the warehouse.

Each plastic resins sack is about 0.2 m thick. The sacks can be separated alternately in the above layer up to 10 layers or 2-meter height of the total stack, which is the maximum height. (Anasaya Munyukong, interview, September 18, 2001)

However, the workers should separate only 8 layers or 1 tons plastic resins to be easier to check and count. So the lift trucks can lift the plastic resins 1 tons per time. The alternately separate method is shown in Figure 4.2.

4.2.1.6 The workers check the quality while unloading and the supervisor checks the quantity after unloading finish.

While unloading the materials, the workers will check the quality of the plastic resins sacks by looking that whether the sacks are wet or broken. If any sacks are wet or broken, the workers will tell the supervisor. The supervisor will decide whether to receive or return the materials to the suppliers. The type, grade and quantity of the returned materials will be

written into the supplier's invoice. The quality of the plastic resins will not be checked, since they are standardized from the suppliers.

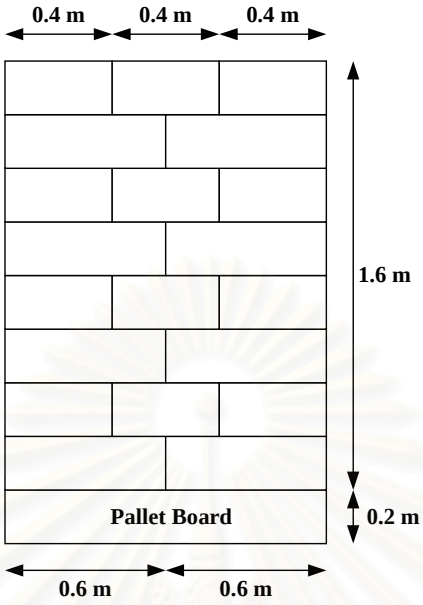


FIGURE 4.2 The Plastic Resins Sacks Layers

The materials are all unitized on the pallet boards. So "Ti*Hi physical manual count method" is appropriate for counting the received plastic resins. Ti means the number of sacks per layer, which are 5 for each pallet board. Hi means the number of layers, which are 8 for each pallet board. So each pallet board will load 40 sacks of plastic resins. (Mulcahy, 1994:4.6) The warehouse supervisor will count the quantity of the received materials from the quantity of the pallet board after the unloading procedures finish. Each delivery truck loads 560 sacks, so there are 14 pallet loads from each truck when there is no return.

4.2.1.7 The workers unload the materials until finish and close the container doors. The supervisor signs the invoices and return the invoice copies back to the truck drivers.

The workers will unload and separate the plastic resins sacks on the pallet loads until finishing all the 14 tons materials.

Each two pallet loads will take about 5 minutes to unload. So the 14 pallet loads will use time to unload 7*5 = 35 minutes to finish.

The workers will close the container doors. The supervisor will sign the invoices and return the invoice copies back to the truck drivers. So this activity will finish around at 8.05+35 = 8.40am.

4.2.1.8 The excess trucks replace the unloaded trucks to start the receiving activities. Until 10.00am, the trucks are allowed to exit the warehouse area.

After the unloading activity is finished, the trucks have to wait until 10.00am to exit the warehouse area following the truck regulation that can be drove in Bangkok after 10.00am. If the delivery trucks are more than 6, the unloaded trucks drivers have to drive the trucks to wait at the truck holding area replace the excess trucks that drive to the dock area.

Each receiving activity takes time 40 minutes. So the receiving activity will start again and finish about 9.20am for the second receiving.

4.2.2 Receiving Invoice

The receiving invoice is the document that the suppliers make for the company to be evidences of materials sent. The detail of receiving invoice includes

- Invoice number
- Supplier's name and address
- The company's name and address
- Sending date, purchasing order number, purchasing order date
- Type, grade, and quantity of each material
- Type, grade, and quantity of the returned material (blank for write after check the quality and quantity of the materials)
- Supplier's authorized signature
- Truck driver's name, truck's registration, and truck driver's signature
- Received (warehouse supervisor)'s signature

TABLE 4-1 Timetable of the receiving activities

Time	Activities
Before 6.00 am	The trucks entry the warehouse.
8.00 am	The dock door is opened.
8.00-8.05 am	Warehouse supervisor checks the invoice. - Type, grade, and quantity of the materials in the invoice are the same with the purchasing department information.
8.05-8.40 am	The workers open the container doors. Unloading the materials. - 2 workers climb up each truck and drop the plastic resins sacks on the pallet boards. - 2 workers are below with the two empty pallet boards and separate the sacks on the pallet boards by 5 sacks in each layer and 8 layers for each pallet load. - Other 2 workers will climb up to help the 2 workers on each truck when unload about half of the container. Quality checking - The workers check the sacks whether wet or broken or not while unloading. - The supervisor will decide to receive or return the unproper plastic resins sacks. Quantity checking - The supervisor checks the quantity by using "Ti*Hi physical manual count method". The supervisor sign on the invoice and return the copy back to the truck drivers.
8.40-9.20 am	The excess of the first 6 trucks are driven to the unloading area.
10.00 am	The trucks exit the warehouse.

4.3 Put-away Design

Put-away is the operation of putting the pallet loads, after the unloading procedure, to the receiving stage area to wait for putting at the storage or the shipping area. The put-away will be designed following the put-away design brief.

4.3.1 Steps of Put-away

4.3.1.1 The lift truck lifts the loaded pallet loads to the receiving stage area.

After the workers unload the sacks and separate on each pallet board, a lift truck has to carry the loaded pallet out of the unloading area and another lift truck will change the empty pallet board to the unloading area. The workers will unload the sacks and separate on the new empty pallet boards. The loaded pallet boards are put on the receiving stage area and sorted into groups of trucks before storing in the storage area to let the lift trucks lift the right pallet loads easily.

4.3.1.2 The supervisor prepare the put-away instruction for the lift truck drivers.

The warehouse supervisor has to prepare the put-away instruction before the sending day. The supervisor checks the storage position of the inventory from the computer, looking at the information of the receiving materials and the information of sending materials from the head office. The supervisor will decide that the receiving materials should store in which zone and which row, or should go to the shipping area by “Cross-dock” concept. (Tompkins et al., 1996: 399) The same type will be stored in the same zone, and the same grade and receiving date will be stored in the same row. The put-away instruction includes the type, grade, and quantity (number of pallet loads) of the receiving plastic resins and place of putting (which zone and row in the storage area or which trucks on the shipping area). The instruction will be printed and sent to the lift trucks drivers.

4.3.1.3 The lift trucks lift the pallet loads from the receiving stage area to the storage area or the shipping area.

If the plastic resins types are the non-polar polymers that cannot dissolve water in the air, “First in First out” is not so strict. When the materials are received, the lift trucks can lift to the shipping area to load and ship to the customers suddenly. Cross-dock is also used in the Just in Time concept. When there is no inventory of the type that has to be sent and this type has just been received, the lift trucks will lift the pallet loads to the shipping area for

loading and shipping to the customers. The lift trucks will lift the pallet loads by following the put-away instruction.

For the polar polymers that can dissolve water in the air (“First in First out” is strict) and non-polar polymers that do not have any shipping to the customers, the lift trucks will lift the pallet loads from the receiving stage area to the storage zone and row by following the put-away instruction.

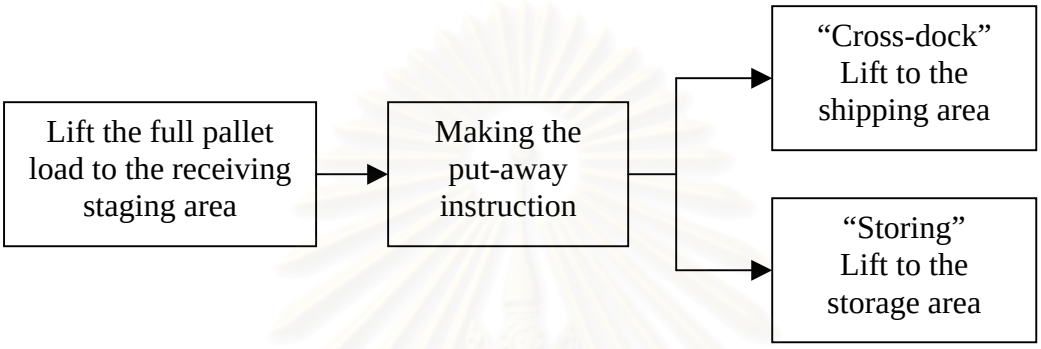


FIGURE 4.3 Put-away diagrams

4.3.2 Put-away Instruction

Put-away instructions are made by the supervisor to give the lift truck drivers know where to put-away the pallet loads. Put-away instructions include

- The put-away instruction for which lift truck (1, 2, 3, or 4)
- Sequence of lifting (1, 2, 3, 4, 5, …)
- Position of the lifting on the receiving stage area (1, 2, 3, 4, 5, or 6)
- Type, grade, and quantity of the plastic resins
- Position of putting-away (the storage area or shipping area)
    - Zone, row, and pallet load in the storage area
    - Position of the shipping truck in the shipping area (1, 2, 3, or 4)

The put-away instruction example is shown in Table 4-2.

TABLE 4-2 The Put-away Instruction Example

ThePut-away instruction for "Lift truck 1 "								
Sequence	**Lifting Position**	**Materials**			**Putting Position**			
		Type	**Grade**	**Tons**	**Zone**	**Row**	**Stack**	**Shipping Truck**
1 and 2	Supplier truck 6	PP Film	PD943	2.000	1	15	1	N/A
3 to 6	Supplier truck 6	PP Film	PD943	4.000	N/A	N/A	N/A	6-wheeled truck 1
7 to 14	Supplier truck 6	PP Film	PD943	8.000	1	15	4	N/A
1 to 14	Supplier truck 5	LDPE	L1905 F	14.000	3	6	5	N/A

4.4 Storage Design

Storage is the operation of storing the pallet loads in the storage area. The storage will be designed following the storage design brief.

4.4.1 Storage Method

The materials that will be stored in the warehouse are unitized in the form of pallet loads. The floor stack is appropriate for storing the pallet loads because it is the most convenient and cheapest storage method. So the storage method of the warehouse will use the floor stack of the pallet loads.

The maximum stack height of the pallet loads to ensure that the plastic resins sacks will not fall down when stored in the warehouse is 2 and half levels of the 10 layers pallet loads or (2.5*2)+(3*0.2) = 5.6 m. (Anasaya Munyukong, interview, September 18, 2001)

So the 8 layers pallet loads can be designed for 5.6/(1.6+0.2) = 3.11 or 3 levels.

4.4.2 Zone Dividing

The zone dividing in the storage area will use the principle of popularity by storing the more popular materials in the front of the storage area with deep storage and storing the less popular materials in the back of the storage area with shallow storage. The zone in the storage area can be divided into two main zones, the front zone and the back zone.

4.4.2.1 Front zone

The front zone is the zone at the front of the warehouse near the receiving and shipping dock. It is used for storing the more popular or the large amount of sales materials. So the materials that are stored in the front zone are PP Film and PP Inject, which have the inventory level of 441 and 420 tons respectively. Front zone will store the materials with deep storage rows. So storing 2 receiving trucks or 28 tons per row for easier to count, store, retrieve, and check. Each stack loads 3 levels or 3 tons, so each row consists of 28/3 = 9.33 or 10 stacks. The front zone can be divided into sub zone using the principle of similarity by storing the same type of materials in the same area.

- **PP Film** is the largest sale product in each month. This type of materials will be the most received and shipped on each day. PP Film must be placed nearest to the receiving and shipping dock. So storing PP Film at the left side when looking toward the warehouse, and naming it Zone 1. Zone 1 has to be designed for storing the maximum amount of PP Film, 441 tons. Each row will store 28 tons, so there are 441/28 = 15.75 or 16 rows of stacks. Zone 1 is designed to have an aisle in the middle and the space for 8 rows of stacks in the left and the right side to allow the lift trucks to be able to access to store or retrieve the pallet loads. The same grade of plastic resins will be stored in the same row, but the position of row will be random for storing flexibility.
- **PP Inject** is the second largest sale product in each month. This type of materials will be the second most received and shipped on each day. PP Inject must be placed near the receiving and shipping dock next to Zone 1. So storing PP Inject at the right side when looking toward the warehouse, and naming it Zone 2. Zone 2 has to be designed for storing the maximum amount of PP Inject, 420 tons. Each row will store 28 tons, so there are 420/28 = 15 rows of stacks. Zone 2 is designed to have an aisle in the middle and the space for 8 rows of stacks in the left and 7 rows in the right side to allow the lift trucks to be able to access to store or retrieve the pallet loads. The same grade of plastic resins will be stored in the

same row, but the position of row will be random for storing flexibility.

4.4.2.2 Back zone

The back zone is the zone at the back of the warehouse far from the receiving and shipping dock. It is used for storing the less popular or the small amount of sales materials. So the materials that are stored in the back zone are the rest 6 types of materials. Back zone will store the materials with shallow storage rows. So storing 1 receiving truck or 14 tons per row for easier to count, store, retrieve, and check. Each stack loads 3 levels or 3 tons, so each row consists of 14/3 = 4.66 or 5 stacks. The back zone can be divided into sub zone using the principle of similarity by storing the same type of materials in the same area.

- **GPPS** is the fourth smallest sale product in each month. This type of materials will be the fourth least received and shipped on each day. The maximum amount of GPPS is 210 tons. Each row will store 14 tons, so there are 210/14 = 15 rows of stacks.
- **LDPE** is the smallest sale product in each month. This type of materials will be the least received and shipped in each day. The maximum amount of LDPE is 105 tons. Each row will store 14 tons, so there are 105/14 = 8 rows of stacks.

GPPS and LDPE can be stored together. They are the fourth least and the least received and shipped on each day. They must be set farthest from the receiving and shipping dock. So storing them at the left side when looking toward the warehouse, and naming it zone 3. Zone 3 is designed to have an aisle in the middle and 8 rows of stacks in the inside left for LDPE, 3 rows of stacks in the outside left for GPPS, and 12 rows of stacks in the right side for GPPS to allow the lift trucks to be able to access to store or retrieve the pallet loads. The same grade of plastic resins will be stored in the same row, but the position of row will be random for storing flexibility.

- **PP Yarn** is the third largest sale product in each month. This type of material will be the third most received and shipped in each day. PP Yarn must be placed near the receiving and shipping dock next

to Zone 1 and Zone 2. So storing PP Yarn at the middle-left side when looking toward the warehouse, and naming it Zone 4. Zone 4 has to be designed for storing the maximum amount of PP Yarn, 294 tons. Each row will store 14 tons, so there are 294/14 = 21 rows of stacks. Zone 4 is designed to have an aisle in the middle and the space for 10 rows of stacks in the left and 11 rows in the right side to allow the lift trucks to be able to access to store or retrieve the pallet loads. The same grade of plastic resins will be stored in the same row, but the position of row will be random for storing flexibility.

- **HDPE** is the third largest sale product in each month. This type of material will be the third most received and shipped in each day. HDPE must be placed near the receiving and shipping dock next to Zone 1 and Zone 2. So storing HDPE at the middle-right side when looking toward the warehouse, and naming it Zone 5. Zone 5 has to be designed for storing the maximum amount of HDPE, 294 tons. Each row will store 14 tons, so there are 294/14 = 21 rows of stacks. Zone 4 is designed to have an aisle in the middle and the space for 11 rows of stacks in the left and 10 rows in the right side to allow the lift trucks to be able to access to store or retrieve the pallet loads. The same grade of plastic resins will be stored in the same row, but the position of row will be random for storing flexibility.

- **HIPS** is the second smallest sale product in each month. This type of material will be the second least receive and ship in each day. The maximum amount of HIPS is 168 tons. Each row will store 14 tons, so there are 168/14 = 12 rows of stacks.

- **ABS** is the second smallest sale product in each month. This type of material will be the second least receive and ship in each day. The maximum amount of ABS is 168 tons. Each row will store 14 tons, so there are 168/14 = 12 rows of stacks.

HIPS and ABS can be stored together. They are the second least received and shipped in each day. They must be set farthest from the receiving and shipping dock. So storing them at the right side when looking toward the warehouse, and naming it zone 6. Zone 6 is designed to have an aisle in the middle and 12 rows of stacks in the left for HIPS and 12 rows of stacks in the right side for ABS to allow the lift trucks to be able to access to store or retrieve the pallet loads. The same grade of plastic resins will be stored in the same row, but the position of row will be random for storing flexibility.

4.4.3 Zone Identification

Zone, row, and stack numbers must be identified to show the lift truck drivers while storing and picking the materials, and to show the supervisor while checking the inventory.

The zones are identified by hanging the plastic labels on the ceiling to show the numbers of the zones, Zone 1 to Zone 6.

The rows are identified by sticking the plastic label to the wall to show the numbers of the rows. Zone 1 has Row 1 to Row 16. Zone 2 has Row 1 to Row 15. Zone 3 has Row 1 to Row 23. Zone 4 has Row 1 to Row 21. Zone 5 has Row 1 to Row 21. Zone 6 has Row 1 to Row 24.

The stacks are identified by using the color to make an area 1.0*1.2 m equal to the pallet loads size and writing the stack numbers on the floor. The front zone has 10 stacks per row and the back zone has 5 stacks per row. The truck drivers and the supervisor will know the number of stack by look at the floor.

The summary of the zone is shown in Table 4-3

4.4.4 Steps of Storing

4.4.4.1 The lift trucks lift the pallet loads to store in the storage area.

The lift trucks will lift the pallet loads from the receiving stage area to store in the correct zone and row following the put-away instruction.

4.4.4.2 The supervisor keep the information in the computer.

After storing the pallet loads, the supervisor will keep the information of type, grade, quantity (sacks and pallet loads), storing zone, storing row, and

receiving date in the computer. With this information, the supervisor can know the storing position of every plastic resins grade. So the supervisor will know where the new received materials should be stored and where the customer orders should be picked.

TABLE 4-3 Zone Summaries

Zone	Position	Type of Plastic resins	Tons	Rows	Stacks/row
Front 1	Left side	PP Film	441	16	10
Front 2	Right side	PP Inject	420	15	10
Back 3	Left side	LDPE	105	8	5
		GPPS	210	15	5
Back 4	Middle-left side	PP Yarn	294	21	5
Back 5	Middle-right side	HDPE	294	21	5
Back 6	Right side	HIPS	168	12	5
		ABS	168	12	5

4.4.5 Inventory Checking

The inventory checking will occur at the end of each day. The supervisor will print the position of every grade of plastic resins, go counting by looking at the stacks identification on the floor at every zone and row, and compare whether they are the same or not. After the inventory checking finishes, the supervisor will use the position of the plastic resins to prepare the put-away instruction and the order picking instruction for the lift truck drivers to use in the storing and shipping on the next day. The amount quantity of every plastic resins grade will be sent to the head office for planning the purchase and sales activity on the next day.

4.5 Order Picking Design

Order picking is the operation of picking the pallet loads from the storage area or the receiving stage area to the shipping area. The order picking will be designed following the order picking design brief.

4.5.1 Steps of Order Picking

4.5.1.1 The supervisor receives the customer orders and plan for sending.

After the supervisor receives the customer orders from the head office, he/she will plan for the sequence and routing of sending the plastic resins to the customers. (This plan is not concerned in this research.)

4.5.1.2 The supervisor plans the sequence of order picking.

At the first shipping trip, the two 6-wheeled trucks and the two 4-wheeled trucks have been at the shipping docks already since the last trips of the previous day work. The order picking is done for shipping 4 trucks. If the truck has to send the products more than one customer, the plastic resin grades of the customer to whom the products will be sent the last must be loaded into the container of the truck first. This is because, when the lift truck carries the order picking grade of the last customer to the shipping area, the worker can separate this grade at the most inside of the truck. Consequently, the orders of the first customer should be picked last. But if the truck has to send the products to only 1 customer, the sequence is not strict.

At the other shipping trips, the trucks have not returned from sending the materials yet. The order picking is done for sorting to let the shipping do immediately when the trucks are back. So the order picking will be done before the shipping trucks return. If the truck has to send the products more than one customers, the plastic resins grades of the first sending customer must be picked first because when the lift truck lifts the order picking grade of the first sending customer to the sortation area, the workers can separate this grade at the most bottom of the sortation stack. By the order of the last sending customer should be picked last. The workers can separate this order at the most top of the sortation stack. So when the truck returns to the shipping area, the worker can separate the first sending customer orders at the most inside of the truck and separate the last sending customer orders at the most outside of the truck. But if the truck has to send the products only 1 customer, the sequence is not strict.

4.5.1.3 The supervisor plans for the position of order picking.

The supervisor will plan for the position of order picking whether from the receiving stage area or the storage area. The picking from the storage area will be picked from the row of the materials received earliest of the picked grade (the earliest receiving date) for First in First out.

4.5.1.4 The supervisor makes the picking instruction.

The supervisor will make the picking instruction by using the sequence and picking position plans. The picking instruction includes the sequence of picking; the type, grade, and quantity of plastic resins; the zone, row, and pallet load quantity position; and the position of truck in the shipping or sortation area. The picking instruction will be printed and sent to the lift truck drivers.

4.5.1.5 The lift trucks pick the materials follow the picking instruction.

After receiving the picking instruction, the drivers will drive the lift trucks to lift the pallet loads following the picking instruction to the shipping or sortation position of each truck.

4.5.2 Customer Orders

The customers will order the materials to the head office via the sales representatives, and the head office will send the information of customer's name and address, grades, types, and quantity of the plastic resins, and the sending date to the warehouse department. The customer order can be divided into two kinds.

4.5.2.1 Order before the sending day The customers order the plastic resins before the sending day, so the supervisor can plan for order picking, sortation, and shipping at the end of the day before the sending day. This kind of the order will be shipped on the early trips.

4.5.2.2 Order at the sending day The customers order the plastic resins at the sending day, so the supervisor has to plan for order picking, sortation, and shipping at the sending day. This kind of the order will be shipped on the afternoon trips.

4.5.3 Picking Instruction

The 6-wheeled trucks can be used for sending the plastic resins to the customers for about 3 trips: 9.00am-11.20am, 11.20am-2.40pm, and 2.40pm-4.00pm and the 4-wheeled trucks are allowed to drive in Bangkok all the day. So on every working day the truck can be used for sending the plastic resins to the customers for about 5 trips: 8.30am-10.10am, 10.10am- 11.50am, 11.50am-1.30pm, 1.30pm-3.10pm, and 3.10pm-4.50pm. So the picking instruction must done 5 times per day. The example of picking instruction is shown in Table 4-4.

4.5.3.1 The first picking instruction

The first picking instructions must be made before the picking day to give to the lift truck drivers before the shipping of the first trip starts. The first picking instructions will be made for the first shipping of the two 6-wheeled and two 4-wheeled trucks. So there are 4 picking instructions for the first. The supervisor has to plans the sequence of shipping activities and makes them to be the sequence of picking instruction. The position of the first trip can be in the storage area or the receiving stage area. The first picking instructions include

- The picking instruction for which lift truck (1, 2, 3, or 4)
- Sequence of picking (1, 2, 3, 4, 5, …)
- Position of picking (the storage area or receiving stage area)
    - Zone, row, and pallet load in the storage area
    - Position of the receiving on the receiving stage area
- Type, grade, and quantity of the plastic resins
- Position of shipping truck in the shipping area (1, 2, 3, or 4)
- The left of plastic resins sacks on the loaded pallet load

If there are plastic resin sacks left on the loaded pallet load, the drivers will drive the lift trucks to lift the pallet loads to the loaded pallet load stage area to wait for storing in the picking position. If there is no plastic resin sack left on the loaded pallet load, the drivers will drive the lift trucks to lift the empty pallet board to the empty pallet board storage.

In this first picking instruction, the put-away instruction must be concerned because the put-away and order picking are combined. The lift trucks will lift the full pallet load to store in the storage and lift the order picking from the storage to the shipping area. So put-away instruction and picking instruction must be sequent.

4.5.3.2 The second picking instruction

The second picking instructions must be made before 10.10am of the picking day to give to the lift truck drivers before the first trip of the 4 shipping trucks return. The second picking instructions will be made for the first sortation of the two 6-wheeled and two 4-wheeled trucks. So there are 4 picking instructions for the second. The supervisor has to plan the sequence of sortation activities and makes them to be the sequence of picking instruction. The second picking instructions include

- The picking instruction for which lift truck (1, 2, 3, or 4)
- Sequence of picking (1, 2, 3, 4, 5, …)
- Position of picking in the storage area
    - Zone, row, and pallet load in the storage area
- Type, grade, and quantity of the plastic resins
- Position of shipping truck in the sortation area (1, 2, 3, or 4)
- The left of plastic resins sacks on the loaded pallet load

If there are plastic resin sacks left on the loaded pallet load, the lift trucks will lift the left loaded pallet load back to store in the storage before picking the new pallet load to the sortation area. If there is no plastic resins sack left on the loaded pallet load, the lift trucks will lift the empty pallet board to the empty pallet board storage.

4.5.3.3 The third picking instruction

The third picking instructions must be made before 11.50am of the picking day to give to the lift truck drivers before the second trip of the 4 shipping trucks return. The third picking instructions will be made for the second sortation of the two 6-wheeled and two 4-wheeled trucks. So there are

4 picking instructions for the third. The supervisor has to plan the sequence of sortation activities and makes them to be the sequence of picking instruction. The third picking instructions include

- The picking instruction for which lift truck (1, 2, 3, or 4)
- Sequence of picking (1, 2, 3, 4, 5, …)
- Position of picking in the storage area
    - Zone, row, and pallet load in the storage area
- Type, grade, and quantity of the plastic resins
- Position of shipping truck in the sortation area (1, 2, 3, or 4)
- The left of plastic resins sacks on the loaded pallet load

If there are plastic resin sacks left on the loaded pallet load, the lift trucks will lift the left loaded pallet load back to store in the storage before picking the new pallet load to the sortation area. If there is no plastic resins sack left on the loaded pallet load, the drivers will drive the lift trucks to lift the empty pallet board to the empty pallet board storage.

4.5.3.4 The fourth picking instruction

The fourth picking instructions must be made before 1.30pm of the picking day to give to the lift truck drivers before the third trip of the two 4-wheeled trucks return. The fourth picking instructions will be made for the third sortation of the two 4-wheeled trucks. So there are 2 picking instructions for the fourth. The supervisor has to plan the sequence of sortation activities and makes them to be the sequence of picking instruction. The fourth picking instructions include

- The picking instruction for which lift truck (1 or 2)
- Sequence of picking (1, 2, 3, 4, 5, …)
- Position of picking in the storage area
    - Zone, row, and pallet load in the storage area
- Type, grade, and quantity of the plastic resins
- Position of shipping truck in the sortation area (1 or 2)

- The left of plastic resins sacks on the loaded pallet load

If there are plastic resin sacks left on the loaded pallet load, the drivers will drive the lift trucks to lift the left loaded pallet load back to store in the storage before picking the new pallet load to the sortation area. If there is no plastic resins sack left on the loaded pallet load, the lift trucks will lift the empty pallet board to the empty pallet board storage.

4.5.3.5 The fifth picking instruction

The fifth picking instructions must be made before 3.10pm of the picking day to give to the lift truck drivers before the fourth trip of the two 4-wheeled trucks return. The fifth picking instructions will be made for the fourth sortation of the two 4-wheeled trucks. So there are 2 picking instructions for the fifth. The supervisor has to plan the sequence of sortation activities and makes them to be the sequence of picking instruction. The fifth picking instructions include

- The picking instruction for which lift truck (1 or 2)
- Sequence of picking (1, 2, 3, 4, 5, …)
- Position of picking in the storage area
    - Zone, row, and pallet load in the storage area
- Type, grade, and quantity of the plastic resins
- Position of shipping truck in the sortation area (1 or 2)
- The left of plastic resins sacks on the loaded pallet load

If there are plastic resin sacks left on the loaded pallet load, the lift trucks will lift the left loaded pallet load back to store in the storage before picking the new pallet load to the sortation area. If there is no plastic resins sack left on the loaded pallet load, the lift trucks will lift the empty pallet board to the empty pallet board storage.

TABLE 4-4 The Picking Instruction Example

The First Picking Instruction for "Lift truck 1 "									
Sequence	Picking Position				Materials				Shipping Truck
	Zone	Row	Stack	Supplier Truck	Type	Grade	Tons	Left	
1	3	23	3	N/A	GPPS	GP110	1.000	0.000	4-wheeled truck 1
2	3	23	3	N/A	GPPS	GP110	1.000	0.000	4-wheeled truck 1
3	N/A	N/A	N/A	Supplier truck 6	PP Film	PD943	1.000	0.000	6-wheeled truck 1
4	N/A	N/A	N/A	Supplier truck 6	PP Film	PD943	1.000	0.000	6-wheeled truck 1
5	N/A	N/A	N/A	Supplier truck 6	PP Film	PD943	1.000	0.000	6-wheeled truck 1
6	N/A	N/A	N/A	Supplier truck6	PP Film	PD943	1.000	0.800	6-wheeled truck 1
7	5	1	3	N/A	HDPE	GA3750	1.000	0.000	6-wheeled truck 1

4.6 Sortation Design

Sortation is the operation of sorting the pallet loads to wait for the shipping trucks at the sortation area. The sortation will be designed following the sortation design brief.

4.6.1 Steps of Sortation

4.6.1.1 The supervisor makes the sortation instruction.

The supervisor will make the sortation instruction following the picking instruction. The sortation instruction includes sequence, type, grade, and quantity of the plastic resins of the customer orders. The instruction is printed and sent to the workers at the sortation area.

4.6.1.2 The workers sort the materials follow the sortation instruction at the sortation area.

After the workers receive the sortation instruction, the workers will sort the materials for each truck. The workers will be at the sortation area with two workers for each truck position (4 trucks).

The 4-wheeled trucks can load 2 tons of plastic resins by separating 4 sacks per layer on the truck (that will be shown in next part), so they are separated in 4 sacks per each layer and the sortation stacks are 10 layers height with 2 stacks per truck to be easier to separate on the shipping truck.

For the 6-wheeled trucks, they can load 5 tons of plastic resins by separating 5 sacks per layer on the truck (that will be shown in next part), so

they are separated in 5 sacks per each layer and the stacks are 10 layers height with 2 stacks per truck to be easier to separate on the shipping truck.

4.6.2 Sortation Instruction

Sortation instruction is made for the workers to know the information of the order picking before sorting. So the sortation instruction is the same as the picking instruction for sortation or the second to fourth picking instruction. But the sortation instruction will include only

- The sortation instruction for which truck (1, 2, 3 or 4)
- Sequence of picking (1, 2, 3, 4, 5, …)
- Type, grade, and quantity of the plastic resins
- Position of shipping truck in the sortation area (1, 2, 3 or 4)

The example of the sortation instruction is shown in Table 4-5.

TABLE 4-5 The Sortation Instruction Example

The First Sortation Instruction for "4-wheeled truck 1"					
Sequence	**Materials**				**Shipping Truck**
	Type	**Grade**	**Tons**	**Left**	
1	LDPE	JJ4324	1.000	0.000	4-wheeled truck 1
2	LDPE	JJ4324	1.000	0.000	4-wheeled truck 1

4.7 Shipping Design

Shipping is the operation of loading the pallet loads to the trucks at the shipping area. The shipping will be designed following the shipping design brief.

4.7.1 Steps of Shipping

4.7.1.1 The supervisor prints the invoices for the shipping truck drivers to give to the customers.

The supervisor will print the invoices of each customer order to the shipping truck drivers. The drivers will send the invoice to the customers when the materials are sent.

4.7.1.2 The workers load the plastic resins sacks to the shipping trucks.

The plastic resins sacks from the order picking or sortation will be loaded to the trucks. Each truck will have 1 worker on the truck to separate the sacks and 1 worker below to send the sacks for the worker on the truck.

On each 4-wheeled truck can load 2 tons, the sacks are separated by about 4 sacks*5 sacks*4 sacks (W*L*H) to fit with the size of the truck.

On each 6-wheeled truck can load 5 tons, the sacks are separated by about 5 sacks*5 sacks*8 sacks (W*L*H) to fit with the size of the truck.

Each 4-wheeled truck needs 4 workers and 1 driver to send the materials to the customers. At the customer's warehouse, two workers will unload the sacks and other two workers will bring the sacks to the storage. Each 6-wheeled truck needs 6 workers and 1 driver to send the materials to the customers. At the customer's warehouse, two workers will unload the sacks and other four workers will bring the sacks to the storage. (The outbound logistics is not considered in this research.)

4.7.1.3 The shipping truck drivers check the sequence, quantity, and quality of the plastic resins sacks.

The drivers that receive the invoices from the supervisor will respond for this activity. Each driver will look at the sequence of the materials orders that the workers ship, count the sacks, and check whether the sacks are broken or wet. If any sacks are broken or wet, the driver will tell the workers to change those sacks.

4.7.1.4 The supervisor updates the inventory level.

The supervisor will erase the type, grade, and quantity that already print the invoices from the zone and row of picking in the computer. So the information in the computer will show only the inventory that left in the warehouse.

4.7.2 Shipping Invoice

The shipping invoice is the document that the company makes for the customer to be an evidence of materials sending. The detail of the shipping invoice includes

- Invoice number
- The company's name and address
- Customer's name and address
- Sending date, purchasing order number, purchasing order date
- Credit term and due date
- Type, grade, quantity, and price of each material
- The company's authorized signature
- The customer's signature

CHAPTER 5

MATERIAL HANDLING SYSTEM

AND PHYSICAL DESIGN

5.1 Material Handling System Design

The designing of material handling system is about using any systems to support the operational design. The material handling system that will be designed consists of two parts, material handling equipment and material handling employees.

5.1.1 Material Handling Equipment

5.1.1.1 Containers and Unitizing Equipment

The operation of material handling in the warehouse will be in the form of unit loads for easier to move, store, and control. PM will use the pallet boards to be the support devices of the unit loads, which is mentioned before in Chapter 4. The workers will separate 5 sacks in each layer, 3 sacks are cross and 2 sacks are straight and separate alternate in the above layer for 8 layers. So each pallet load loads 40 sacks or 1 ton of plastic resins.

5.1.1.1.1 Pallet characteristics

The pallet that will be used in PM's warehouse is the plastic pallet board because the plastic is strong and durable while the wood is easy to break and the broken wood can cause sacks to tear. The size of the pallet board is 1.0 * 1.2 m for just enough for 5 plastic resins sacks per layer. The plastic pallet board will be about 0.2 m thick and have a two-way entry at the side of 1.2 m. So the fork of the lift truck will insert to the 1.0 m.

5.1.1.1.2 Pallet quantity

The quantity of the pallet boards must be enough for the maximum inventory level, which is 2100 tons. Each pallet load loads 1 ton, so the quantity of the pallet board is 2100 boards.

5.1.1.2 Material Transport, Storage, and Retrieval Equipment

The transportation, storing, and retrieving of the unit loads will use the same equipment to do for the ability to replace each other. The equipment has to load the pallet loads to transport in both horizontal and vertical. Each pallet load loads l000 kg of plastic resins sacks, so the equipment has to load 1000 kg plus the pallet load weight. The storage is 3-pallet loads high stack. Each pallet load is high 1.8 m (8 layers plus the pallet board thick), so the equipment has to lift higher than the second pallet load of the stack to store the third pallet load or higher than 1.8*2 = 3.6 m. So the transport equipment that will be used in the warehouse will be the "Counterbalanced Lift Truck". This kind of lift truck is a very maneuverable and versatile pallet-handling vehicle. It is the intermediate-lift vehicle that can lift the pallet load up to 4.8-5.4 m. It can lift the pallet load 900-1800 kg. (Mulcahy, 1994: 10.3) It is the Wide-Aisle lift truck that needs the space 3.6-3.9 m-wide aisles to operate (Mulcahy, 1994: 3.9). This kind of lift truck is also called forklift, since it uses the forks to lift the pallet load. The "Counterbalanced Lift Truck" is shown in Figure 5.1.

FIGURE 5.1 Counterbalanced Lift Truck

From Warehouse of Thai Asia Plastic Co., Ltd. (18 September 2001)

5.1.2 Material Handling Employee

The employees in the warehouse are divided by the jobs as following.

5.1.2.1 Supervisor

The supervisor acts as a manger of the warehouse that will be designed to require two supervisors.

5.1.2.1.1 Receiving and storing supervisor

Receiving and storing supervisor is the supervisor that takes care of the receiving and storing in the warehouse; which includes planning for the receiving and storage position, making the instruction documents for the lift trucks drivers, and checking and controlling the quantity and quality of the received plastic resins. Moreover, this supervisor has to update and check the inventory in the warehouse.

5.1.2.1.2 Shipping supervisor

Shipping supervisor is the supervisor that takes care of the customer orders; which includes planning for the type and quantity of the customer orders, planning for the trip and route of delivery truck, planning for the sequence and picking position of the customer orders, making the instruction documents for the lift trucks drivers, and checking and controlling the quantity and quality of the shipping plastic resins.

5.1.2.2 Unloading workers

The unloading workers are the workers that response to unload the receiving materials in the morning. As designed in Chapter 4 before, each truck has 6 workers to unload the materials (4 workers are on the truck and 2 workers separate the plastic resins sacks). There are 6 trucks in the operation, so using 36 workers in this job.

5.1.2.3 Lift trucks drivers

That will be designed in next part, the designed warehouse uses 4 lift trucks, so it needs 4 lift trucks drivers. The lift truck drivers will lift the pallet load to any positions by following the instruction documents.

5.1.2.4 Delivery trucks drivers

Delivery truck drivers are responsible to control the plastic resins along the trips and drive the delivery trucks to send the products to the customers. The delivery

trucks are designed to have 4 trucks, two 4-wheeled trucks and two 6-wheeled trucks. So PM needs 4 trucks drivers.

5.1.2.5 Loading workers

The loading workers are responsible to load the plastic resins sacks to the delivery trucks. As designed before in Chapter 4, each truck needs 2 workers to load the products (one on the truck and one on the ground right behind the truck). So PM needs 2*4 = 8 workers to load the products to the trucks for the first trip.

5.1.2.6 Sorting workers

These workers will sort the plastic resins to prepare the products for loading before the delivery trucks come back. As designed before in Chapter 4, this activity uses 2 workers for each truck position. However, these workers are those from the unloading activities that already finish their job.

5.1.2.7 Customer service workers

The customer service workers are the workers who go with the delivery trucks to unloading the plastic resins for the customers. Each 4-wheeled truck needs 4 workers and each 6-wheeled truck needs 6 workers. For the 4-wheeled truck, the 4 workers are those from the 2 loading workers at the truck position and another 2 workers. So the two 4-wheeled trucks need another 4 workers to go with them. For the 6-wheeled truck, the 6 workers are those from the 2 loading workers at the truck position and another 4 workers from the unloading activities that already finish their job. So the 6-wheeled trucks do not need more workers to operate the job.

In conclusion, the designed warehouse needs 2 supervisors, 4 lift trucks drivers, 4 trucks drivers, and 48 (36+8+4) workers. The workers are not fixed with one certain job but change through the day.

TABLE 5-1 Employee summary

Jobs	Employees	Notes
Supervisor	2	
Unloading worker	36	
Lift truck driver	4	
Delivery truck driver	4	
Loading worker	8	
Sorting worker	8	All is from the unloading workers
Customer service worker	20	8 are from the loading workers
		Other 8 are from the unloading workers
Summary	82	Need 58 workers to work for the warehouse

5.2 Physical Design

5.2.1 Inside the Warehouse

5.2.1.1 The Space for Storage

As designed before in Chapter 4, the storage area is divided into a back zone and a front zone.

5.2.1.1.1 Back zone

The back zone is the zone at the back of the warehouse far from the receiving and shipping dock. It is used for storing the less popular materials or the small amount of sales materials. The back zone will store the materials with shallow storage rows. Store 14 tons per row. Each stack loads 3 levels or 3 tons, so each row consists of 14/3 = 4.66 or 5 stacks. The back zone can be divided into 4 sub zones.

1. **Zone 3** is at the left side of the warehouse. It is used for storing LDPE and GPPS. Layout of Zone 3 is shown in Figure 5.2.

- LDPE needs 8 rows. Store LDPE in the inside left.
- GPPS needs 15 rows. Store GPPS in the outside left 3 rows and in the right 12 rows.

- Each pallet board is 1.0 m wide, storing 5 stacks per row. So each row is 5 m long.
- The aisle in the middle must be large enough for the counterbalanced lift trucks, so designing 3.6 m for the picking aisle. (Mulcahy, 1994: 3.9)
- The pallet board is long 1.2 m. The space between two pallet loads of wide aisle equipment is 0.2 m (Mulcahy, 1994: 3.9). There are 12 rows for the longest of the zone. So there are 13 spaces for 12 rows. The zone is (1.2*12) + (0.2*13) = 17 m long.

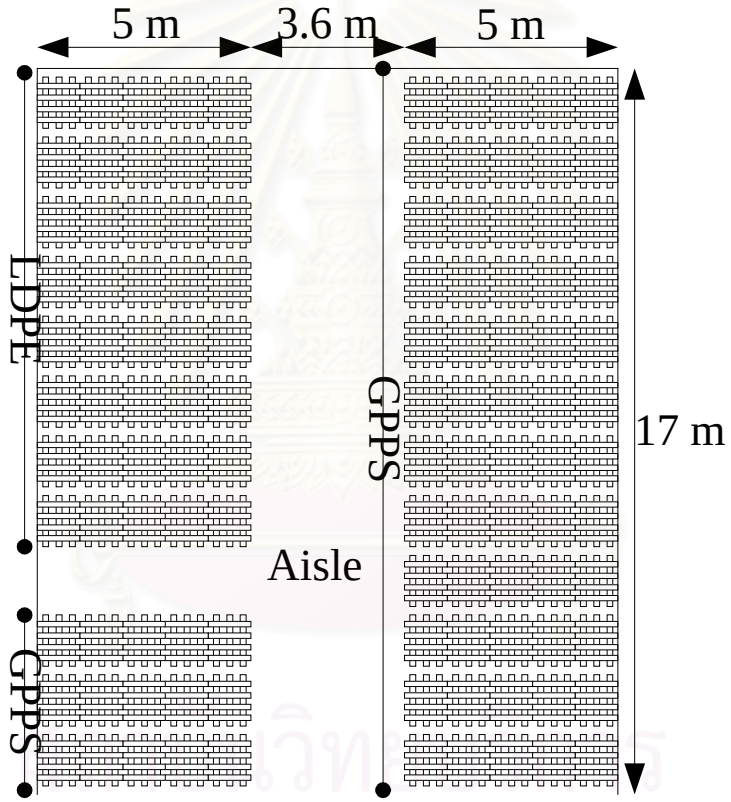


FIGURE 5.2 Layout of Zone 3

2. **Zone 4** is at the middle-left side of the warehouse. It is used for storing PP Yarn. Layout of Zone 4 is shown in Figure 5.3.

- PP Yarn needs 21 rows. Store PP Yarn 10 rows in the left and 11 rows in the right.
- Each pallet board is 1.0 m wide, storing 5 stacks per row. So each row is 5 m long.

- The aisle in the middle must be large enough for the counterbalanced lift trucks, so designing 3.6 m for the picking aisle. (Mulcahy, 1994: 3.9)
- The pallet board is 1.2 m long. The space between two pallet loads of wide aisle equipment is 0.2 m (Mulcahy, 1994: 3.9). There are 11 rows for the longest of the zone. So there are 12 spaces for 11 rows. The zone is (1.2*11) + (0.2*12) = 15.6 m long.

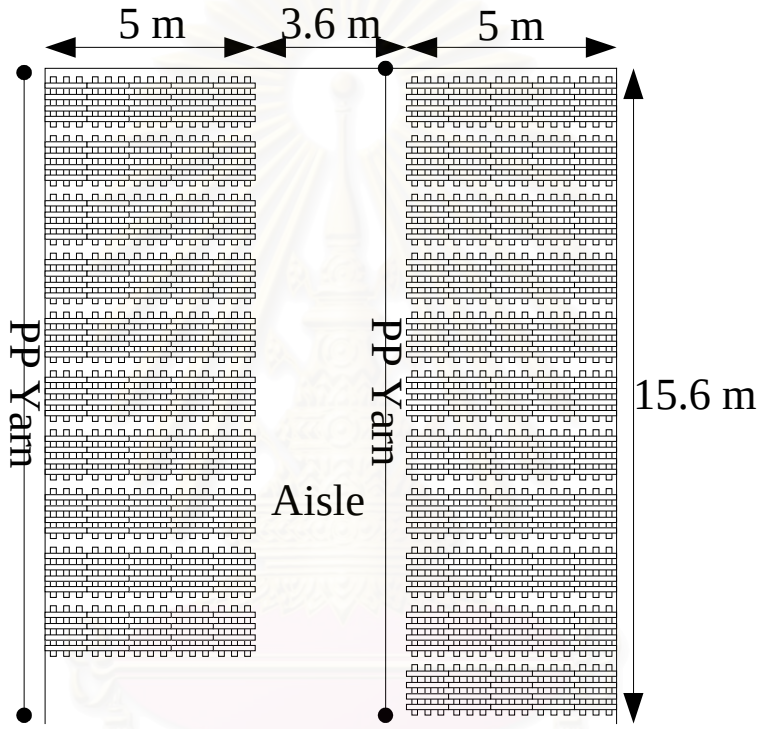


FIGURE 5.3 Layout of Zone 4

3. **Zone 5** is at the middle-right side of the warehouse. It is used for storing HDPE. Layout of Zone 5 is shown in Figure 5.4.

- HDPE needs 21 rows. Store HDPE 11 rows in the left and 10 rows in the right.
- Each pallet board is 1.0 m wide, storing 5 stacks per row. So each row is 5 m long.
- The aisle in the middle must be large enough for the counterbalanced lift trucks, so designing 3.6 m for the picking aisle. (Mulcahy, 1994: 3.9)

- The pallet board is 1.2 m long. The space between two pallet loads of wide aisle equipment is 0.2 m (Mulcahy, 1994: 3.9). There are 11 rows for the longest of the zone. So there are 12 spaces for 11 rows. The zone is (1.2*11) + (0.2*12) = 15.6 m long.

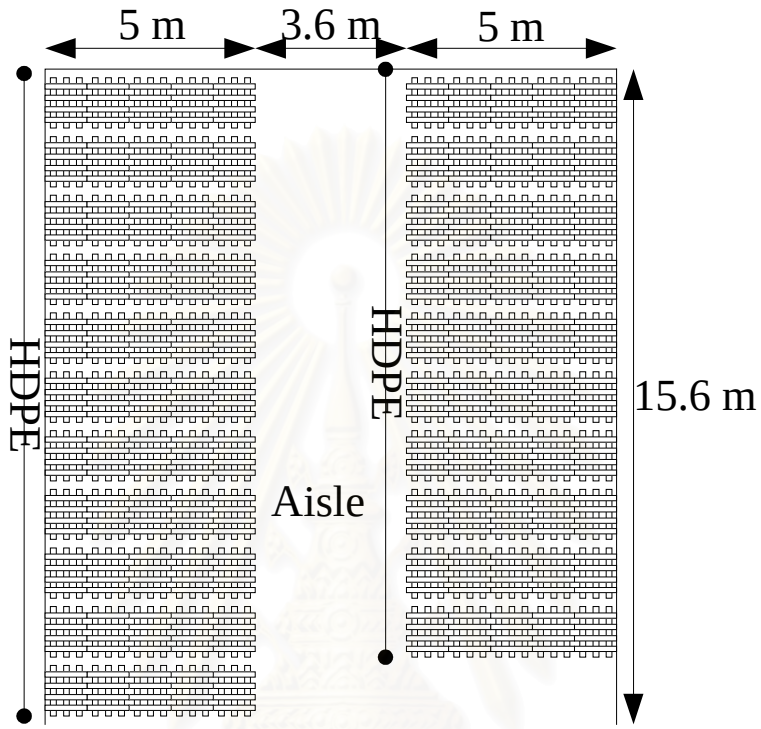


FIGURE 5.4 Layout of Zone 5

4. **Zone 6** is at the right side of the warehouse. It is used for storing HIPS and ABS. Layout of Zone 6 is shown in Figure 5.5.

- HIPS needs 12 rows. Store LDPE in the left.
- ABS needs 12 rows. Store ABS in the right.
- Each pallet board is 1.0 m wide, storing 5 stacks per row. So each row is 5 m long.
- The aisle in the middle must be large enough for the counterbalanced lift trucks, so designing 3.6 m for the picking aisle. (Mulcahy, 1994: 3.9)
- The pallet board is 1.2 m long. The space between two pallet loads of wide aisle equipment is 0.2 m (Mulcahy, 1994: 3.9). There are 12 rows in each side of the zone. So there are 13 spaces for 12 rows. The zone is (1.2*12) + (0.2*13) = 17 m long.

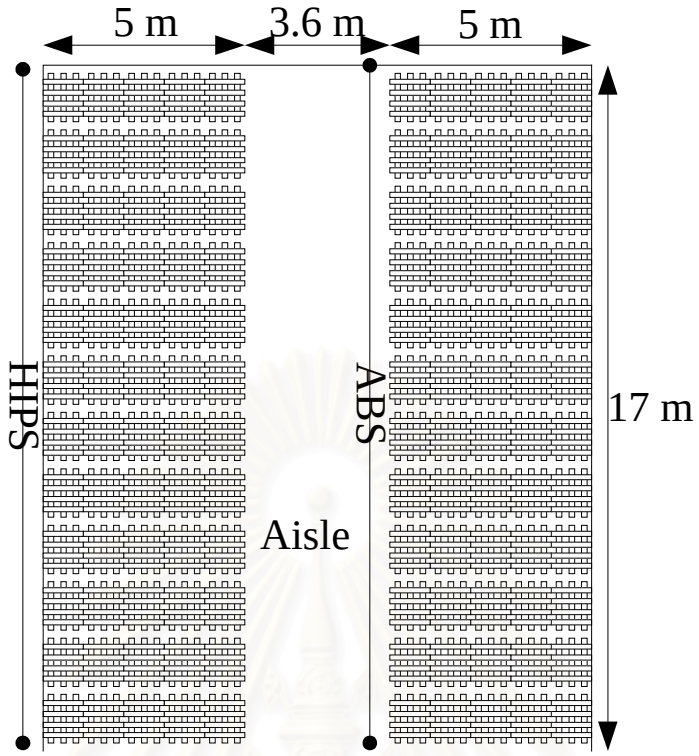


FIGURE 5.5 Layout of Zone 6

In the back zone, there are 4 zones and each zone wide 13.6 m. Use the walls 0.2 m thick to separate each zone out and to be a support device for storing the pallet loads. So the width of the back zone is (13.6*4)+(0.2*3) = 55 m. The length of the back zone will be designed by using the longest zone length that is 17 m. Layout of Back zone is shown in Figure 5.6.

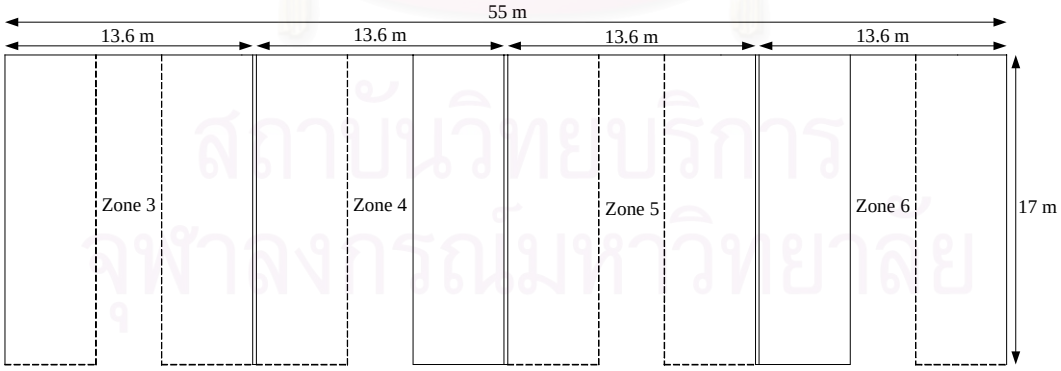


FIGURE 5.6 Layout of Back zone

5.2.1.1.2 Front zone

The front zone is the zone at the front of the warehouse near the receiving and shipping dock. It is used for storing the more popular materials or the large amount of sales materials. Front zone will store the materials with

deep storage rows. Store 28 tons per row. Each stack loads 3 levels or 3 tons, so each row consists of 28/3 = 9.33 or 10 stacks. The front zone can be divided into 2 sub zones.

1. **Zone 1** is at the left side of the warehouse. It is used for storing PP Film. Layout of Zone 1 is shown in Figure 5.7.

- PP Film needs 16 rows. Store PP Film 8 rows in the left and in the right.
- Each pallet board is 1.0 m wide, storing 10 stacks per row. So each row is 10 m long.
- The aisle in the middle must be large enough for the counterbalanced lift trucks, so designing 3.6 m for the picking aisle. (Mulcahy, 1994: 3.9)
- The pallet board is 1.2 m long. The space between two pallet loads of wide aisle equipment is 0.2 m (Mulcahy, 1994: 3.9). There are 8 rows in each side of the zone. So there are 9 spaces for 8 rows. The zone is (1.2*8) + (0.2*9) = 11.4 m long.

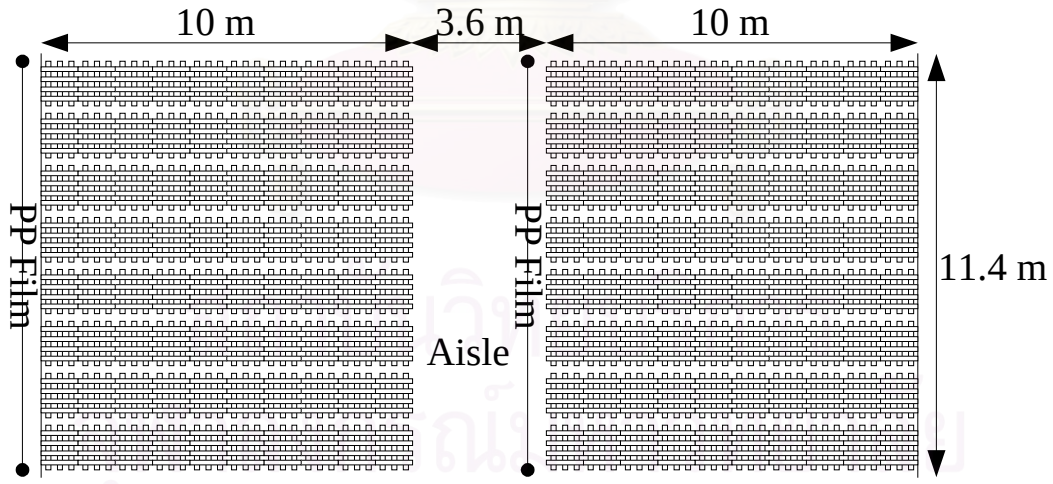


FIGURE 5.7 Layout of Zone 1

2. **Zone 2** is at the right side of the warehouse. It is used for storing PP Inject. Layout of Zone 2 is shown in Figure 5.8.

- PP Inject needs 15 rows. Store PP Film 8 rows in the left and 7 rows in the right.

- Each pallet board is 1.0 m wide, storing 10 stacks per row. So each row is 10 m long.
- The aisle in the middle must be large enough for the counterbalanced lift trucks, so designing 3.6 m for the picking aisle. (Mulcahy, 1994: 3.9)
- The pallet board is 1.2 m long. The space between two pallet loads of wide aisle equipment is 0.2 m (Mulcahy, 1994: 3.9). There are 8 rows for the longest of the zone. So there are 9 spaces for 8 rows. The zone is (1.2*8) + (0.2*9) = 11.4 m long.

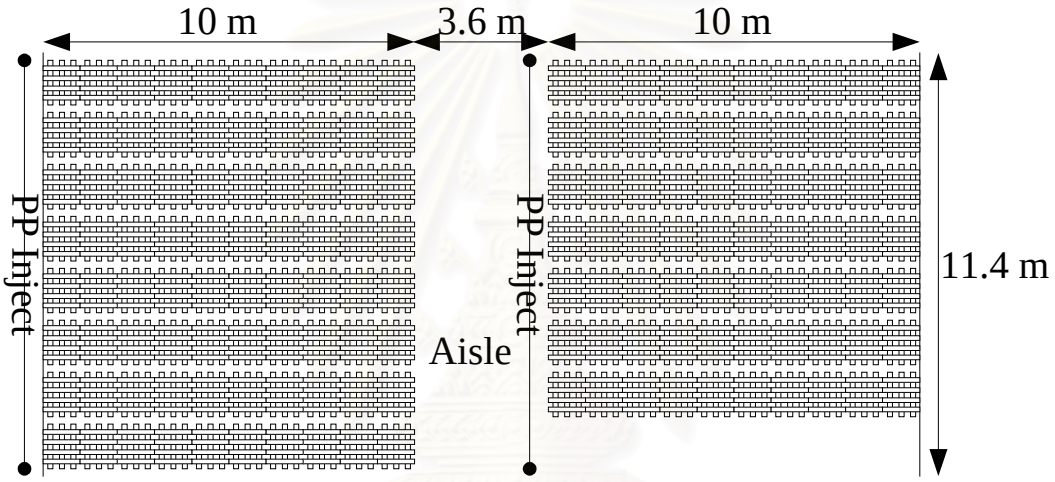


FIGURE 5.8 Layout of Zone 2

In the front zone, there are 2 zones and each zone wide 23.6 m. So the two zones are wide 47.2 m. The back zone is wide 55 m. Zone 1 and Zone 2 are in the left and the right, the wall between zone 1 and the middle and between the middle and zone 2 to separate each zone out and to be a support device for storing the pallet loads are 0.2 m thick. So in the middle there is a space 55-47.2-(0.2*2) = 7.4 m wide. The length of the front zone is 11.4 m. So in the middle there is a free space of 7.4*11.4 = 84.36 m^2. This free space will be designed to be the employees' lounge. The employees' lounge needs 11.25 m^2 for the first employee and an additional 2.25 m^2 for each additional expected. (Tompkins and Smith, 1988: 100-101) About 1+[(84.36-11.25)/2.25] = 33 employees can use the lounge at the same time. Layout of Front zone is shown in Figure 5.9.

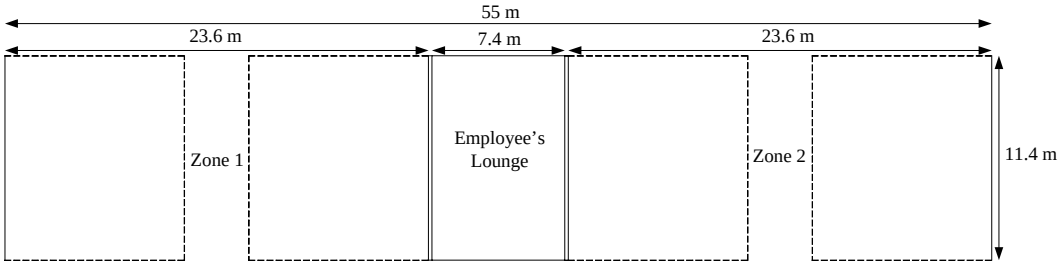


FIGURE 5.9 Layout of Front zone

Between back zone and front zone there must be an aisle, which is the main aisle that has intersecting to the storage and pick aisles. So the aisle must allow two vehicles to pass each other and needs 0.3 m added from the pick aisle. (Mulcahy, 1994: 3.9) So the aisle will be designed to have 3.6+0.3 = 3.9 m width. Layout of the space for storage is shown in Figure 5.10.

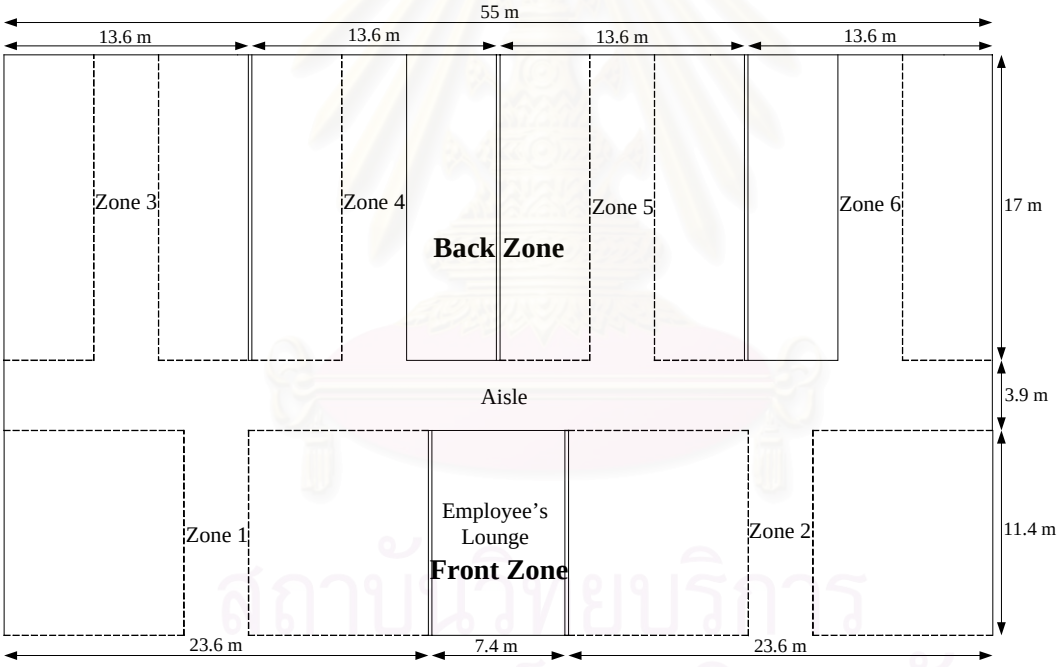


FIGURE 5.10 Layout of the space for storage

So the storage is 55 m wide and 17+3.9+11.4 = 32.3 m long.

5.2.1.2 The Space for Receiving and Shipping

The space for receiving and shipping consists of many parts. The lay out of the space for receiving and shipping is shown in Figure 5.11.

5.2.1.2.1 Dock Location

The receiving and shipping dock of the warehouse will be designed by using separated docks concept. This concept is to have separated dock location for the receiving and shipping activities. This concept is appropriate for a large operation that handles high volume and product mix. The warehouse can operate the scheduling of trucks flexibly; track and control the product flow more easily. The dock doors used will be the doors that can open all, since the operations of the company are based on labors. So the workers can do the works more convenient.

1. **Receiving dock** From the 6 receiving trucks positions, the dock doors must have 6 doors. The trucks are 2.5 m wide, so the receiving docks are designed to be 2.7 m wide. The trucks are 3.8 m high, so the receiving docks are designed 4.2 m high. (Mulcahy, 1994: 4.28) The interval between each truck at the truck receiving area will be designed for 0.9 m. (Mulcahy, 1994: 4.16) So the interval between the docks must be 0.9-0.1 = 0.8 m each side. The dock leveling will be 1 m wide to put the pallet boards while unloading the plastic resins sacks.
2. **Shipping dock** From the 4 shipping trucks positions, the dock doors must have 4 doors. The widest trucks are 2 m wide, so the shipping docks are designed 2.4 m wide. The highest trucks are 3.8 m high, so the shipping docks are designed 4.2 m high. (Mulcahy, 1994: 4.28) The interval between each truck at the truck receiving area will be designed for 0.9 m. (Mulcahy, 1994: 4.16) So the interval between the docks must be 0.9-0.2 = 0.7 m each side. The dock leveling will be 1 m wide to put the pallet boards while unloading the plastic resins sacks.

5.2.1.2.2 Receiving stage

Receiving stage is the stage for putting the full pallet load to wait for storing in the storage. Receiving stage will be designed by having each position for each receiving truck. Each receiving time has 6 trucks. So there are 6 positions on the receiving stage. The positions are divided by rows. Each

row consists of 14 tons or 14 pallet loads. The stack can load 3 pallet loads. So each row has 14/3 = 4.66 or 5 stacks. The space between each row is 0.2 m (Mulcahy, 1994: 3.9), so the width of the stage will be (1.2*6) + (0.2*7) = 8.6 m and the length of the stage is 1*5 = 5 m.

5.2.1.2.3 Empty pallet board storage

Empty pallet board storage is the area for storing the empty pallet boards. The lift trucks will lift the loaded empty pallet boards from the shipping area to store in the empty pallet board storage and another lift truck will lift the empty pallet boards to the receiving area. The empty pallet board storage will be designed for supporting the sales level 1000 tons per month. So the storage must be designed to store about 1000 pallet boards. The maximum height of the stack is 5.6 m with which the materials will not fall down. (Anasaya Munyukong, interview, September 18, 2001) The pallet boards are 0.2 m thick, so each stack of an empty pallet board can put 5.6/0.2 = 28 boards. There must be 1000/28 = 35.17 or 36 stacks. Designing 6 rows by 6 stacks per row. The space between each row is 0.2 m (Mulcahy, 1994: 3.9), so the width of the stage will be (1.2*6) + (0.2*7) = 8.6 m. Each row will be designed to have 4 stacks. So the length of the stage is 1*6 = 6 m.

5.2.1.2.4 Sortation area

Sortation area is the area for preparing the order picking plastic resins before the trucks come back. The plastic resins are separated in 8 sacks per layer (4 sacks by 2 rows) for the 4-wheeled trucks and 20 sacks per layer (5 sacks by 4 rows) for the 6-wheeled trucks. The sack is 0.6 m long. The area must be designed for 4 rows, so the area is long 0.6*4 = 2.4 m and another 1 m for the picked pallet load. So the sortation area is long 3.4 m.

5.2.1.2.5 Loaded pallet load stage

Loaded pallet load stage is the stage for putting the loaded pallet loads to wait for storing in the storage. Loaded pallet load stage will be designed by having each position for each shipping truck position. Each shipping or sortation time is for 4 trucks. So there are 4 positions on the loaded pallet load stage. The positions are divided by rows. The row of the 4-wheeled truck positions consists of 2 tons or 2 pallet loads, while the row of the 6-wheeled

truck positions consists of 5 tons or 5 pallet loads. The stack can load 3 pallet loads. So the rows are designed by having 5/3 = 1.66 or 2 stacks. The space between each row is 0.2 m (Mulcahy, 1994: 3.9), so the width of the stage will be (1.2*4) + (0.2*5) = 5.8 m and the length of the stage is 1*2 = 2 m.

5.2.1.2.6 Supervisor office

Supervisor office will be designed by using the left of the width in the warehouse. Receiving stage uses the space of the warehouse width of 5 m. Receiving docks use the space of the warehouse width (2.7*6)+(0.8*7) = 21.8 m. Empty pallet board storage uses the space of the warehouse width of 8.6 m. Shipping docks use the space of the warehouse width (2.4*4)+(0.7*5) = 13.1 m. Loaded pallet load stage uses the space of the warehouse width of 2 m. So there is the space width left 55-(5+21.8+8.6+13.1+2) = 4.5 m. The office needs 11.25 m^2 for each supervisor. (Tompkins and Smith, 1988: 100-101) So the office needs 22.5 m^2 for the 2 supervisors. The office is 4.5 m in width, so it is 22.5/4.5 = 5 m in length.

5.2.1.2.7 Aisle

The aisle in the receiving and shipping area must be enough for the lift trucks. This aisle is the main aisle that has intersecting to the storage and pick aisles. So the aisle must allow two vehicles to pass each other and needs 0.3 m added from the pick aisle. (Mulcahy, 1994: 3.9) So the aisle will be designed to have 3.6+0.3 = 3.9 m width. So every position must have the area at least 3.6 m. The empty pallet board storage is the longest part that relates to the aisle, it is long 6 m. It has to plus the aisle 3.9 m. So the space for receiving and shipping is long 6+3.9 = 9.9 m.

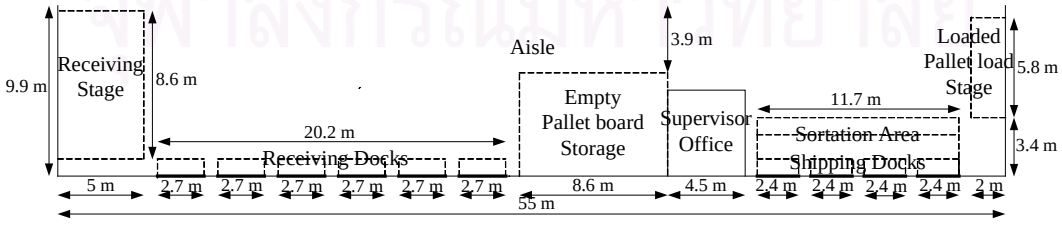


FIGURE 5.11 Layout of the space for receiving and shipping

So the warehouse is 55 m wide. The space for storage is 32.3 m long and the space for receiving and shipping is 9.9 m long. So the warehouse is 32.3+9.9 = 42.2 m

long. The warehouse area is 55*42.2 = 2321 m^2. The plastic resins sacks are thick about 0.2 m and the pallet boards are 0.2 m thick. Each pallet load loads 8 layers of plastic resins. So the pallet loads are (0.2*8) + 0.2 = 1.8 m high. Each stack loads 3 pallet loads. So each stack is 1.8*3 = 5.4 m high. The clear space between the ceiling sprinklers and the top of the highest pallet load must be designed for at least 0.45 m. So the warehouse is at least 5.85 m high, using 6 m. The size of the warehouse is 55*42.2*6. The layout of the warehouse is shown in Figure 5.12.

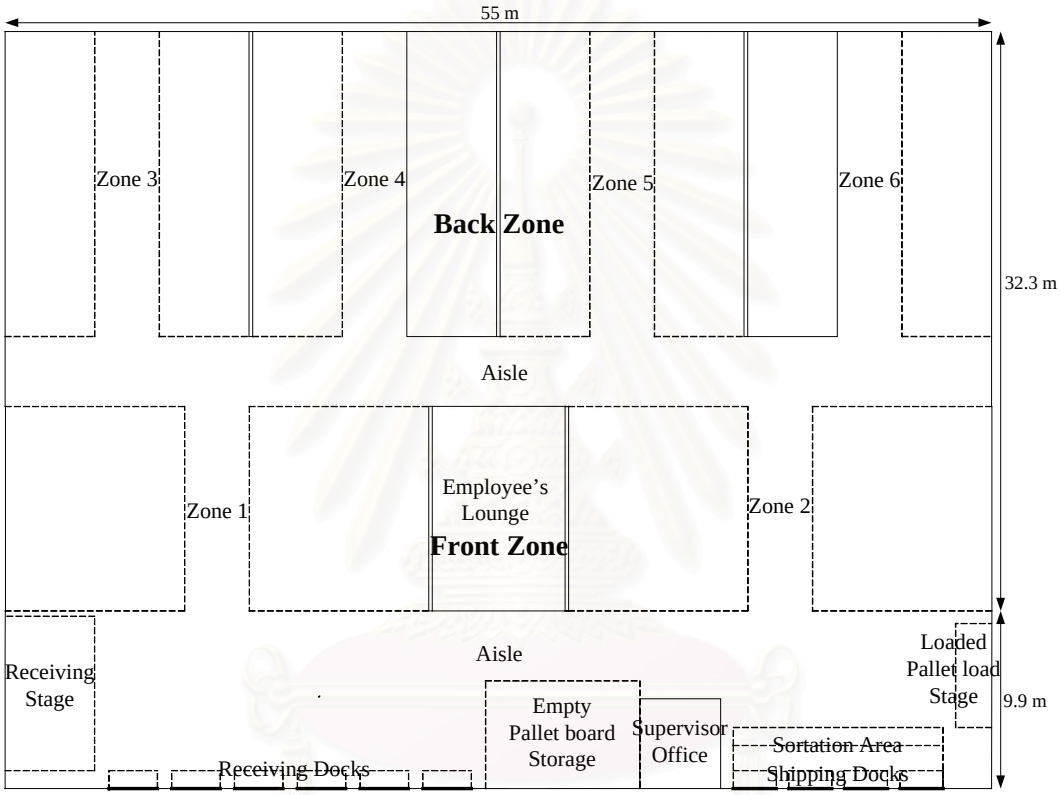


FIGURE 5.12 Layout of the warehouse

5.2.2 Outside the Warehouse

Outside the warehouse consists of many parts. The layout of the area outside the warehouse is shown in Figure 5.13.

5.2.2.1 Truck Road

Truck road is the road for the trucks to access and exit the warehouse area. The road is designed for two-way flow. The road will be designed for 7.8 m wide and another 1.2 m for the employee walkway. So the road is wide 9 m. The road will be designed twice the length of the longest truck. So the load is long 2*7.5 = 15 m. (Mulcahy, 1994: 4.13)

5.2.2.2 Truck Receiving Area

Truck receiving area is the area for parking the trucks while unloading the materials. The area is as long as the length of the trucks, which is 7.5 m. The width of the area is equal to the width of the 6 docks plus the interval between the trucks of 0.9 m on each side of the widest truck. (Mulcahy, 1994: 4.16) Truck receiving area is as wide as the receiving docks space in the warehouse, the width is (2.7*6)+(0.8*7) = 21.8 m.

5.2.2.3 Truck Shipping Area

Truck shipping area is the area for parking the trucks while loading the materials. The area is as long as the length of the trucks, which is 5 m. The width of the area is equal to the width of the 4 docks plus the interval between the docks of 0.9 m on each side of the widest truck. (Mulcahy, 1994: 4.16). Truck shipping area is as wide as the shipping docks space in the warehouse, the width is (2.4*4)+(0.7*5) = 13.1 m.

5.2.2.4 Maneuvering Area

Maneuvering area is the area for backing up the truck area. The maneuvering area for the clockwise vehicular traffic is doubled in length of the truck receiving or shipping plus 1.5 m. The receiving trucks are 7.5 m long, so the maneuvering of the truck receiving area is (2*7.5)+1.5 = 16.5 m. The longest shipping truck is 5 m long, so the maneuvering of the truck shipping area is (2*5)+1.5 = 11.5 m.

5.2.2.5 Truck Holding Area

Truck holding area is the area for the trucks to wait to start the receiving activity or exit the warehouse. The area is designed for parking 6 trucks, 3 in the left and 3 in the right. The width of each area is equal to the width of the 3 trucks plus the interval between the trucks. The trucks are wide 2.5 m and the intervals are 0.9 m. So each area is wide (2.5*3) + (0.9*4) = 11.1 m. The length of each area is equal to the length of the truck area plus the maneuvering area. So each area is long 7.5+16.5 = 24 m.

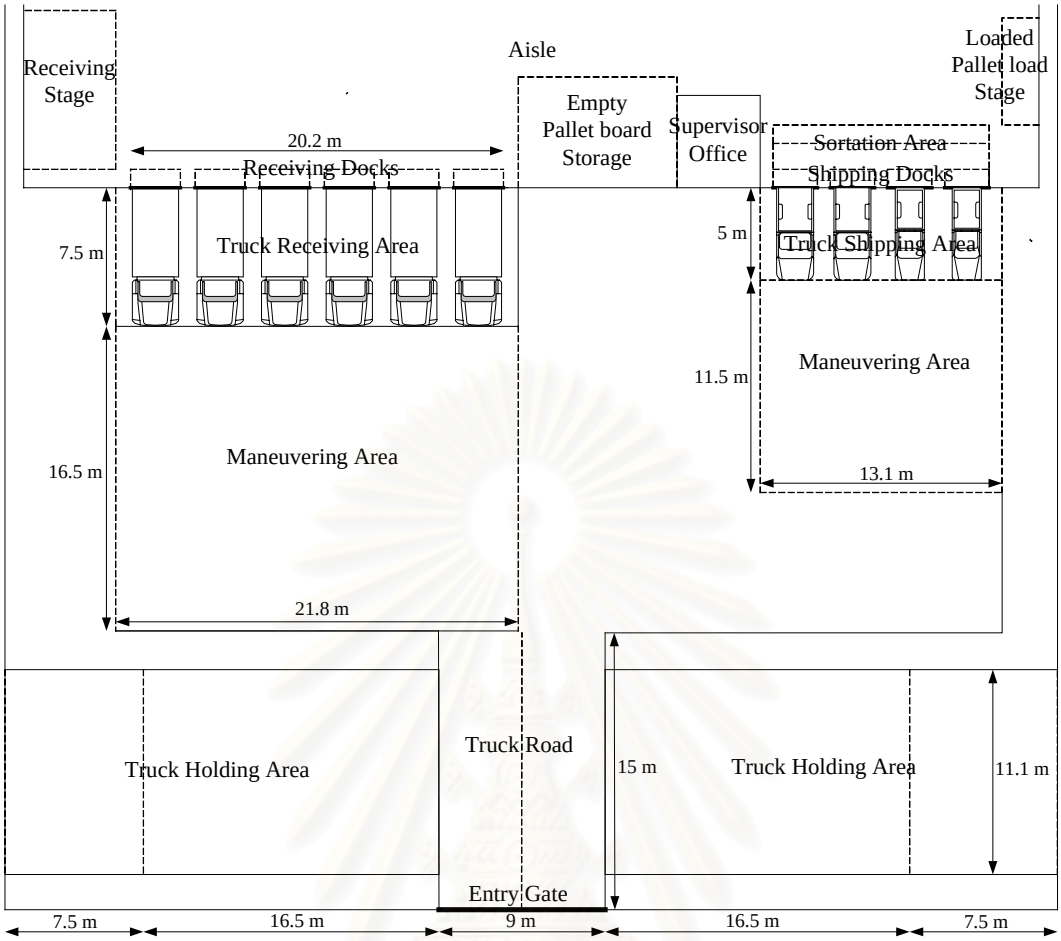


FIGURE 5.13 Layout of the area outside the warehouse

5.3 Lift Truck Activity Design

Each lift truck is assigned to pick for 1 shipping truck position in one time to be easier to make the order picking instruction. The lift truck activity is divided into 2 types. Figure 5.14 is used for explaining the activity of the lift trucks.

5.3.1 Picking for shipping

This is designed for the first pick of the day. The storing of the receiving materials and the picking for the shipping materials will be done together. The lift truck, called “Lift truck 1”, is assigned to pick for “4-wheeled truck 1” and “6-wheeled truck 1”. The lift truck, called “Lift truck 2”, is assigned to pick for “4-wheeled truck 2” and “6-wheeled truck 2”.

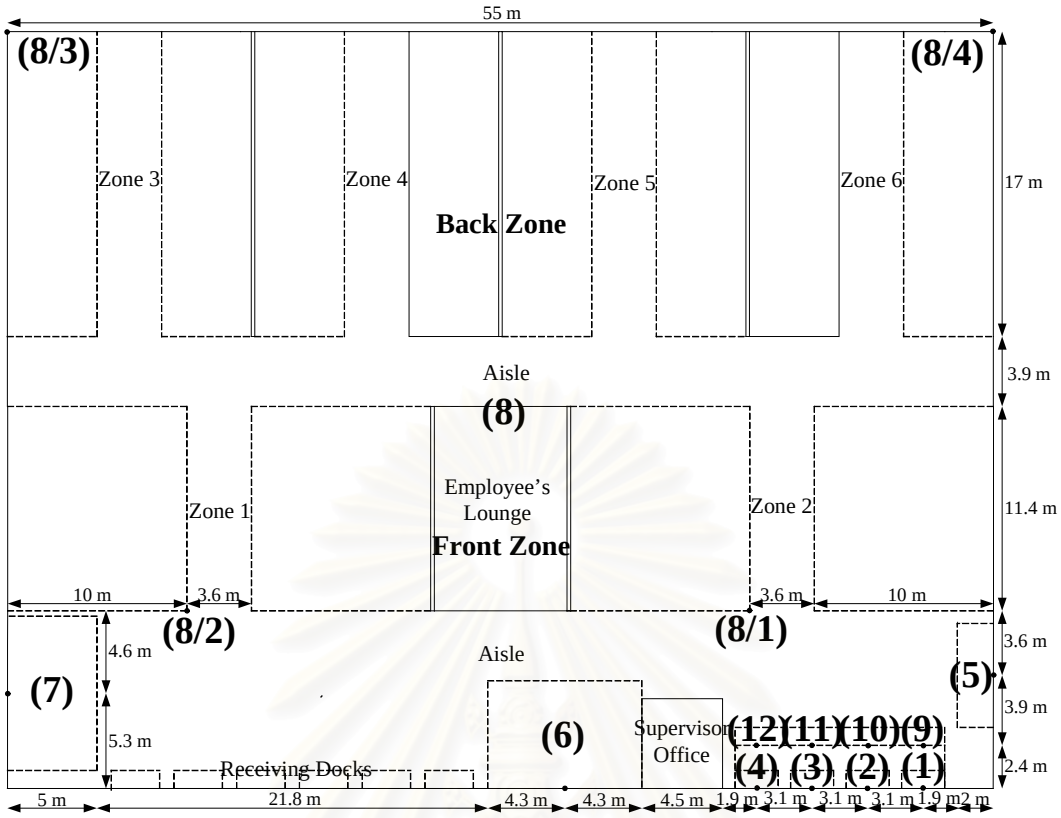


FIGURE 5.14 Layout of the warehouse's position and distance

"Lift truck 1" will start the work by receiving the put-away instruction and the picking instruction of "lift truck 1" from the supervisor. The steps of "Lift truck 1" are as following.

1. "Lift truck 1" will go to the picking position (8) following the picking instruction, pick the pallet load to the "4-wheeled truck 1" shipping position (1), and let the workers load the plastic resins sacks to the truck. The nearest picking position to (1) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is 9.9+(10+3.6-1.9-2) = 19.6 m. The farthest picking position to (1) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+9.9) +(55-1.9-2) = 93.3 m.

2. Then "Lift truck 1" will go from the "4-wheeled truck 1" shipping position (1) to the receiving stage area (7). The distance is (55-1.9-2)+5.3 = 56.4 m.

3. At the receiving stage area (7) "Lift truck 1" will lift the received pallet load to the storage area (8) or the shipping area (1) following

the put-away instruction. If the received pallet load is picked to (8), the nearest storage position (8) is in Zone 1, Row 8, and Stack 10 (8/2). So the minimum distance is 10+4.6 = 14.6 m. The farthest storage position is in Zone 6, Row 13, and Stack 1 (8/4). So the maximum distance is (4.6+11.4+3.9+17)+55 = 91.9 m. If the received pallet load is picked to (1), the distance is (55-1.9-2)+5.3 = 56.4 m.

4. Then “Lift truck 1” will go from the storage position (8) or the “4-wheeled truck 1” shipping position (1) to the picking position (8) following the picking instruction again. If “Lift truck 1” go from the storage position (8) to the picking position (8), the minimum distance is the range between 2 pallet loads. So the minimum distance is 1.4 m. The maximum distance is the distance between the two farthest storage stacks. So the maximum distance is 55+(11.4+3.9+17) = 87.3 m. If “Lift truck 1” goes from the shipping position (1) to the picking position (8), the nearest picking position from (1) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is 9.9+(10+3.6-1.9-2) = 19.6 m. The farthest picking position from (1) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+9.9) +(55-1.9-2) = 93.3 m.

5. At the picking position (8), “Lift truck 1” will pick the pallet loads to the “4-wheeled truck 1” shipping position (1) after “Lift truck 2” has lifted the loaded pallet load to the loaded pallet load stage area (5) or the empty pallet board to the empty pallet board storage area (6) already, and let the workers load the plastic resins sacks to the truck. The nearest picking position to (1) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is 9.9+(10+3.6-1.9-2) = 19.6 m. The farthest picking position to (1) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+9.9) +(55-1.9-2) = 93.3 m.

6. “Lift truck 1” will go to the “Lift truck 2” shipping position (2). The distance is 3.1 m.

7. Then “Lift truck 1” will lift the loaded pallet load or the empty pallet board from “Lift truck 2” shipping position (2) to the loaded pallet load stage area (5) or the empty pallet board storage area (6). If “Lift truck 1” picks the loaded pallet load to (5), the distance is (3.1+1.9+2)+6.3 = 13.3 m. If “Lift truck 1” picks the empty pallet board to (6), the distance is 3.1+3.1+1.9+4.5+4.3 = 16.9 m.
8. Then “Lift truck 1” will go from (5) or (6) to the receiving stage area (7). If “Lift truck 1” go from (5) to (7), the distance is 55+(6.3-5.3) = 56 m. If “Lift truck 1” goes from (6) to (7), the distance is 5.3+(4.3+21.8+5) = 36.4 m.
9. At the receiving stage area (7), “Lift truck 1” will lift the receiving pallet load to the storage area (8) or the shipping area (1) following the put-away instruction again.

The activities will be the loop like above until the shipping for “4-wheeled truck 1” finish. The loop of “Lift truck 1” is shown in Figure 5.15. The step summary is shown in Table 5-2.

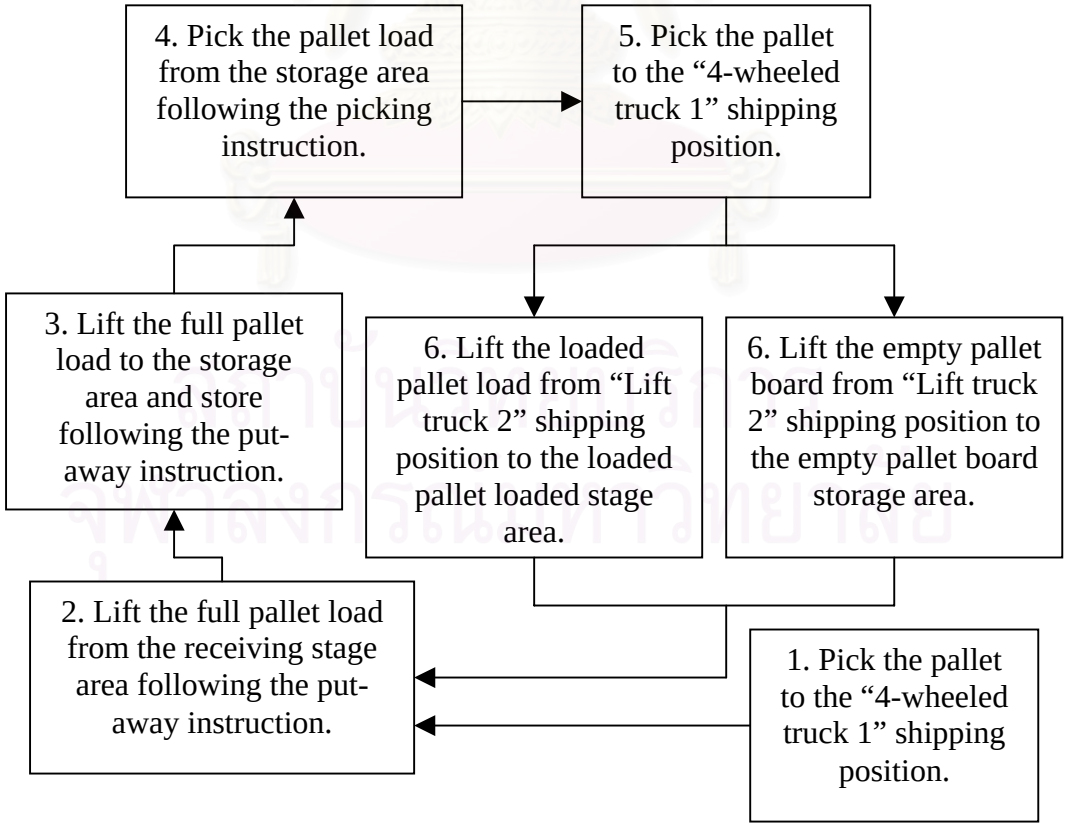


FIGURE 5.15 Loop of “Lift truck 1” to ship for “4-wheeled truck 1”

TABLE 5-2 Step summary of “Lift truck 1” to Ship for “4-wheeled truck 1”

Steps	Position		Distance (m)	
	From	To	Min.	Max.
1	(8)	(1)	19.6	93.3
2	(1)	(7)	56.4	56.4
3	(7)	(8)	14.6	91.9
Or	(7)	(1)	56.4	56.4
4	(8)	(8)	1.4	87.3
Or	(1)	(8)	19.6	93.3
5	(8)	(1)	19.6	93.3
6	(1)	(2)	3.1	3.1
7	(2)	(5)	13.3	13.3
Or	(2)	(6)	16.9	16.9
8	(5)	(7)	56	56
Or	(6)	(7)	36.4	36.4

“Lift truck 2” will start the work by receiving the put-away instruction and the picking instruction of “lift truck 2” from the supervisor. The steps of “Lift truck 2” are as following.

1. “Lift truck 2” will wait until the first pallet load of “Lift truck 1” position has shipped finish, “Lift truck 2” will lift the loaded pallet load or the empty pallet board from “Lift truck 1” shipping position (1) to the loaded pallet load stage area (5) or the empty pallet board storage area (6). If “Lift truck 2” picks the loaded pallet load to (5), the distance is (1.9+2)+6.3 = 10.2 m. If “Lift truck 2” picks the empty pallet board to (6), the distance is 3.1+3.1+3.1+1.9+4.5+4.3 = 20 m.
2. Then “Lift truck 2” will go from (5) or (6) to the picking position (8) following the picking instruction. If “Lift truck 2” goes from (5) to (8), the nearest picking position from (5) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is 3.6+(10+3.6) = 17.2 m. The farthest picking position from (5) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6) +55 = 90.9 m. If “Lift truck 2” goes from (6) to (8), the nearest

picking position from (6) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.6+6.3)+(4.3+4.5+1.9) = 20.6 m. The farthest picking position from (6) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+6.3) +(4.3+21.8+5) = 73.3 m.

3. At the picking position (8), “Lift truck 2” will pick the pallet loads to the “4-wheeled truck 2” shipping position (2), and let the workers load the plastic resins sacks to the truck. The nearest picking position to (2) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is 9.9+(10+3.6-1.9-2-3.1) = 16.5 m. The farthest picking position to (2) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+6.3) +(55-1.9-2-3.1) = 90.2 m.
4. Then “Lift truck 2” will go from (2) to the receiving stage area (7). The distance is (55-1.9-2-3.1)+5.3 = 53.3 m.
5. At the receiving stage area (7), “Lift truck 2” will lift the received pallet load to the storage area (8) or the shipping area (2) following the put-away instruction. If the received pallet load is picked to (8), the nearest storage position (8) is in Zone 1, Row 8, and Stack 10 (8/2). So the minimum distance is 10+4.6 = 14.6 m. The farthest storage position is in Zone 6, Row 13, and Stack 1 (8/4). So the maximum distance is (4.6+11.4+3.9+17)+55 = 91.9 m. If the received pallet load is picked to (2), the distance is (55-1.9-2-3.1)+5.3 = 53.3 m.
6. Then “Lift truck 2” will go from the storage area (8) or the shipping area (2) to the picking position (8) following the picking instruction again. If “Lift truck 2” goes from the storage position (8) to the picking position (8), the minimum distance is the range between 2 pallet loads. So the minimum distance is 1.4 m. The maximum distance is the distance between the two farthest storage stacks. So the maximum distance is 55+(11.4+3.9+17) = 87.3 m. If “Lift truck 2” goes from the shipping position (2) to the picking

position (8), the nearest picking position from (2) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is 9.9+(10+3.6-1.9-2-3.1) = 16.5 m. The farthest picking position from (2) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+9.9) +(55-1.9-2-3.1) = 90.2 m.

7. At the picking position (8), “Lift truck 2” will pick the pallet loads to the “4-wheeled truck 2” shipping position (2) after “Lift truck 1” has lifted the loaded pallet load to the loaded pallet load stage area (5) or the empty pallet board to the empty pallet board storage area (6) already, and let the workers load the plastic resins sacks to the truck. The nearest picking position to (2) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is 9.9+(10+3.6-1.9-2-3.1) = 16.5 m. The farthest picking position to (1) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+9.9) +(55-1.9-2-3.1) = 90.2 m.
8. Then “Lift truck 2” will go from (1) to (2). The distance is 3.1 m.
9. Then “Lift truck 2” will lift the loaded pallet load or the empty pallet board from “Lift truck 1” shipping position (1) to the loaded pallet load stage area (5) or the empty pallet board storage area (6).
10. Then “Lift truck 2” will go to the receiving stage area (7) and lift the receiving pallet load to the storage area (8) or the shipping area (2) following the put-away instruction again.

The activities will be the loop like above until the shipping for “4-wheeled truck 2” finish. The loop of “Lift truck 2” is shown in Figure 5.16. The step summary is shown in Table 5-3.

After “4-wheeled truck 1” and “4-wheeled truck 2” are shipped finish, “Lift truck 1” and “Lift truck 2” will change the position to “6-wheeled truck 1” (3) and “6-wheeled truck 2” (4), and start the activity loop until “6-wheeled truck 1” and “6-wheeled truck 2” have shipped finish. “4-wheeled truck 1” and “4-wheeled truck 2” have to ship finish before 8.30am or before the first trip starts. While “6-wheeled truck 1” and “6-wheeled truck 2” have to ship finish before 9.00am or before the first trip starts.

After “6-wheeled truck 1” and “6-wheeled truck 2” are shipped finish, “Lift truck 1” and “Lift truck 2” will have to go to the receiving stage area (7) and lift the receiving pallet load to the storage area until finish its put-away instruction. Then “Lift truck 1” and “Lift truck 2” will go to the loaded pallet load stage area (5) and pick the left loaded pallet loads back to the storage area following the picking instruction.

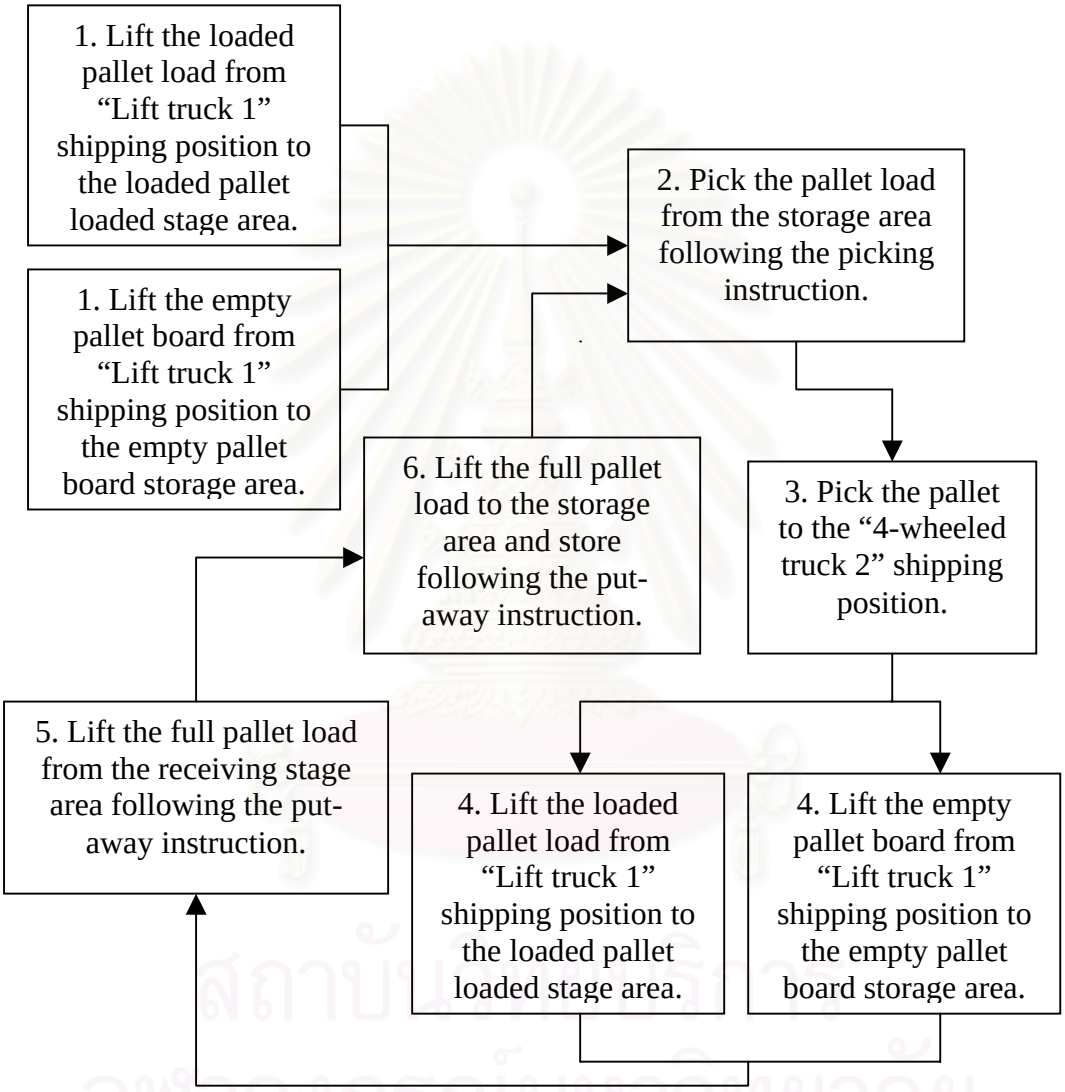


FIGURE 5.16 Loop of “Lift truck 2” to ship for “4-wheeled truck 2”

At the receiving area, a lift truck, called “Lift truck 3”, will lift the full-loaded pallet loads from the unloading area to the receiving stage area and let another one, called “Lift truck 4”, lift the empty pallet boards to the unloading area replace the full-loaded pallet loads. If the suppliers’ trucks are not more than 6, “Lift truck 3” and

“Lift truck 4” will finish their works at 8.40am. But if the suppliers’ trucks are more than 6, “Lift truck 3” and “Lift truck 4” will finish their works at 9.20am.

After “Lift truck 3” and “Lift truck 4” finish their works, they will receive the put-away instruction of the receiving stage position that has not stored from the supervisor to help “Lift truck 1” and “Lift truck 2” storing the pallet loads until finish all the receiving pallet loads.

TABLE 5-3 Step summary of “Lift truck 2” to ship for “4-wheeled truck 2”

Steps	Position		Distance (m)	
	From	To	Min.	Max.
1	(1)	(5)	10.2	10.2
Or	(1)	(6)	20	20
2	(5)	(8)	17.2	90.9
Or	(6)	(8)	20.6	73.3
3	(8)	(2)	16.5	90.2
4	(2)	(7)	53.3	53.3
5	(7)	(8)	14.6	91.9
Or	(7)	(2)	53.3	53.3
6	(8)	(8)	1.4	87.3
Or	(2)	(8)	16.5	90.2
7	(8)	(2)	16.5	90.2
8	(2)	(1)	3.1	3.1

5.3.2 Picking for sortation

This is designed for the second to the last pick of the day. “Lift truck 1”, is assigned to pick for “4-wheeled truck 1”, “Lift truck 2”, is assigned to pick for “4-wheeled truck 2”, “Lift truck 3”, is assigned to pick for “6-wheeled truck 1”, and “Lift truck 4”, is assigned to pick for “6-wheeled truck 2”.

“Lift truck 1” will start the work by receiving the picking instruction of “lift truck 1” from the supervisor. The steps of “Lift truck 1” are as following.

1. “Lift truck 1” will go to the picking position (8) following the picking instruction, pick the pallet load to the “4-wheeled truck 1” sortation position (9), and let the workers sort the plastic resins

sacks to the sortation area. The nearest picking position to (9) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.9+3.6)+(10+3.6-1.9-2) = 17.2 m. The farthest picking position to (9) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+3.9) +(55-1.9-2) = 90.9 m.

2. Then “Lift truck 1” will go from (9) to the picking position (8) following the picking instruction again. The nearest picking position from (9) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.9+3.6)+(10+3.6-1.9-2) = 17.2 m. The farthest picking position from (9) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+3.9) +(55-1.9-2) = 90.9 m.

3. At the picking position (8), “Lift truck 1” will pick the pallet loads to the “4-wheeled truck 1” sortation position (9) after “Lift truck 2” has lifted the sorted pallet load to the loaded pallet load stage area (5) or the empty pallet board to the empty pallet board storage area (6) already, and let the workers load the plastic resins sacks to the truck. The nearest picking position to (9) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.9+3.6)+(10+3.6-1.9-2) = 17.2 m. The farthest picking position to (9) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+3.9) +(55-1.9-2) = 90.9 m.

4. Then “Lift truck 1” will go from (9) to the “Lift truck 2” sortation position (10). The distance is 3.1 m.

5. At “Lift truck 2” sortation position (10), “Lift truck 1” will lift the sorted pallet load to the loaded pallet load stage area (5) or lift the empty pallet board to the empty pallet board storage area (6). If “Lift truck 1” picks the sorted pallet load to (5), the distance is (3.1+1.9+2)+3.9 = 10.9 m. If “Lift truck 1” picks the empty pallet board to (6), the distance is (3.1+3.1+1.9+4.5+4.3)+2.4 = 19.3 m.

6. If there is a sorted pallet load at the loaded pallet load stage area (5), "Lift truck 1" will go to (5) and lift the sorted pallet load from the loaded pallet load stage area to the storage area (8).

The activities will be the loop like above until the sortation for "4-wheeled truck 1" finish. The loop of "Lift truck 1" is shown in Figure 5.17. The step summary is shown in Table 5-4.

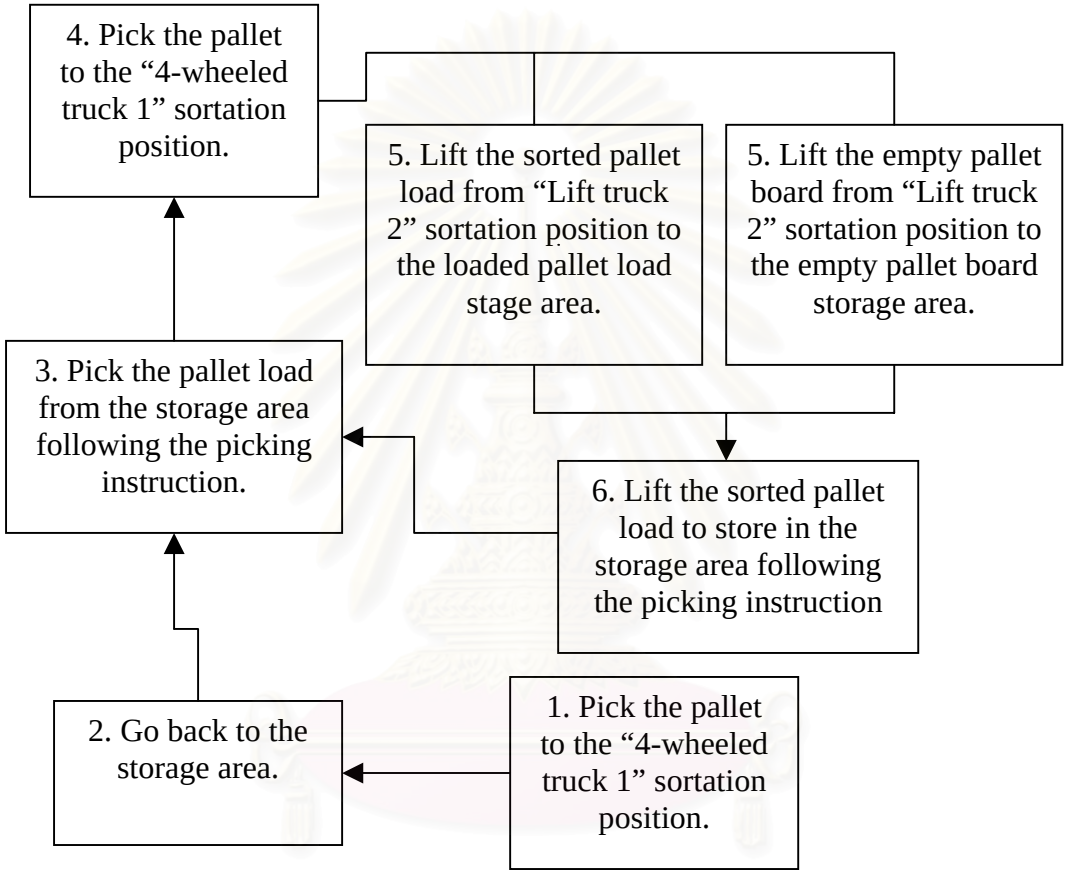


FIGURE 5.17 Loop of "Lift truck 1" to sort for "4-wheeled truck 1"

TABLE 5-4 Step summary of "Lift truck 1" to sort for "4-wheeled truck 1"

Steps	Position		Distance (m)	
	From	To	Min.	Max.
1	(8)	(9)	17.2	90.9
2	(9)	(8)	17.2	90.9
3	(8)	(9)	17.2	90.9
4	(9)	(10)	3.1	3.1
5	(10)	(5)	10.9	10.9
Or	(10)	(6)	19.3	19.3

"Lift truck 2" will start the work by receiving the picking instruction of "lift truck 2" from the supervisor. The steps of "Lift truck 2" are as following.

1. "Lift truck 2" will wait until the first pallet load of "Lift truck 1" position has completed sorting, "Lift truck 2" will lift the sorted pallet load or the empty pallet board from "Lift truck 1" sortation position (9) to the loaded pallet load stage area (5) or the empty pallet board storage area (6). If "Lift truck 2" picks the loaded pallet load to (5), the distance is (1.9+2)+3.9 = 7.8 m. If "Lift truck 2" picks the empty pallet board to (6), the distance is (3.1+3.1+3.1+1.9+4.5+4.3)+2.4 = 22.4 m.
2. Then "Lift truck 2" will go from (5) or (6) to the picking position (8) following the picking instruction. If "Lift truck 2" goes from (5) to (8), the nearest picking position from (5) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is 3.6+(10+3.6) = 17.2 m. The farthest picking position from (5) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6) +55 = 90.9 m. If "Lift truck 2" goes from (6) to (8), the nearest picking position from (6) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.6+6.3)+(4.3+4.5+1.9) = 20.6 m. The farthest picking position from (6) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+6.3) +(4.3+21.8+5) = 73.3 m.
3. At the picking position (8), "Lift truck 2" will pick the pallet loads to the "4-wheeled truck 2" sortation position (10), and let the workers load the plastic resins sacks to the truck. The nearest picking position to (10) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.6+3.9)+(10+3.6-1.9-2-3.1) = 14.1 m. The farthest picking position to (10) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+3.9) +(55-1.9-2-3.1) = 87.8 m.
4. Then "Lift truck 2" will go from (10) to (9). The distance is 3.1 m.

5. At (9) “Lift truck 2” will lift the loaded pallet load or the empty pallet board from “Lift truck 1” shipping position (9) to the loaded pallet load stage area (5) or the empty pallet board storage area (6). If “Lift truck 2” picks the sorted pallet load to (5), the distance is (1.9+2)+3.9 = 7.8 m. If “Lift truck 2” picks the empty pallet board to (6), the distance is (3.1+3.1+3.1+1.9+4.5+4.3)+2.4 = 22.4 m.

6. Then “Lift truck 2” will go from (5) or (6) to the picking position (8) following the picking instruction again. If “Lift truck 2” goes from (5) to (8), the nearest picking position from (5) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is 3.6+(10+3.6) = 17.2 m. The farthest picking position from (5) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6) +55 = 90.9 m. If “Lift truck 2” goes from (6) to (8), the nearest picking position from (6) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.6+6.3)+(4.3+4.5+1.9) = 20.6 m. The farthest picking position from (6) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+6.3) +(4.3+21.8+5) = 73.3 m.

7. At (8), “Lift truck 2” will pick the pallet loads to the “4-wheeled truck 2” sortation position (10) after “Lift truck 1” has lifted the sorted pallet load to the loaded pallet load stage area (5) or the empty pallet board to the empty pallet board storage area (6) already, and let the workers load the plastic resins sacks to the truck. The nearest picking position to (10) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.6+3.9)+(10+3.6-1.9-2-3.1) = 14.1 m. The farthest picking position to (10) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+3.9) +(55-1.9-2-3.1) = 87.8 m.

8. Then “Lift truck 2” will lift the loaded pallet load or the empty pallet board from “Lift truck 1” sortation position (9) to the loaded pallet load stage area (5) or the empty pallet board storage area (6).

9. If there is a sorted pallet load at the loaded pallet load stage area (5), "Lift truck 2" will go to (5) and lift the sorted pallet load from the loaded pallet load stage area to the storage area (8).

The activities will be the loop like above until the sortation for "4-wheeled truck 2" finish. The loop of "Lift truck 2" is shown in Figure 5.18. The step summary is shown in Table 5-5.

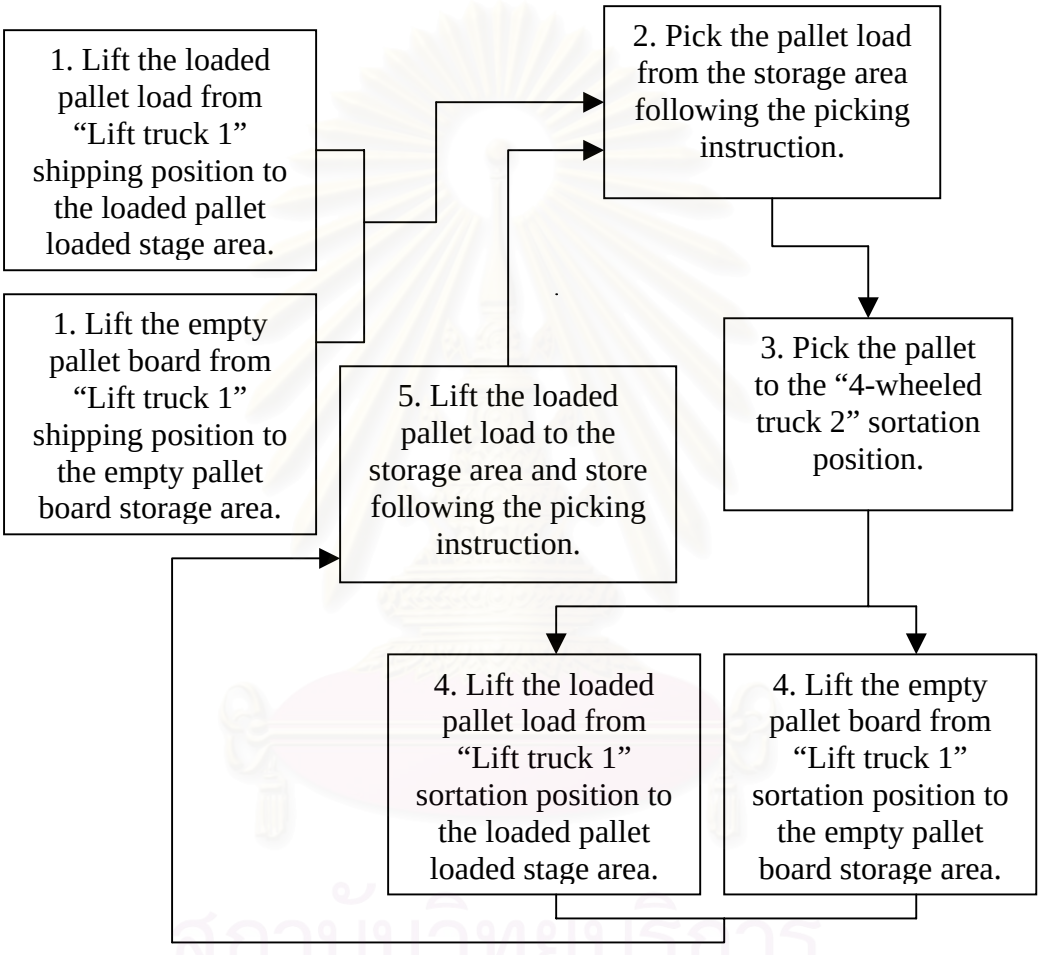


FIGURE 5.18 Loop of "Lift truck 2" to sort for "4-wheeled truck 2"

TABLE 5-5 Step summary of “Lift truck 2” to sort for “4-wheeled truck 2”

Steps	Position		Distance (m)	
	From	To	Min.	Max.
1	(9)	(5)	7.8	7.8
Or	(9)	(6)	22.4	22.4
2	(5)	(8)	17.2	90.9
Or	(6)	(8)	20.6	73.3
3	(8)	(10)	14.1	87.8
4	(10)	(9)	3.1	3.1
5	(9)	(5)	7.8	7.8
Or	(9)	(6)	22.4	22.4
6	(5)	(8)	17.2	90.9
Or	(6)	(8)	20.6	73.3
7	(8)	(10)	14.1	87.8

“Lift truck 3” will start the work by receiving the picking instruction of “lift truck 3” from the supervisor. The steps of “Lift truck 3” are as following.

1. “Lift truck 3” will go to the picking position (8) following the picking instruction, pick the pallet load to the “6-wheeled truck 1” sortation position (11), and let the workers sort the plastic resins sacks to the sortation area. The nearest picking position to (11) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.9+3.6)+(10+3.6-1.9-2-3.1-3.1) = 11 m. The farthest picking position to (11) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+3.9) +(55-1.9-2-3.1-3.1) = 84.7 m.
2. Then “Lift truck 3” will go from (11) to the picking position (8) following the picking instruction again. The nearest picking position from (11) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.9+3.6)+(10+3.6-1.9-2-3.1-3.1) = 11 m. The farthest picking position from (11) is in Zone 3, Row 1, and Stack

1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+3.9) +(55-1.9-2-3.1-3.1) = 84.7 m.

3. At the picking position (8), “Lift truck 3” will pick the pallet loads to the “6-wheeled truck 1” sortation position (11) after “Lift truck 4” has lifted the sorted pallet load to the loaded pallet load stage area (5) or the empty pallet board to the empty pallet board storage area (6) already, and let the workers load the plastic resins sacks to the truck. The nearest picking position to (11) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.9+3.6)+(10+3.6-1.9-2-3.1-3.1) = 11 m. The farthest picking position to (11) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+3.9) +(55-1.9-2-3.1-3.1) = 84.7 m.
4. Then “Lift truck 3” will go from (11) to the “Lift truck 4” sortation position (12). The distance is 3.1 m.
5. At “Lift truck 4” sortation position (12), “Lift truck 3” will lift the sorted pallet load to the loaded pallet load stage area (5) or lift the empty pallet board to the empty pallet board storage area (6). If “Lift truck 3” picks the sorted pallet load to (5), the distance is (3.1+3.1+3.1+1.9+2)+3.9 = 17.1 m. If “Lift truck 3” picks the empty pallet board to (6), the distance is (1.9+4.5+4.3)+2.4 = 13.1 m.
6. If there is a sorted pallet load at the loaded pallet load stage area (5), “Lift truck 3” will go to (5) and lift the sorted pallet load from the loaded pallet load stage area to the storage area (8).

The activities will be the loop like above until the sortation for “6-wheeled truck 1” finish. The loop of “Lift truck 3” is shown in Figure 5.19. The step summary is shown in Table 5-6.

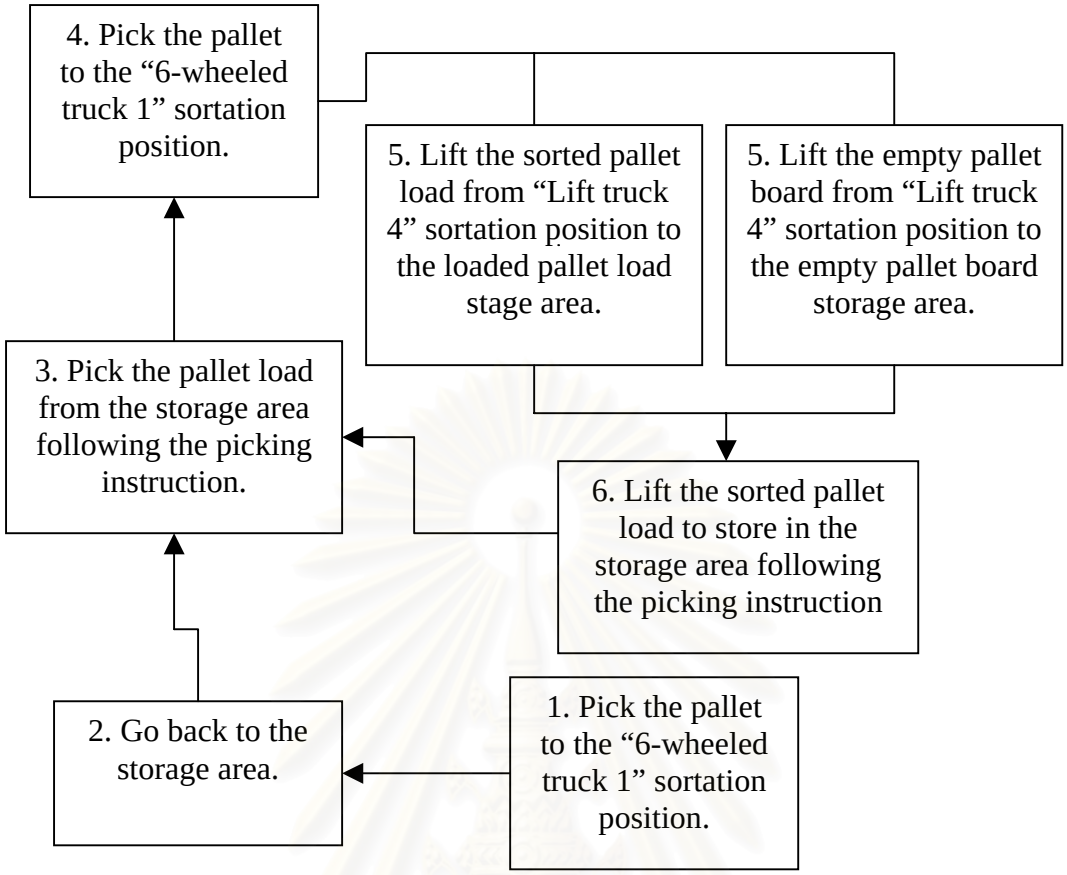


FIGURE 5.19 Loop of “Lift truck 3” to sort for “6-wheeled truck 1”

TABLE 5-6 Step summary of “Lift truck 3” to sort for “6-wheeled truck 1”

Steps	Position		Distance (m)	
	From	To	Min.	Max.
1	(8)	(11)	11	84.7
2	(11)	(8)	11	84.7
3	(8)	(11)	11	84.7
4	(11)	(12)	3.1	3.1
5	(12)	(5)	17.1	17.1
Or	(12)	(6)	13.1	13.1

“Lift truck 4” will start the work by receiving the picking instruction of “lift truck 4” from the supervisor. The steps of “Lift truck 4” are as following.

1. “Lift truck 4” will wait until the first pallet load of “Lift truck 3” position has sorted finish, “Lift truck 4” will lift the sorted pallet load or the empty pallet board from “Lift truck 3” sortation position (11) to the loaded pallet load stage area (5) or the empty

pallet board storage area (6). If “Lift truck 4” picks the loaded pallet load to (5), the distance is (3.1+3.1+1.9+2)+3.9 = 14 m. If “Lift truck 4” picks the empty pallet board to (6), the distance is (3.1+1.9+4.5+4.3)+2.4 = 16.2 m.

2. Then “Lift truck 4” will go from (5) or (6) to the picking position (8) following the picking instruction. If “Lift truck 4” goes from (5) to (8), the nearest picking position from (5) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is 3.6+(10+3.6) = 17.2 m. The farthest picking position from (5) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6) +55 = 90.9 m. If “Lift truck 4” goes from (6) to (8), the nearest picking position from (6) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.6+6.3)+(4.3+4.5+1.9) = 20.6 m. The farthest picking position from (6) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+6.3) +(4.3+21.8+5) = 73.3 m.
3. At the picking position (8), “Lift truck 4” will pick the pallet loads to the “6-wheeled truck 2” sortation position (12), and let the workers load the plastic resins sacks to the truck. The nearest picking position to (12) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.6+3.9)+(10+3.6-1.9-2-3.1-3.1-3.1) = 7.9 m. The farthest picking position to (12) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+3.9) +(55-1.9-2-3.1-3.1-3.1) = 81.6 m.
4. Then “Lift truck 4” will go from (12) to (11). The distance is 3.1 m.
5. At (11) “Lift truck 4” will lift the loaded pallet load or the empty pallet board from “Lift truck 3” shipping position (11) to the loaded pallet load stage area (5) or the empty pallet board storage area (6). If “Lift truck 4” picks the sorted pallet load to (5), the distance is (3.1+3.1+1.9+2)+3.9 = 14 m. If “Lift truck 4” picks the

empty pallet board to (6), the distance is (3.1+1.9+4.5+4.3)+2.4 = 16.2 m.

6. Then “Lift truck 4” will go from (5) or (6) to the picking position (8) following the picking instruction again. If “Lift truck 4” goes from (5) to (8), the nearest picking position from (5) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is 3.6+(10+3.6) = 17.2 m. The farthest picking position from (5) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6) +55 = 90.9 m. If “Lift truck 4” goes from (6) to (8), the nearest picking position from (6) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.6+6.3)+(4.3+4.5+1.9) = 20.6 m. The farthest picking position from (6) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+6.3) +(4.3+21.8+5) = 73.3 m.
7. At (8), “Lift truck 4” will pick the pallet loads to the “6-wheeled truck 2” sortation position (12) after “Lift truck 3” has lifted the sorted pallet load to the loaded pallet load stage area (5) or the empty pallet board to the empty pallet board storage area (6) already, and let the workers load the plastic resins sacks to the truck. The nearest picking position to (12) is in Zone 2, Row 8, and Stack 10 (8/1). So the minimum distance is (3.6+3.9)+(10+3.6-1.9-2-3.1-3.1-3.1) = 7.9 m. The farthest picking position to (12) is in Zone 3, Row 1, and Stack 1 (8/3). So the maximum distance is (17+3.9+11.4+3.6+3.9) +(55-1.9-2-3.1-3.1-3.1) = 81.6 m.
8. Then “Lift truck 4” will lift the loaded pallet load or the empty pallet board from “Lift truck 3” sortation position (11) to the loaded pallet load stage area (5) or the empty pallet board storage area (6).
9. If there is a sorted pallet load at the loaded pallet load stage area (5), “Lift truck 4” will go to (5) and lift the sorted pallet load from the loaded pallet load stage area to the storage area (8).

The activities will be the loop like above until the sortation for “6-wheeled truck 2” finish. The loop of “Lift truck 4” is shown in Figure 5.20. The step summary is shown in Table 5-7.

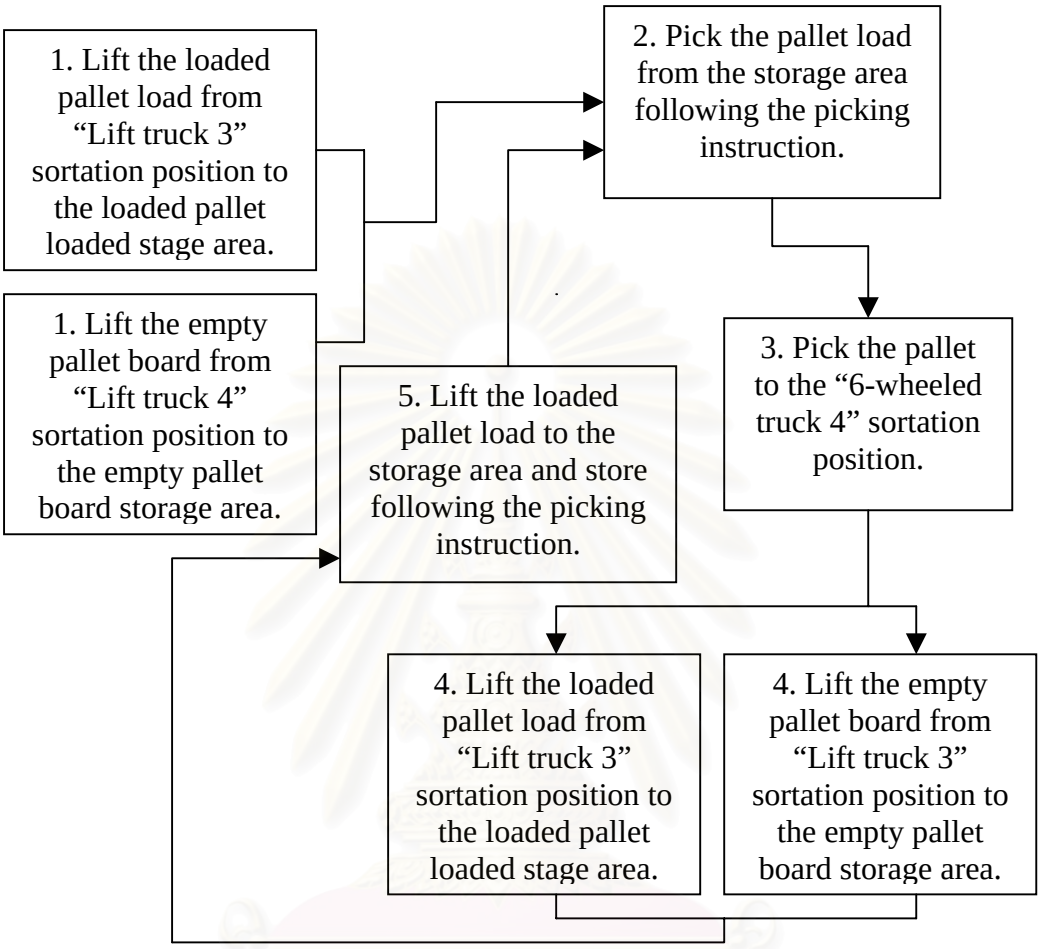


FIGURE 5.20 Loop of “Lift truck 4” to sort for “6-wheeled truck 2”

The first to fourth picking for sortation of the two 4-wheeled trucks must be finished before 10.10am, 11.50am, 1.30pm, and 3.10pm respectively. While the first and second picking for sortation of the two 6-wheeled trucks must be finished before 11.20am and 2.40pm respectively

5.3.3 Lift truck quantity

From the lift truck activity design, it can see that the warehouse has to use 4 lift trucks; “Lift truck 1”, “Lift truck 2”, “Lift truck 3”, and “Lift truck 4”.

TABLE 5-7 Step summary of “Lift truck 4” to sort for “6-wheeled truck 2”

Steps	Position		Distance (m)	
	From	To	Min.	Max.
1	(11)	(5)	14	14
Or	(11)	(6)	16.2	16.2
2	(5)	(8)	17.2	90.9
Or	(6)	(8)	20.6	73.3
3	(8)	(12)	7.9	81.6
4	(12)	(11)	3.1	3.1
5	(11)	(5)	14	14
Or	(11)	(6)	16.2	16.2
6	(5)	(8)	17.2	90.9
Or	(6)	(8)	20.6	73.3
7	(8)	(12)	7.9	81.6

CHAPTER 6

DESIGN EVALUATION

6.1 Warehouse Validation

In this warehouse design, I will do the warehouse validation by walking through the operational procedure design, look whether the operation of the design is appropriate or not, and whether the equipment and physical design can support the operational procedure design or not.

Assume that today is Friday 4th January 2002; the supervisor has already checked the inventory level since yesterday evening. The followings are the inventory level of the warehouse today.

TABLE 6-1 The Inventory Level of PP Film in Zone 1

Zone 1 : Inventory level of PP Film									
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1					9	P601 F	10	28.000	26/12/2001
2	1126 NK	5	14.000	27/12/2001	10	PD943	2	5.000	3/12/2001
3					11	1126 NK	2	4.000	6/12/2001
4	1126 NN	3	8.000	4/12/2001	12				
5	1126 NK	10	28.000	28/12/2001	13	P600 F	5	13.000	19/12/2001
6	PD943	6	17.000	15/12/2001	14				
7					15				
8	P600 F	3	9.000	11/12/2001	16	1126 NN	9	25.000	12/12/2001

TABLE 6-2 The Inventory Level of PP Inject in Zone 2

Zone 2 : Inventory level of PP Inject									
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1	1100 NK	10	28.000	3/1/2002	9	P700 J	6	16.000	8/12/2001
2					10	1100 NN	3	9.000	14/12/2001
3					11				
4	1100 NK	5	14.000	28/12/2001	12	6331	5	14.000	19/12/2001
5	1100 RC	3	8.000	29/11/2001	13				
6					14	1100 NK	1	3.000	10/12/2001
7	6331	4	11.000	4/12/2001	15				
8									

TABLE 6-3 The Inventory Level of LDPE and GPPS in Zone 3

Zone 3 : Inventory level of LDPE					Zone 3 : Inventory level of GPPS				
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1	JJ4324	5	14.000	2/1/2002	12	GP110	5	14.000	28/12/2001
2					13	656 D	3	8.700	11/12/2001
3	ST1018	5	12.600	26/12/2001	14				
4	SU1018	4	11.000	22/12/2001	15	GP150	5	14.000	19/12/2001
5	JJ4324	3	8.000	18/12/2001	16				
6					17	685 D	1	3.000	13/12/2001
7	LD1905 F	3	7.800	4/12/2001	18	685 D	5	14.000	25/12/2001
8	ST1018	2	5.000	4/12/2001	19				
Zone 3 : Inventory level of GPPS					20	GP150	5	12.300	20/12/2001
9	656 D	4	12.000	12/12/2001	21				
10	GP110	2	5.500	28/11/2001	22	GP150	1	2.500	12/12/2001
11					23	GP110	3	9.000	17/12/2001

TABLE 6-4 The Inventory Level of PP Yarn in Zone 4

Zone 4 : Inventory level of PP Yarn									
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1					11	1102 K	2	5.000	7/12/2001
2	1102 K	5	14.000	29/12/2001	12				
3	P400 S	5	13.000	24/12/2001	13				
4					14	P401 J	1	3.000	27/12/2001
5	1102 J	2	6.000	3/12/2001	15	6531	2	5.500	17/12/2001
6					16				
7	6531	4	11.000	25/12/2001	17	1102 J	4	11.000	15/12/2001
8					18				
9	P400 S	1	3.000	20/12/2001	19				
10					20	1102 K	3	8.000	21/12/2001
					21				

TABLE 6-5 The Inventory Level of HDPE in Zone 5

Zone 5 : Inventory level of HDPE									
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1	GA3750	3	9.000	14/12/2001	12				
2					13	H6240 B	3	6.800	7/12/2001
3	700 F	4	12.000	6/12/2001	14	G2855	1	2.000	28/11/2001
4	GM2865	3	7.500	15/12/2001	15				
5	V1160	2	5.400	18/12/2001	16	GM2865	3	6.400	26/12/2001
6					17				
7	N3260	5	14.000	22/12/2001	18	V1160	4	11.500	29/12/2001
8					19				
9					20	GA3750	3	7.000	21/12/2001
10	N3260	2	5.000	20/12/2001	21				
11	G2855	5	13.000	24/12/2001					

TABLE 6-6 The Inventory Level of HIPS and ABS in Zone 6

Zone 6 : Inventory level of HIPS					Zone 6 : Inventory level of ABS				
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1	HI650	5	14.000	27/12/2001	13				
2					14	MH-1	5	14.000	2/12/2001
3					15	GA800	5	14.000	24/12/2001
4	486 M	3	7.400	18/12/2001	16				
5	HI650	2	5.600	22/12/2001	17	MH-1	3	8.000	2/12/2001
6					18				
7	HI830	3	8.000	24/12/2001	19	GA800	3	7.500	11/12/2001
8					20				
9					21				
10	486 B	5	14.000	29/12/2001	22	MH-1	5	14.000	22/12/2001
11					23				
12	486 B	2	3.800	6/12/2001	24	MH-1	5	14.000	14/12/2001

The receiving and storing supervisor has received the information about the sending supplier, sending date, and type, grade, and quantity of each material from the head office before the sending day. Assume that they are as followings.

TABLE 6-7 Information of the Receiving Materials

Supplier	Type	Grade	Tons	Sending Date
A	PP Inject	1100 RC	14	4/1/2002
A	HIPS	HI830	14	4/1/2002
B	HDPE	G2865	14	4/1/2002
C	PP Yarn	401 J	14	4/1/2002
C	LDPE	LD1905 F	14	4/1/2002
D	PP Film	PD943	14	4/1/2002
E	HIPS	486 M	14	4/1/2002

The shipping supervisor has also received the information about customer's name and address, grades, types, and quantity of the plastic resins, and the sending date of the customer orders from the head office before the sending day. Assume that they are as followings.

TABLE 6-8 Information of the Customer Orders

Customer	Type	Grade	Tons	Sending Date
A	PP Film	1126 NK	5.000	4/1/2002
	LDPE	JJ4324	2.000	4/1/2002
B	HDPE	N3260	4.000	4/1/2002
	PP Yarn	401 J	2.000	4/1/2002
C	HIPS	HI830	1.500	4/1/2002
D	GPPS	GP110	2.000	4/1/2002
	HIPS	HI830	1.000	4/1/2002
E	PP Inject	6331	1.500	4/1/2002
F	ABS	MH-1	2.500	4/1/2002
G	PP Film	PD943	3.200	4/1/2002
	HDPE	GA3750	1.000	4/1/2002

After that the operation of every working day will start.

6.1.1 Receiving

6.1.1.1From the information of receiving materials, there are 7 trucks from 5 suppliers today. The 7 trucks will entry the warehouse area before 6.00am. The 6 trucks are driven to the receiving docks area and moved backward to the dock doors. The seventh truck will wait at the truck holding area.

6.1.1.2The six dock doors will open at 8.00am. The 6 truck drivers from supplier A, B, C, and D will go to the warehouse office and give the invoice of the materials in each truck to the supervisor.

6.1.1.3The receiving and storing supervisor will check the information of the invoices and compare with the information of the receiving materials. The invoices will show that

"Supplier truck 1" from "Supplier A" sends PP Inject (1100RC) 14,000 kg

"Supplier truck 2" from "Supplier A" sends HIPS (HI830) 14,000 kg

"Supplier truck 3" from "Supplier B" sends HDPE (G2865) 14,000 kg

"Supplier truck 4" from "Supplier C" sends PP Yarn (401J) 14,000 kg

"Supplier truck 5" from "Supplier C" sends LDPE (LD1905F) 14,000 kg

"Supplier truck 6" from "Supplier D" sends PP Film (PD943) 14,000 kg

6.1.1.4"Lift truck 4" will lift the empty pallet boards to put under the back of the trucks at the unloading area by 2 pallet boards per truck. The receiving and storing supervisor will go to the receiving area and tell the workers to open the 6 container doors. The workers will start to unload the plastic resins sacks. At each truck, 2 workers will climb up the truck while other two workers are at below. The two workers on the truck will drop the sacks of plastic resins to each pallet and the workers below will separate the sacks on the pallet board.

6.1.1.5The workers will separate 5 sacks in each layer, 3 sacks are cross and 2 sacks are straight and alternate in the above layer until 8 layers height for each pallet load. "Lift truck 3" will the full pallet load out of the unloading area to the receiving stage area by putting 1100RC in row 1, HI830 in row 2, G2865 in row 3, 401J in row 4, LD1905F in row 5, and PD943 in row 6. At the same time, "Lift truck 4" will lift

the empty pallet boards to put at the position that “Lift truck 3” has already lifted the pallet board out.

6.1.1.6The activities of 6.1.1.4 and 6.1.1.5 will be done continuously. The workers will check the quality of the plastic resins sacks by looking that whether the sacks are wet or broken. If any sacks are wet or broken, the workers will tell the receiving and storing supervisor. The supervisor will decide whether to receive or return to the suppliers. The type, grade and quantity of the return materials will be written into the supplier’s invoice. The supervisor will count the quantity of the received materials from the quantity of the pallet board. Assuming that there is no return; there are 14 full pallet loads.

6.1.1.7When the materials are unloaded about half of the container; other two workers will climb up into the trucks to help the first two workers drop the plastic resins sacks. The activities of 6.1.1.4 and 6.1.1.5 will be done continuously until all the 14 tons materials of each truck are processed in the activities. The workers will close the container doors. The receiving and storing supervisor will sign the invoices and return the invoice copies back to the truck drivers.

6.1.1.8“Truck 6” will drive out of the receiving area to the truck holding area and let “Truck 7” replace it at the receiving area. The truck driver will give the invoice of the materials to the receiving and storing supervisor. The receiving and storing supervisor will check the information of the invoice and compare with the information of the receiving materials. It will show that “Truck 7” from “Supplier E” sends HIPS (486M) 14,000 kg.

6.1.1.9The receiving activities of “Truck 7” will start again and proceed until all the 14 tons materials are processed in the activities. All the trucks have to wait until 10.00am; the 7 trucks will exit the warehouse.

6.1.2 Put-away

6.1.2.1The receiving and storing supervisor will prepare the put-away instruction by cooperating with the shipping supervisor that will prepare the picking instruction. Assume that the shipping supervisor has planned for sending the materials to the customers for the first trip as following.

TABLE 6-9 Customers Sending for the First Trip

Shipping Truck	Customer	Type	Grade	Tons
4-wheeled truck 1	D	GPPS	GP110	2.000
4-wheeled truck 2	B	PP Yarn	401 J	2.000
6-wheeled truck 1	G	PP Film	PD943	3.200
		HDPE	GA3750	1.000
6-wheeled truck 2	D	HIPS	HI830	1.000
	B	HDPE	N3260	4.000

The receiving and storing supervisor will check the storage position of the inventory from the computer, look at the information of the receiving materials and the information of customers sending, and decide whether the receiving materials should store in which zone and which row, or should go to the shipping area.

TABLE 6-10 Supervisor's Decision

Type	Grade	Tons	Zone	Row	Stacks	Pallets	Shipping Truck
PP Inject	1100 RC	14.000	2	8	5	14	N/A
HIPS	HI830	14.000	6	9	5	14	N/A
HDPE	G2865	14.000	5	21	5	14	N/A
PP Yarn	401 J	12.000	4	10	4	12	N/A
PP Yarn	401 J	2.000	N/A	N/A	N/A	2	4-wheeled truck 2
LDPE	LD1905 F	14.000	3	6	5	14	N/A
PP Film	PD943	10.800	1	15	4	11	N/A
PP Film	PD943	3.200	N/A	N/A	N/A	4	6-wheeled truck 1
HIPS	486 M	14.000	6	11	5	14	N/A

The supervisor will make the put-away instruction and give to "Lift truck driver 1" and "Lift truck driver 2".

TABLE 6-11 The Put-away Instruction for "Lift truck 1"

ThePut-away instruction for "Lift truck 1"								
Sequence	Lifting Position	Materials			Putting Position			
		Type	Grade	Tons	Zone	Row	Stack	Shipping Truck
1 and 2	Supplier truck 6	PP Film	PD943	2.000	1	15	1	N/A
3 to 6	Supplier truck 6	PP Film	PD943	4.000	N/A	N/A	N/A	6-wheeled truck 1
7 to 14	Supplier truck 6	PP Film	PD943	8.000	1	15	4	N/A
1 to 14	Supplier truck 5	LDPE	L1905 F	14.000	3	6	5	N/A

TABLE 6-12 The Put-away Instruction for “Lift truck 2”

ThePut-away instruction for "Lift truck 2"								
Sequence	Lifting Position	Materials			Putting Position			
		Type	Grade	Tons	Zone	Row	Stack	Shipping Truck
1 and 2	Supplier truck 4	PP Yarn	401J	2.000	N/A	N/A	N/A	4-wheeled truck 2
3 to 14	Supplier truck 4	PP Yarn	401J	12.000	4	10	4	N/A
1 to 14	Supplier truck 3	HDPE	GM2865	14.000	5	21	5	N/A

6.1.2.2The 2 lift trucks will lift the pallet loads to the storage or the shipping area following the 2 put-away instructions. It can see that, the non-polar polymers such as PP Yarn and PP Film that cannot dissolve water in the air, “First in First out” is not so strict. When the materials are received, the lift trucks can lift the materials to the shipping area to load and ship to the customers suddenly. While the polar polymers that can dissolve water in the air (“First in First out” is strict) such as HIPS, and non-polar polymers such as HDPE and LDPE that do not have any shipping to the customers, the lift trucks will lift the pallet loads to store in the storage area.

6.1.2.3After the seventh truck is received completely, “Lift truck 3” and “Lift truck 4” will help “Lift truck 1” and “Lift truck 2” putting the received pallet loads from the receiving stage area to the storage area. The receiving and storing supervisor will give the put-away instruction to “Lift truck driver 3” and “Lift truck driver 4”.

TABLE 6-13 The Put-away Instruction for “Lift truck 3”

ThePut-away instruction for "Lift truck 3"								
Sequence	Lifting Position	Materials			Putting Position			
		Type	Grade	Tons	Zone	Row	Stack	Shipping Truck
1 to 14	Supplier truck 2	HIPS	HI830	14.000	6	9	5	N/A
1 to 7	Supplier truck 6	HIPS	486M	7.000	6	11	5	N/A

TABLE 6-14 The Put-away Instruction for “Lift truck 4”

ThePut-away instruction for "Lift truck 4"								
Sequence	Lifting Position	Materials			Putting Position			
		Type	Grade	Tons	Zone	Row	Stack	Shipping Truck
1 to 14	Supplier truck 1	PP Inject	1100RC	14.000	2	8	5	N/A
1 to 7	Supplier truck 6	HIPS	486M	7.000	6	11	5	N/A

6.1.3 Storage

6.1.3.1The lift trucks will lift the pallet loads from the receiving stage area to store in the correct zone and row following the put-away instruction.

6.1.3.2After storing the pallet loads, the receiving and storing supervisor will update the inventory level in the computer. With this information, the supervisor can know the storing position of every plastic resins grade. So the supervisor will know where the new receiving materials should be stored and where the customer orders should be picked.

TABLE 6-15 The Updated Inventory Level of PP Film in Zone 1

Zone 1 : Inventory level of PP Film									
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1					9	P601 F	10	28.000	26/12/2001
2	1126 NK	5	14.000	27/12/2001	10	PD943	2	5.000	3/12/2001
3					11	1126 NK	2	4.000	6/12/2001
4	1126 NN	3	8.000	4/12/2001	12				
5	1126 NK	10	28.000	28/12/2001	13	P600 F	5	13.000	19/12/2001
6	PD943	6	17.000	15/12/2001	14				
7					**15**	**PD943**	**4**	**10 .800**	**4/1/2002**
8	P600 F	3	9.000	11/12/2001	16	1126 NN	9	25.000	12/12/2001

TABLE 6-16 The Updated Inventory Level of PP Inject in Zone 2

Zone 2 : Inventory level of PP Inject									
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1	1100 NK	10	28.000	3/1/2002	9	P700 J	6	16.000	8/12/2001
2					10	1100 NN	3	9.000	14/12/2001
3					11				
4	1100 NK	5	14.000	28/12/2001	12	6331	5	14.000	19/12/2001
5	1100 RC	3	8.000	29/11/2001	13				
6					14	1100 NK	1	3.000	13/12/2001
7	6331	4	11.000	4/12/2001	15				
8	**1100 RC**	**5**	**14 .000**	**4/1/2002**					

TABLE 6-17 The Updated Inventory Level of LDPE and GPPS in Zone 3

Zone 3 : Inventory level of LDPE					Zone 3 : Inventory level of GPPS				
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1	JJ4324	5	14.000	2/1/2002	12	GP110	5	14.000	28/12/2001
2					13	656 D	3	8.700	11/12/2001
3	ST1018	5	12.600	26/12/2001	14				
4	SU1018	4	11.000	22/12/2001	15	GP150	5	14.000	19/12/2001
5	JJ4324	3	8.000	18/12/2001	16				
6	**LD1905 F**	**5**	**14 .000**	**4/1/2002**	17	685 D	1	3.000	13/12/2001
7	LD1905 F	3	7.800	4/12/2001	18	685 D	5	14.000	25/12/2001
8	ST1018	2	5.000	4/12/2001	19				
Zone 3 : Inventory level of GPPS					20	GP150	5	12.300	20/12/2001
9	656 D	4	12.000	12/12/2001	21				
10	GP110	2	5.500	28/11/2001	22	GP150	1	2.500	12/12/2001
11					23	GP110	3	9.000	17/12/2001

TABLE 6-18 The Updated Inventory Level of PP Yarn in Zone 4

Zone 4 : Inventory level of PP Yarn									
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1					11	1102 K	2	5.000	7/12/2001
2	1102 K	5	14.000	29/12/2001	12				
3	P400 S	5	13.000	24/12/2001	13				
4					14	P401 J	1	3.000	27/12/2001
5	1102 J	2	6.000	3/12/2001	15	6531	2	5.500	17/12/2001
6					16				
7	6531	4	11.000	25/12/2001	17	1102 J	4	11.000	15/12/2001
8					18				
9	P400 S	1	3.000	20/12/2001	19				
10	**401 J**	**4**	**12 .000**	**4/1/2002**	20	1102 K	3	8.000	21/12/2001
					21				

TABLE 6-19 The Updated Inventory Level of HDPE in Zone 5

Zone 5 : Inventory level of HDPE									
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1	GA3750	3	9.000	14/12/2001	12				
2					13	H6240 B	3	6.800	7/12/2001
3	700 F	4	12.000	6/12/2001	14	G2855	1	2.000	28/11/2001
4	GM2865	3	7.500	15/12/2001	15				
5	V1160	2	5.400	18/12/2001	16	GM2865	3	6.400	26/12/2001
6					17				
7	N3260	5	14.000	22/12/2001	18	V1160	4	11.500	29/12/2001
8					19				
9					20	GA3750	3	7.000	21/12/2001
10	N3260	2	5.000	20/12/2001	**21**	**G2865**	**5**	**14 .000**	**4/1/2002**
11	G2855	5	13.000	24/12/2001					

TABLE 6-20 The Updated Inventory Level of HIPS and ABS in Zone 6

Zone 6 : Inventory level of HIPS					Zone 6 : Inventory level of ABS				
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1	HI650	5	14.000	27/12/2001	13				
2					14	MH-1	5	14.000	2/12/2001
3					15	GA800	5	14.000	24/12/2001
4	486 M	3	7.400	18/12/2001	16				
5	HI650	2	5.600	22/12/2001	17	MH-1	3	8.000	2/12/2001
6					18				
7	HI830	3	8.000	24/12/2001	19	GA800	3	7.500	11/12/2001
8					20				
9	**HI830**	**5**	**14 .000**	**4/1/2002**	21				
10	486 B	5	14.000	29/12/2001	22	MH-1	2	14.000	22/12/2001
11	**486 M**	**5**	**14 .000**	**4/1/2002**	23				
12	486 B	2	3.800	6/12/2001	24	MH-1	2	14.000	14/12/2001

6.1.4 Order Picking for Shipping

6.1.4.1After the shipping supervisor receives the customer orders from the head office; he/she will plan for the sequence and routing of sending the plastic resins to the customers. (This plan is not concerned in this research.) The customers sending of the first trip is assumed and shown in Table 6-9.

6.1.4.2The shipping supervisor will plan for the sequence of order picking. If the truck has to send products to more than one customers such as “6-wheeled truck 2”, the plastic resins grades of the last sending customer must be picked first because

when the lift truck lifts the order picking grade of the last sending customer to the shipping area, the workers can separate this grade at the most inside of the truck.

6.1.4.3The shipping supervisor will plan for the position of order picking whether from the receiving stage area or the storage area. The picking from the storage area will be picked from the row that receives earliest of the picked grade (the earliest receiving date) for First in First out.

6.1.4.4The shipping supervisor will make the first picking instructions for “Lift truck 1” and “Lift truck 2”.

TABLE 6-21 The First Picking Instruction for “Lift truck 1”

The First Picking Instruction for "Lift truck 1 "									
Sequence	Picking Position				Materials				Shipping Truck
	Zone	Row	Stack	Supplier Truck	Type	Grade	Tons	Left	
1	3	23	3	N/A	GPPS	GP110	1.000	0.000	4-wheeled truck 1
2	3	23	3	N/A	GPPS	GP110	1.000	0.000	4-wheeled truck 1
3	N/A	N/A	N/A	Supplier truck 6	PP Film	PD943	1.000	0.000	6-wheeled truck 1
4	N/A	N/A	N/A	Supplier truck 6	PP Film	PD943	1.000	0.000	6-wheeled truck 1
5	N/A	N/A	N/A	Supplier truck 6	PP Film	PD943	1.000	0.000	6-wheeled truck 1
6	N/A	N/A	N/A	Supplier truck6	PP Film	PD943	1.000	0.800	6-wheeled truck 1
7	5	1	3	N/A	HDPE	GA3750	1.000	0.000	6-wheeled truck 1

TABLE 6-22 The First Picking Instruction for “Lift truck 2”

The First Picking Instruction for "Lift truck 2 "									
Sequence	Picking Position				Materials				Shipping Truck
	Zone	Row	Stack	Supplier Truck	Type	Grade	Tons	Left	
1	N/A	N/A	N/A	Supplier truck 4	PP Yarn	401J	1.000	0.000	4-wheeled truck 2
2	N/A	N/A	N/A	Supplier truck 4	PP Yarn	401J	1.000	0.000	4-wheeled truck 2
3	5	10	2	N/A	HDPE	N3260	1.000	0.000	6-wheeled truck 2
4	5	10	2	N/A	HDPE	N3260	1.000	0.000	6-wheeled truck 2
5	5	10	1	N/A	HDPE	N3260	1.000	0.000	6-wheeled truck 2
6	5	10	1	N/A	HDPE	N3260	1.000	0.800	6-wheeled truck 2
7	6	7	3	N/A	HIPS	HI830	1.000	0.000	6-wheeled truck 2

6.1.4.5“Lift truck 1” will go to the picking position at zone 3 row 23, pick a pallet load of GP110 to the “4-wheeled truck 1” shipping position, and let the workers load the plastic resins sacks to the truck. Then “Lift truck 1” will go to the receiving stage area at “Supplier truck 6” and lift a pallet load of PD943 to the storage area zone 1 row 15. Then “Lift truck 1” will go to the picking position at zone 3 row 23 again, pick the pallet load of GP110 to the “4-wheeled truck 1” shipping position after “Lift truck 2” has lifted the empty pallet board to the empty pallet board storage area

already, and let the workers load the plastic resins sacks to the truck. Then “Lift truck 1” will lift the empty pallet board from “Lift truck 2” shipping position to the empty pallet board storage area. Then “Lift truck 1” will go to the receiving stage area at “Supplier truck 6” and lift the pallet load of PD943 to the “4-wheeled truck 1” shipping position. Then “Lift truck 1” will lift the empty pallet board from “Lift truck 2” shipping position to the empty pallet board storage area. The activity will be like the loop above following the put-away instruction and picking instruction until the picking is finished.

“Lift truck 2” will wait until the first GP110 pallet load of “Lift truck 1” position has shipped finish, “Lift truck 2” will lift the empty pallet board from “Lift truck 1” shipping position to the empty pallet board storage area. Then “Lift truck 2” will go to the receiving stage area at “Supplier truck 4” and lift a pallet load of 701J to the “4-wheeled truck 2” shipping position. Then “Lift truck 2” will go to the receiving stage area at “Supplier truck 4” and lift a pallet load of 701J to the “4-wheeled truck 2” shipping position again after “Lift truck 1” has lifted the empty pallet board to the empty pallet board storage area already, and let the workers load the plastic resins sacks to the truck. Then “Lift truck 2” will lift the empty pallet board from “Lift truck 1” shipping position to the empty pallet board storage area. Then “Lift truck 2” will go to the receiving stage area at “Supplier truck 4” and lift pallet load of 701J to the storage area zone 4 row 10. Then “Lift truck 2” will go to the picking position at zone 5 row 10, pick a pallet load of N3260 to the “6-wheeled truck 2” shipping position. The activity will be like the loop above following the put-away instruction and picking instruction until the picking is finished.

6.1.5 Shipping

6.1.5.1The shipping supervisor will print the invoice of the materials of the customer orders to the truck drivers.

“4-wheeled truck driver 1” will receive the invoice for Customer D of GP110 2 tons, “4-wheeled truck driver 2” will receive the invoice for Customer B of 401J 2 tons, “6-wheeled truck driver 1” will receive the invoice for Customer G of PD943 3.2 tons and GA3750 1 ton, and “6-wheeled truck driver 2” will receive the invoice for Customer D of HI830 1 ton and for Customer B of N3260 4 tons.

6.1.5.2At the shipping area, the workers will load the picking materials to the trucks. Each truck will have 1 worker on the truck to separate the sacks and 1 worker below to send the sacks for the worker on the truck.

For “4-wheeled truck 1”, the worker on the truck will separate the 80 sacks of GP110 by 4 sacks with 4 layers and 5 sacks long.

For “4-wheeled truck 2”, the worker on the truck will separate the 80 sacks of 401J by 4 sacks with 4 layers and 5 sacks long.

For “6-wheeled truck 1”, the worker on the truck will separate the 128 sacks of PD943 in the depth of the truck by 5 sacks with 8 layers and 4 sacks long, the 40 sacks of GA3750 in the shallow of the truck by 5 sacks with 8 layers and 1 sack long.

For “6-wheeled truck 2”, the worker on the truck will separate the 160 sacks of N3260 in the deep of the truck by 5 sacks with 8 layers and 4 sacks long, the 40 sacks of HI830 in the shallow of the truck by 5 sacks with 8 layers and 1 sack long.

6.1.5.3The truck drivers will look to the sequence of the materials orders that the workers ship, count the sacks, and check whether the sacks are broken or wet or not. If any sacks are broken or wet, the driver will tell the workers to change those sacks.

6.1.5.4After shipping the pallet loads, the shipping supervisor will update the inventory level in the computer.

TABLE 6-23 The Updated Inventory Level of GPPS After First Shipping in Zone 3

Zone 3 : Inventory level of LDPE					**Zone 3 : Inventory level of GPPS**				
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1	JJ4324	5	14.000	2/1/2002	12	GP110	5	14.000	28/12/2001
2					13	656 D	3	8.700	11/12/2001
3	ST1018	5	12.600	26/12/2001	14				
4	SU1018	4	11.000	22/12/2001	15	GP150	5	14.000	19/12/2001
5	JJ4324	3	8.000	18/12/2001	16				
6	**LD1905 F**	**5**	**14 .000**	**4/1/2002**	17	685 D	1	3.000	13/12/2001
7	LD1905 F	3	7.800	4/12/2001	18	685 D	5	14.000	25/12/2001
8	ST1018	2	5.000	4/12/2001	19				
Zone 3 : Inventory level of GPPS					20	GP150	5	12.300	20/12/2001
9	656 D	4	12.000	12/12/2001	21				
10	GP110	2	5.500	28/11/2001	22	GP150	1	2.500	12/12/2001
11					**23**	**GP110**	**3**	**7.000**	**17 /12 /2001**

TABLE 6-24 The Updated Inventory Level of HDPE After First Shipping in Zone 5

Zone 5 : Inventory level of HDPE									
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1	**GA3750**	**3**	**8.000**	**14 /12 /2001**	12				
2					13	H6240 B	3	6.800	7/12/2001
3	700 F	4	12.000	6/12/2001	14	G2855	1	2.000	28/11/2001
4	GM2865	3	7.500	15/12/2001	15				
5	V1160	2	5.400	18/12/2001	16	GM2865	3	6.400	26/12/2001
6					17				
7	N3260	5	14.000	22/12/2001	18	V1160	4	11.500	29/12/2001
8					19				
9					20	GA3750	3	7.000	21/12/2001
10	**N3260**	**1**	**1.800**	**20 /12 /2001**	**21**	**G2865**	**5**	**14 .000**	**4/1/2002**
11	G2855	5	13.000	24/12/2001					

TABLE 6-25 The Updated Inventory Level of HIPS After First Shipping in Zone 5

Zone 6 : Inventory level of HIPS					Zone 6 : Inventory level of ABS				
Row	**Grade**	**Stacks**	**Tons**	**Receving Date**	**Row**	**Grade**	**Stacks**	**Tons**	**Receving Date**
1	HI650	5	14.000	27/12/2001	13				
2					14	MH-1	5	14.000	2/12/2001
3					15	GA800	5	14.000	24/12/2001
4	486 M	3	7.400	18/12/2001	16				
5	HI650	2	5.600	22/12/2001	17	MH-1	3	8.000	2/12/2001
6					18				
7	**HI830**	**3**	**7.000**	**24 /12 /2001**	19	GA800	3	7.500	11/12/2001
8					20				
9	**HI830**	**5**	**14 .000**	**4/1/2002**	21				
10	486 B	5	14.000	29/12/2001	22	MH-1	2	14.000	22/12/2001
11	**486 M**	**5**	**14 .000**	**4/1/2002**	23				
12	486 B	2	3.800	6/12/2001	24	MH-1	2	14.000	14/12/2001

6.1.6 Order Picking for Sortation

6.1.6.1After the shipping supervisor receives the customer orders from the head office; he/she will plan for the sequence and routing of sending the plastic resins to the customers. (This plan is not concerned in this research.) The customers sending of the second trip is assumed as shown in Table 6-26.

6.1.6.2The shipping supervisor will plan for the sequence of order picking. If the truck has to send more than one customers such as “6-wheeled truck 2”, the plastic

resins grades of the first sending customer must be picked first because when the lift truck lifts the order picking grade of the first sending customer to the sortation area, the workers can separate this grade at the most below of the sortation stack.

TABLE 6-26 Customers Sending for the Second Trip

Shipping Truck	Customer	Type	Grade	Tons
4-wheeled truck 1	A	LDPE	JJ4324	2.000
4-wheeled truck 2	C	HIPS	HI830	1.500
6-wheeled truck 1	A	PP Film	1126 NK	5.000
6-wheeled truck 2	E	PP Inject	6331	1.500
	F	ABS	MH-1	2.500

6.1.6.3The shipping supervisor will plan for the position of order picking whether from the receiving stage area or the storage area. The picking from the storage area will be picked from the row that receives earliest of the picked grade (the earliest receiving date) for First in First out.

6.1.6.4The shipping supervisor will make the second picking instructions for “Lift truck 1”, “Lift truck 2”, “Lift truck 3”, and “Lift truck 4”.

TABLE 6-27 The Second Picking Instruction for “Lift truck 1”

The Second Picking Instruction for "Lift truck 1 "									
Sequence	Picking Position				Materials				Shipping Truck
	Zone	Row	Stack	Supplier Truck	Type	Grade	Tons	Left	
1	3	5	3	N/A	LDPE	JJ4324	1.000	0.000	4-wheeled truck 1
2	3	5	3	N/A	LDPE	JJ4324	1.000	0.000	4-wheeled truck 1

TABLE 6-28 The Second Picking Instruction for “Lift truck 2”

The Second Picking Instruction for "Lift truck 2 "									
Sequence	Picking Position				Materials				Shipping Truck
	Zone	Row	Stack	Supplier Truck	Type	Grade	Tons	Left	
1	6	7	3	N/A	HIPS	HI830	1.000	0.000	4-wheeled truck 2
2	6	7	2	N/A	HIPS	HI830	1.000	0.500	4-wheeled truck 2

TABLE 6-29 The Second Picking Instruction for “Lift truck 3”

The Second Picking Instruction for "Lift truck 3 "									
Sequence	Picking Position				Materials				Shipping Truck
	Zone	Row	Stack	Supplier Truck	Type	Grade	Tons	Left	
1	1	11	2	N/A	PP Film	1126 NK	1.000	0.000	6-wheeled truck 1
2	1	11	1	N/A	PP Film	1126 NK	1.000	0.000	6-wheeled truck 1
3	1	11	1	N/A	PP Film	1126 NK	1.000	0.000	6-wheeled truck 1
4	1	11	1	N/A	PP Film	1126 NK	1.000	0.000	6-wheeled truck 1
5	1	2	5	N/A	PP Film	1126 NK	1.000	0.000	6-wheeled truck 1

TABLE 6-30 The Second Picking Instruction for “Lift truck 4”

The Second Picking Instruction for "Lift truck 4 "									
Sequence	Picking Position				Materials				Shipping Truck
	Zone	Row	Stack	Supplier Truck	Type	Grade	Tons	Left	
1	2	7	4	N/A	PP Inject	6331	1.000	0.000	6-wheeled truck 1
2	2	7	4	N/A	PP Inject	6331	1.000	0.500	6-wheeled truck 1
3	6	17	3	N/A	ABS	MH-1	1.000	0.000	6-wheeled truck 1
4	6	17	3	N/A	ABS	MH-1	1.000	0.000	6-wheeled truck 1
5	6	17	2	N/A	ABS	MH-1	1.000	0.500	6-wheeled truck 1

6.1.6.5“Lift truck 1” will go to the picking position at zone 3 row 5, pick a pallet load of JJ4324 to the “4-wheeled truck 1” sortation position, and let the workers sort the plastic resins sacks. Then “Lift truck 1” will go to the picking position at zone 3 row 5 again, pick the pallet load of JJ4324 to the “4-wheeled truck 1” sortation position after “Lift truck 2” has lifted the empty pallet board to the empty pallet board storage area already, and let the workers sort the plastic resins sacks. Then “Lift truck 1” will lift the empty pallet board from “Lift truck 2” sortation position to the empty pallet board storage area. Then “Lift truck 1” will wait until the last pallet load of HI830 at the “Lift truck 2” sortation position sort already. “Lift truck 1” will lift the loaded pallet load to the loaded pallet load stage area for “4-wheeled truck 1”.

“Lift truck 2” will wait until the first JJ4324 pallet load of “Lift truck 1” position has sorted finish, “Lift truck 2” will lift the empty pallet board from “Lift truck 1” sortation position to the empty pallet board storage area. Then “Lift truck 2” will go to the picking position at zone 6 row 7, pick a pallet load of HI830 to the “4-wheeled truck 2” sortation position, and let the workers sort the plastic resins sacks. Then “Lift truck 2” will lift the empty pallet board from “Lift truck 1” sortation position to the empty pallet board storage area. Then “Lift truck 2” will go to the

picking position at zone 6 row 7 again, pick a pallet load of HI830 to the “4-wheeled truck 2” sortation position, and let the workers sort the plastic resins sacks.

“Lift truck 3” will go to the picking position at zone 1 row 11, pick a pallet load of 1126NK to the “6-wheeled truck 1” sortation position, and let the workers sort the plastic resins sacks. Then “Lift truck 3” will go to the picking position at zone 1 row 11 again, pick the pallet load of 1126NK to the “6-wheeled truck 1” sortation position after “Lift truck 4” has lifted the empty pallet board to the empty pallet board storage area already, and let the workers sort the plastic resins sacks. Then “Lift truck 3” will lift the empty pallet board from “Lift truck 2” sortation position to the empty pallet board storage area. The activity will be like the loop above following the put-away instruction and picking instruction until the picking is finished.

“Lift truck 4” will wait until the first 1126NK pallet load of “Lift truck 3” position has sorted finish, “Lift truck 4” will lift the empty pallet board from “Lift truck 3” sortation position to the empty pallet board storage area. Then “Lift truck 4” will go to the picking position at zone 2 row 7, pick a pallet load of 6331 to the “6-wheeled truck 2” sortation position, and let the workers sort the plastic resins sacks. Then “Lift truck 4” will lift the empty pallet board from “Lift truck 3” sortation position to the empty pallet board storage area. Then “Lift truck 4” will go to the picking position at zone 2 row 7 again, pick a pallet load of 6331 to the “6-wheeled truck 2” sortation position, and let the workers sort the plastic resins sacks. “Lift truck 4” will lift the empty pallet board from “Lift truck 3” sortation position to the empty pallet board storage area. Then “Lift truck 4” will lift the left loaded pallet load of 6331 from the loaded pallet load stage to store at zone 2 row 7. The activity will be like the loop above following the put-away instruction and picking instruction until the picking is finished.

6.1.6.6The shipping supervisor will receive the customer orders from the head office and plan for the third to last sending trip. The order picking activities will start again.

6.1.7 Sortation

6.1.7.1The shipping supervisor will make the first sortation instructions for the workers at the sortation area.

TABLE 6-31 The First Sortation Instruction for “4-wheeled truck 1”

The First Sortation Instruction for "4-wheeled truck 1"					
Sequence	**Materials**				**Shipping Truck**
	Type	**Grade**	**Tons**	**Left**	
1	LDPE	JJ4324	1.000	0.000	4-wheeled truck 1
2	LDPE	JJ4324	1.000	0.000	4-wheeled truck 1

TABLE 6-32 The First Sortation Instruction for “4-wheeled truck 2”

The First Sortation Instruction for "4-wheeled truck 2"					
Sequence	**Materials**				**Shipping Truck**
	Type	**Grade**	**Tons**	**Left**	
1	HIPS	HI830	1.000	0.000	4-wheeled truck 2
2	HIPS	HI830	1.000	0.500	4-wheeled truck 2

TABLE 6-33 The First Sortation Instruction for “6-wheeled truck 1”

The First Sortation Instruction for "6-wheeled truck 1"					
Sequence	**Materials**				**Shipping Truck**
	Type	**Grade**	**Tons**	**Left**	
1	PP Film	1126 NK	1.000	0.000	6-wheeled truck 1
2	PP Film	1126 NK	1.000	0.000	6-wheeled truck 1
3	PP Film	1126 NK	1.000	0.000	6-wheeled truck 1
4	PP Film	1126 NK	1.000	0.000	6-wheeled truck 1
5	PP Film	1126 NK	1.000	0.000	6-wheeled truck 1

TABLE 6-34 The First Sortation Instruction for “6-wheeled truck 2”

The First Sortation Instruction for "6-wheeled truck 2"					
Sequence	**Materials**				**Shipping Truck**
	Type	**Grade**	**Tons**	**Left**	
1	PP Inject	6331	1.000	0.000	6-wheeled truck 1
2	PP Inject	6331	1.000	0.500	6-wheeled truck 1
3	ABS	MH-1	1.000	0.000	6-wheeled truck 1
4	ABS	MH-1	1.000	0.000	6-wheeled truck 1
5	ABS	MH-1	1.000	0.500	6-wheeled truck 1

6.1.7.2The workers at the sortation area will sort the plastic resins sacks for each shipping truck by using 2 workers per truck.

The workers at “4-wheeled truck 1” sortation position will sort the 80 sacks of JJ4324 by 8 sacks each layer and sort 10 layers height.

The workers at “4-wheeled truck 2” sortation position will sort the 60 sacks of HI830 by 8 sacks each layer and sort 8 layers height.

The workers at “6-wheeled truck 1” sortation position will sort the 200 sacks of 1126NK by 20 sacks each layer and sort 10 layers height.

The workers at “6-wheeled truck 2” sortation position will sort the 60 sacks of 6331 by 8 sacks each layer and sort 8 layers height and the 60 sacks of MH-1 by putting on the 6331 sacks.

6.1.7.3The sortation will finish before the shipping trucks come back and the shipping activities will start again.

6.1.8 Summary

After going through the operational procedure design of the warehouse, it can be seen that the design is appropriate to the operation of the warehouse. The procedure of the operation can flow continuously without any obstacles. The material handling system and physical design can support the operational procedure design well.

6.2 Costs

6.2.1 Fixed Cost

6.2.1.1 The Warehouse Cost

The building of the warehouse must be designed to store the stacks of pallet load. Each stack loads 3 pallet loads of plastic resins or 3000 kg. The cost to build the warehouse is 6000 Baht per m^2 (Adirek Eiampornrat, interview, November 25, 2001). The warehouse is wide 55 m and long 42.2 m. The area is 2321 m^2. The cost of the warehouse is 6,000*2321 = 13,926,000 Baht.

The road must be designed to give the trucks traveling outside the warehouse. The cost to build the road is 600 Baht per m^2 (Adirek Eiampornrat, interview, November 25, 2001). The outside of the warehouse is wide 57 m and long 39 m. The area is 2223 m^2. The cost of the road is 600*2223 = 1,333,800 Baht.

The overall cost of building the warehouse is 13,926,000+1,333,800 = 15,259,800 Baht.

The useful life of the warehouse is 20 years. The interest rate is 8 % per year. The factor of the present value of an annuity of 8 % per year for 20 years is 9.8181. The present value is 15,259,800 Baht, so the annuity is 15,259,800/9.8181 = 1,554,251.84. The cost of building the warehouse is 1,554,251.84/12 = 129,520.98 per month.

6.2.1.2 The Lift Trucks Cost

The price of the lift truck that can load 2500 kg and lift 4 m is about 809,250 Baht (www.lifttruck.co.uk/forklifts). The warehouse uses 4 lift trucks, so the cost of the lift trucks is 3,237,000 Baht.

The useful life of the lift truck is 5 years. The interest rate is 8 % per year. The factor of the present value of an annuity of 8 % per year for 5 years is 3.9927. The present value is 3,237,000 Baht, so the annuity is 3,237,000/3.9927 = 810,729.58. The cost of lift trucks is 810,729.58/12 = 67,560.80 per month.

The maintenance and energy cost for each lift truck is about 4000 Baht per truck per month (Anasaya Munyukong, interview, November 26, 2001). So the

maintenance and energy cost of the lift trucks in the warehouse is 4000*4 = 16,000 Baht per month.

6.2.1.3 The Trucks Cost

The price of the 4-wheeled truck is 416,000 Baht (www.isuzu-cck.com). The price of the 6-wheeled truck is 645,000 Baht. The warehouse uses two 4-wheeled trucks and two 6-wheeled trucks. So the cost of the trucks is 2,122,000 Baht.

The useful life of the lift truck is 5 years. The interest rate is 8 % per year. The factor of the present value of an annuity of 8 % per year for 5 years is 3.9927. The present value is 2,122,000 Baht, so the annuity is 2,122,000/3.9927 = 531,469.93. The cost of lift trucks is 531,469.93/12 = 44,289.16 Baht per month.

6.2.1.4 The Pallet Boards Cost

The price of the plastic pallet board is 1200 Baht (Anasaya Munyukong, interview, November 26, 2001). The warehouse uses 2100 pallet boards, so the cost of the pallet boards is 2100*1200 = 2,520,000 Baht.

The useful life of the pallet board is 5 years. The interest rate is 8 % per year. The factor of the present value of an annuity of 8 % per year for 5 years is 3.9927. The present value is 2,064,000 Baht, so the annuity is 2,520,000/3.9927 = 631,151.85. The cost of the pallet boards is 631,151.85/12 = 52,595.98 per month.

6.2.1.5 The Employees Cost

The warehouse needs 2 supervisors and another 56 workers. Each supervisor salary is 15,000 Baht per month, so the supervisor cost is 30,000 Baht per month. Each worker salary is 200 Baht per day and 25 working days per month. So the worker cost is 200*25*56 = 280,000 Baht per month. The cost of employees is 310,000 Baht per month.

6.2.1.6 The Overhead Cost

The overhead cost is the monthly cost in the warehouse. The costs are the electricity, water supply, computer, telephone, paper, etc. The cost is about 25,000 Baht per month.

6.2.1.7 The Overall Fixed Cost

TABLE 6-35 Summary of the Fixed Cost

Costs	Baht per month
Fixed Cost	
The warehouse cost	129,520.98
The lift trucks cost	67,560.80
- The maintenance cost	16,000.00
The trucks cost	44,289.16
The pallet boards cost	52,595.98
The employees cost	310,000.00
The overhead cost	25,000.00
The overall fixed cost	644,966.92

6.2.2 Variable Cost

The variable cost is the fuel and the maintenance cost of the 4 shipping trucks. From TaP's warehouse, the trucks have to send the materials about 1100 tons per month. The fuel cost of the trucks is about 80,000 Baht per month. (Anasaya Munyukong, interview, November 26, 2001). So the variable cost is about 80000/(1100*1000) = 0.07 Baht per kilogram of sent materials.

6.3 Cost Evaluation

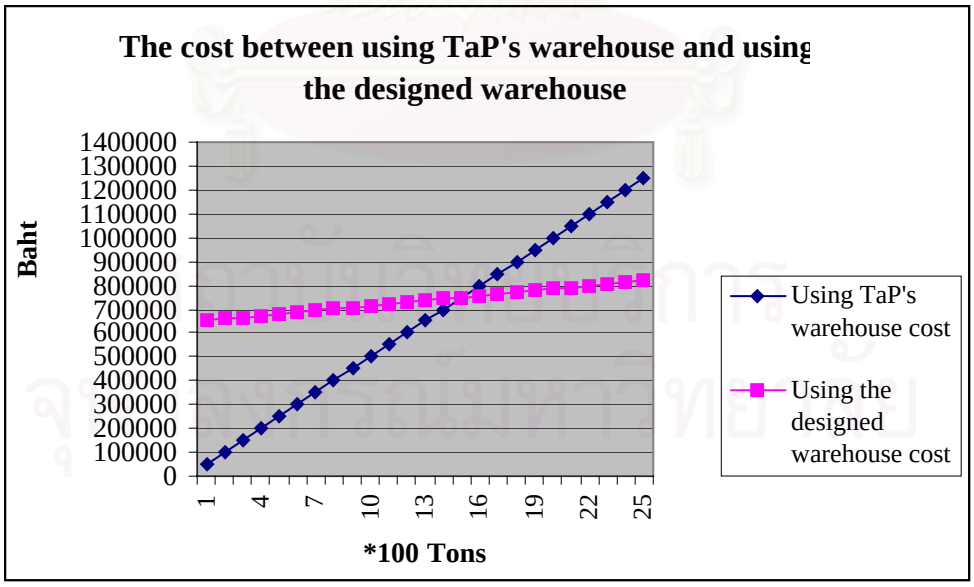
The overall fixed cost is 644,966.92 Baht per month. The variable cost is 0.07 Baht/kg. So the cost of every 100 tons from using the designed warehouse is shown in Table 6-36. The cost that charged from using TaP's warehouse is 0.50 Baht per kilogram. So the cost of every 100 tons from using TaP's warehouse is shown in Table 6-36.

From Figure 6.1, the break-even point of the graph is around 1500 tons. That means the cost of using TaP's warehouse is less than the cost of using the designed warehouse when the operate level is less than 1500 tons per month. The cost of using the designed warehouse is less than the cost of using TaP's warehouse when the operate level is more than 1500 tons per month.

TABLE 6-36 The Cost of Using TaP's Warehouse and the Cost of Using the Designed Warehouse in every 100 Tons

Tons	TaP (Baht)	Designed (Baht)	Tons	TaP (Baht)	Designed (Baht)
0	0.00	644,966.92	1300	650,000.00	735,966.92
100	50,000.00	651,966.92	1400	700,000.00	742,966.92
200	100,000.00	658,966.92	1500	750,000.00	749,966.92
300	150,000.00	665,966.92	1600	800,000.00	756,966.92
400	200,000.00	672,966.92	1700	850,000.00	763,966.92
500	250,000.00	679,966.92	1800	900,000.00	770,966.92
600	300,000.00	686,966.92	1900	950,000.00	777,966.92
700	350,000.00	693,966.92	2000	1,000,000.00	784,966.92
800	400,000.00	700,966.92	2100	1,050,000.00	791,966.92
900	450,000.00	707,966.92	2200	1,100,000.00	798,966.92
1000	500,000.00	714,966.92	2300	1,150,000.00	805,966.92
1100	550,000.00	721,966.92	2400	1,200,000.00	812,966.92
1200	600,000.00	728,966.92	2500	1,250,000.00	819,966.92

FIGURE 6.1 The Graph of Using TaP's Warehouse Cost and Using the Designed Warehouse Cost



The estimated sales level of the designed warehouse is 1000 tons per month. So the cost of using the designed warehouse is more than the cost of using TaP's warehouse. However, the operate level or the inventory level of the designed warehouse is 2100 tons. The cost of using the designed warehouse 2100 tons is less than the cost of using TaP's warehouse. So the new warehouse must be designed. The designed warehouse has some advantages more than using the TaP's warehouse as following.

1. The warehouse has enough capacity to serve PM's customers.
2. The operational procedure, material handling system, and physical are designed for using in PM's warehouse specifically. So the inventory management of the warehouse is suitable for PM's customers.
3. The warehouse can store the materials easily when the price is cheap
4. The company can make more profit than using the warehouse of TaP.

CHAPTER 7

CONCLUSION AND RECOMMENDATION

7.1 Conclusion

Since the plastic industry in Thailand has a very high potential to grow up in the present time and the plastic resins is the most important factor of the plastic products, so the plastic resins industry will be growing also. Polymer Marketing and Trading Co., Ltd. (PM) is a plastic resins trading company that was established in May 2000. PM buys the plastic resins from Thai Asia Plastic Co., Ltd. (TaP), which is an plastic resins' agent of Thai Petrochemical Industry Public Co., Ltd. (TPI). At the first time PM still does not have it own warehouse and transportation trucks. TaP has done these jobs for PM and charged some fees (about 0.5 Baht per kilogram) for them. Nowadays, PM can sell plastic resins for the plastic product companies about 150 tons per month.

PM has estimated the sales in the future to be about 1000 tons per month. So the warehouse's capacities will not be large enough to handle two companies' plastic resins. Moreover, the inventory management of TaP is not suitable for PM because the customers are not the same. This research is about designing a new warehouse for PM to cover 1000 tons per month sales expectation.

The design starts with studying all the warehouse design theories and the material characteristics. Then the existing system of the company is studied. The products that the company sells are the several grades of plastic resins by packing in the 25 kg sacks. The size of the sack is about 0.4 m wide, 0.6 m long, and 0.2 m thick. The sales of the company were shown in Table 3-1. The warehouse of TaP is studied for using as an example of the design. The area inside the warehouse is 1,250 m^2 by the office is 25 m^2, the employees' lounge is 25 m^2, the storage area is 850 m^2, and the parking and shipping area is the rest. The area outside the warehouse is 400 m^2 for the receiving activities. The operation procedure of TaP's warehouse consists of 5 operations; receiving, put-away, storage, order picking, and shipping.

The requirement and forecasting for the design is as following.

1. Sales level in the future will be about 1000 tons per month by PP Film 210, PP Inject 200, PP Yarn 140, HDPE 140, LDPE 50, GPPS 100, HIPS 80, and ABS 80 tons per month.
2. Inventory level will be 2100 tons.
3. Receiving level will be 77.5 tons per day.
4. Suppliers' trucks are the 10-wheeled trucks that can load 14 tons of plastic resins. So PM has to receive about 6 trucks each day.
5. Shipping level will be 50 tons per day.
6. Shipping trucks are 6-wheeled trucks and 4-wheeled trucks. 6-wheeled truck can load 5 tons of plastic resins and can send 3 trips. 4-wheeled truck can load 2 tons of plastic resins and can send 5 trips. So using two 6-wheeled trucks and two 4-wheeled trucks.

After studying the problems that occur in the TaP's warehouse, the warehouse of PM is designed by starting with design brief and designed in 3 parts; an operational procedure design, a material handling system design, and a physical design.

7.1.1 Design Brief

1. Receiving

- The receiving area of TaP's warehouse is too small so the receiving design will support the receiving level 77.5 tons or 6 trucks per day.
- Pallet boards are big and heavy so the receiving operation will be designed by using the lift trucks to move the pallet boards and pallet loads.
- The 1-ton or 40 sacks per pallet load is easier to count and check than the 1.25 tons or 50 sacks per pallet load that is used in TaP's warehouse.

2. Put-away

- The put-away of the TaP's warehouse wastes time so the put-away design must sort the received materials before a put-away operation in the storage area. Moreover, the supervisor has to make the instruction for the lift truck drivers.
- The put-away design has to minimize time of the put-away operation by cross-docking the received materials that can cross-dock to the shipping area, and combining put-away and order picking activities together.

3. Storage

- The storage of TaP's warehouse is not big enough so the designed warehouse must support the inventory level of 2100 tons.
- The TaP's warehouse storage is hard to memorize and find the position of the required grade. The storage design will use "Fixed Storage" by storing the same material in the same group and fixing the location. And the design has to make the identification for the storage position.
- Use "Popularity" by storing the more popular materials in the front section of the storage area with a deep storage and storing the less popular materials in the back section of the storage area with a shallow storage. Use "Similarity" by storing the same type of materials in the same area.

4. Order Picking

- The supervisor of TaP's warehouse has to waste time to find the position of order picking. The order picking design has to eliminate the material-searching activity by using the storage identification and a computer to identify the picking position. The supervisor of the order picking design has to sequence the order picking to minimize the travel time.
- The supervisor has to make the picking instruction for the lift trucks drivers to minimize materials-searching time and errors.

5. **Sortation**

    - There is no sortation activity before the shipping trucks come back to the shipping area. So time is wasted. The sortation design will be made for the warehouse design.

6. **Shipping**

    - The shipping area of the TaP's warehouse is not appropriate for the shipping activities because the shipping area is too big and obstructs the traffic to the receiving area. The shipping procedure will be designed to support the shipping level of 50 tons per day.
    - The customer's orders before the shipping day must be shipped at the early trips. The customer's orders on the shipping day must be shipped at the later trips.

7.1.2 Operational Procedure Design

The operation procedure of the warehouse is designed by having 6 operations.

1. **Receiving** is designed by having 8 steps from the trucks entry the warehouse until the trucks exit the warehouse.
2. **Put-away** is designed by having 3 steps from the lift truck lifts the full pallet loads to the receiving stage area until the lift trucks lift the pallet loads to the storage or shipping area.
3. **Storage** is designed by using floor stack of the 3 levels pallet loads because it is the most convenient and cheapest storage method. Each pallet loads 1 ton or 40 sacks of plastic resins. The storage is divided into zones, front zone and back zone. Front zone is divided into 2 zones for storing PP Film and PP Inject. Back zone is divided into 4 zones for storing GPPS, LDPE, PP Yarn, HDPE, HIPS, and ABS. Storage is designed by having 2 steps from the lift trucks lift the pallet loads to the storage area until the supervisor keep the information of storing in the computer.
4. **Order picking** is designed by having 5 steps from the supervisor receives the customer orders until the lift trucks lift the materials follow the picking instruction.

5. **Sortation** is designed by having 2 steps from the supervisor makes the sortation instruction until the workers sort the materials follow the sortation instruction.
6. **Shipping** is designed by having 4 steps from the supervisor prints the invoices for the shipping truck drivers until the supervisor updates the inventory level.

7.1.3 Material Handling System Design

The material handling system is designed by having two parts, material handling equipment and material handling employees.

1. **Material handling equipment** is designed for 2 purposes. Containers and unitizing equipment is designed in the form of unit loads by using the pallet boards. The designed pallet boards are 1.0*1.2 m and used 2100 pallet boards for the maximum inventory level 2100 tons. Material transport, storage, and retrieval equipment is designed by using the "Counterbalanced Lift Truck". The system is designed by using 4 lift trucks for doing the operations.
2. **Material handling employee** is designed by having 2 supervisors, 36 unloading workers, 4 lift truck drivers, 4 delivery truck drivers, 8 loading workers, 8 sorting workers, and 20 customer service workers. All the sorting workers are from the unloading workers, 8 customer service workers are from the loading workers, and another 8 customer service workers are from the unloading workers. So the warehouse is designed by having 2 supervisors, 4 lift trucks drivers, 4 trucks drivers, and 48 workers.

7.1.4 Physical Design

The physical structure of the warehouse is designed by consisting of inside and outside the warehouse.

1. **Inside the warehouse** is designed by having the space for storage and the space for receiving and shipping.
    - The space for storage is designed by having back zone and front zone. Back zone is 55 m wide and 17 m long. Front zone is 55 m wide and 11.4 m long. Between back zone and front zone there is a

main aisle 3.9 m wide. So the space for storage is 55 m wide and 32.3 m long.

- The space for receiving and shipping is designed by having receiving dock, shipping dock, receiving stage, empty pallet board storage, sortation area, loaded pallet load stage, and supervisor office. The space is 55 m wide and 9.9 m long.

So the warehouse is 55 m wide and 42.2 m long. The stacks load 3 pallet loads or 5.4 m high and the clear space between the ceiling sprinklers and the top of the highest pallet load must be designed for at least 0.45 m. So the warehouse is designed by using 6 m high.

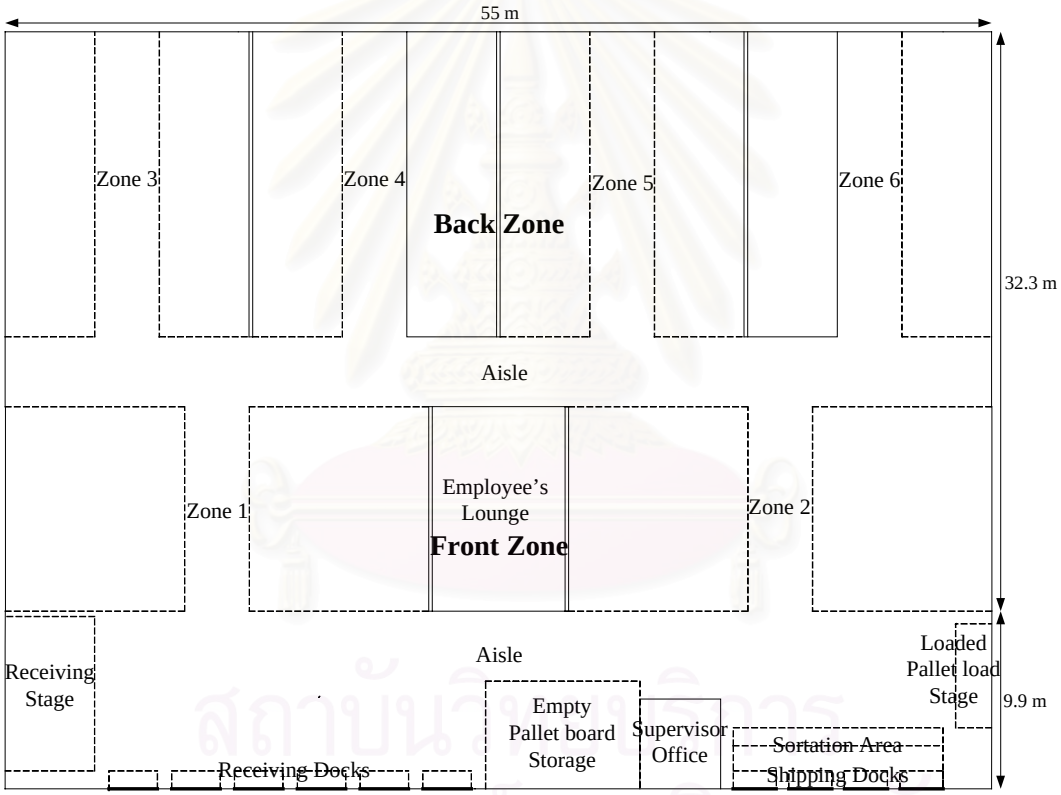


FIGURE 7.1 Inside the Warehouse

2. **Outside the warehouse** is designed by having truck road, truck receiving area, truck shipping area, maneuvering area, and truck holding area. The area is 57 m wide and 39 m long.

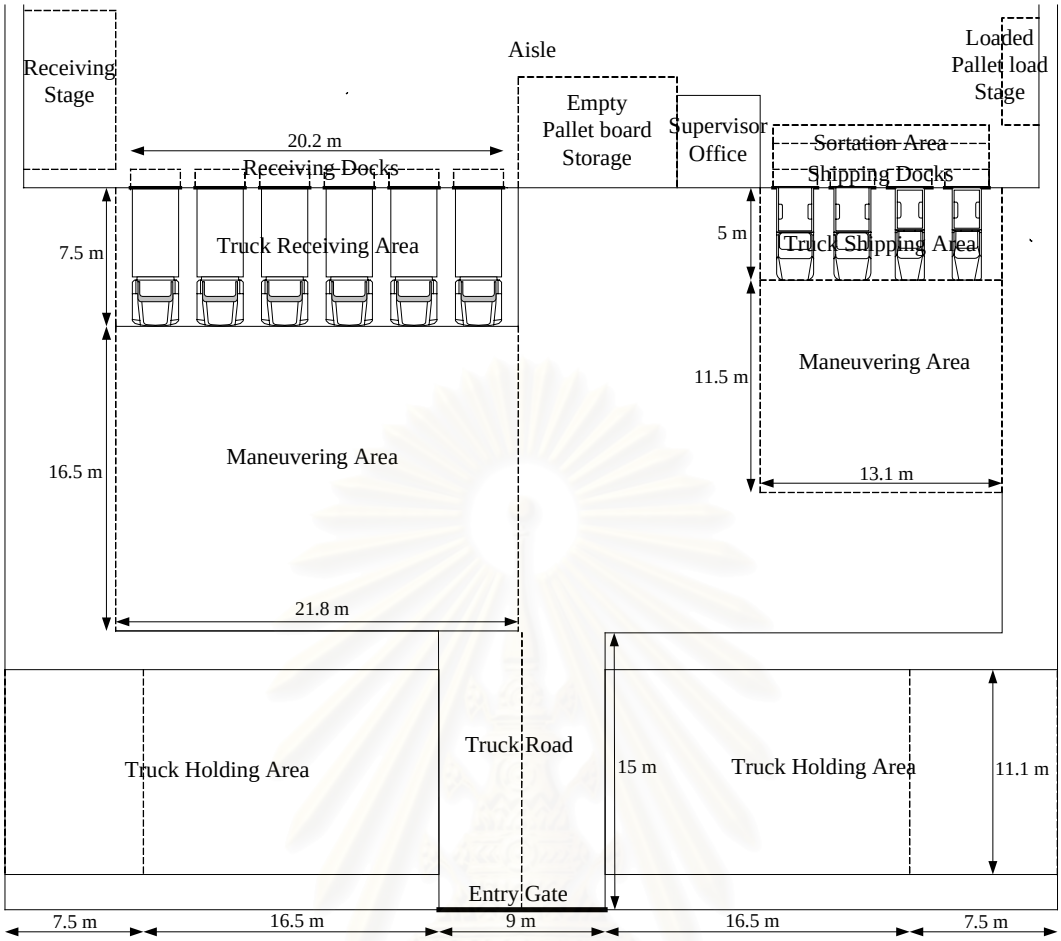


FIGURE 7.2 Outside the Warehouse

After the warehouse was already designed, the design evaluation is done. The design evaluation is done in 2 methods, warehouse validation and cost evaluation.

1. **Warehouse validation** is done by walking through the operational procedure design, look that the operation of the design is appropriate or not, and the equipment and physical design can support the operational procedure design or not. After going through the operational procedure design of the warehouse, it can see that the design is appropriate to the operation of the warehouse. The procedure of the operation can flow continuously without any obstacles. The material handling system and physical design can support the operational procedure design well.

2. **Cost evaluation** consists of

    - Fixed Cost

        ♦ The warehouse cost is 129,520.98 Baht per month.

- ♦ The lift trucks cost is 67,560.80 Baht per month.
- ♦ The maintenance cost is 16,000.00 Baht per month.
- ♦ The trucks cost is 44,289.16 Baht per month.
- ♦ The pallet boards cost is 52,595.98 Baht per month.
- ♦ The employee cost is 310,000.00 Baht per month.
- ♦ The overhead cost is 25,000.00 Baht per month.
- ♦ The overall fixed cost is 644,966.92 Baht per month.

- Variable Cost
  - ♦ The fuel and maintenance cost of the shipping trucks is 0.07 Baht per kg.

The break-even point between the cost of using TaP's warehouse and using the designed warehouse is around 1500 tons per month. The estimated sales level of the designed warehouse is 1000 tons per month. So the cost of using the designed warehouse is more than the cost of using TaP's warehouse. However, the operate level or the inventory level of the designed warehouse is 2100 tons. The cost of using the designed warehouse 2100 tons is less than the cost of using TaP's warehouse. So the new warehouse must be designed. The new warehouse has some advantages over using the warehouse of TaP. The warehouse capacity is enough for the inventory, the design is suitable for PM's customers, the storing is easy, and the company can make more profit.

7.2 Recommendation

1. The plastic resins are packed in the 25 kg sacks. The plastic resins sacks are stored by using pallet loads. So this warehouse design can be use as an example for any warehouses that have to store plastic resins. Moreover, the warehouses that have to store any materials packed in the sacks can use this research to apply in their warehouses design.
2. In the storage area of this warehouse design, it is designed by storing the plastic resins in fixed storage location. So the storage area uses large

spaces. The further study can apply the research to reduce the space by storing the plastic resins in random storage location.

3. The cost of the designed warehouse is higher than the fees that TaP charged. The highest cost comes from the employee cost. While operating the designed warehouse, the company can apply the research to reduce the employee cost by hiring the part-time workers. The workers are designed for not working all day. If the company hires part-time workers, it has not to pay the workers in full rate.

REFERENCES

Adirek Eiampornrat. Engineer, The Industrial Finance Corporation of Thailand, Interview, 25 November 2001.

Anasaya Munyukong. Warehouse Supervisor, Thai Asia Plastic Co., Ltd. Interview, 18 September 2001 and 26 November 2001.

Castle Forklifts. 2001. Used Fork Lift Trucks by Several Brands, Available from: http://www.lifttrucks.co.uk/forklifts.html [2001, November 25]

Isuzu Chaichareonkij Motors Co., Ltd. 2001. Isuzu, Available from: http://www.isuzu-cck.com [2001, November 25]

Jenkins, C. H. 1968. Modern Warehouse Management ., USA: McGraw-Hill.

Mulcahy, D. E. 1994. Warehouse Distribution & Operations Handbook., USA: McGraw-Hill.

Numpon Tungsub. 1995. Utilization improvement of a warehouse for air-conditioning industry**.** Master's Thesis, Department of Industrial Engineering, Graduate School, Chulalongkorn University.

Pranee Kammarabootara. 1979. Warehouse Management., Master's Thesis, Department of Accountancy, Graduate School, Chulalongkorn University.

Pongpat Phetrungrueng. 1996. An Efficiency Improvement of Warehousing Operations: A Case Study of Air Conditioner Warehouse. Master's Thesis, Department of Industrial Engineering, Graduate School, Chulalongkorn University.

Spechler, J. W. 1975. Administering the Company Warehouse and Inventory Function., USA: Prentice-Hall.

The Federation of Thai Industries. 2001. Plastic Indusrtry, Available from: http://www.fti.or.th [2001, June 5]

The module notes 2000. Logistics and Operations Management., Chulalongkorn University And The Warwick Manufacturing Group University

Tompkins, J.A., and Smith, J.D., eds. 1988. The Warehouse Management Handbook., USA: McGraw-Hill.

Tompkins, J.A., et al. 1996. Facilities Planning 2nd edition., USA: John Wiley & Sons.

Supanee Kosonwattana., and Jadesada Nuntanart. 1999. Study and analysis of plant layout development for the most efficiency in inventory system., Senior Project, Department of Industrial Engineering, Faculty of Engineering, Thammasat University.

Thamnoo Vasrinont. 2001. Interview. Plastic Journal, No.2: 59-67.

Thong-moh Phungpai. 1992. Productivity improvement of a small air conditioner factory in Thailand**.** Master's Thesis, Department of Industrial Engineering, Graduate School, Chulalongkorn University.

Warman, J. 1983. Warehouse Management ., UK: Heinemann.

Biography

Mr. Nathapong Amarase was born on September 24th, 1979 in Bangkok, Thailand. He obtained his Bachelor degree in Environmental Engineering from the Faculty of Engineering, Chulalongkorn University in 2000. He started to study for Master of Engineering and Master of Science in Engineering Management jointly offered by Chulalongkorn University and Warwick Manufacturing Group of University of Warwick at The Regional Centre for Manufacturing Systems Engineering. At that same time, he was also working in his family business, which is a plastic resins trading company.