CHAPTER III

THEORETICAL REVIEW

This chapter will present the academic theories and principles on warehousing. Framework, model, methodology and technique used to improve the warehouse performance will be discussed. Specific emphasis will be placed on certain aspects.

3.1 Introduction of Warehousing

Warehouse is one of most critical functions within the organization and good warehouse management and control is a major factor affecting business efficiency and productivity. Before processing further, thus, it's essential to understand the fundamental principle of warehousing.

3.1.1 Definition and Concept

Warehousing, as it indicates, refers to the activities occurring in the warehouse. Chorafas (1974) defined the term "Warehousing" as *"both the physical processes of materials handling and keeping, and the methodology underlying this process."* In a short word, it is the ***storage and retrieval of goods***. He also concluded that the general warehouse concept should *"include the storage and retrieval operations, the organization aspects, the mechanical equipment for materials handling the racks and other media for materials storage and the building necessary to protect the goods form wind, rain, and sun."* On the basis of warehousing concept, he categorized all warehouse activities into six major functions, **Transfer**, **Receiving**, **Storage**, **Handling**, **Expediting**, and **Packing**, all of which are interpreted as follows according to his notes.

1) Transfer

Transfer function deals with the movement of goods from the reception to storage and from the retrieval to their delivery. The transferring activity is performed by the mechanical equipments and manual.

2) Receiving

The activities involve in this field are stock unloading, unpacking, quantities verification, inspection, information recording and entering after the items being delivered to the warehouse. The efficiency of this operation relies on the equipments and the labor.

3) Storage

Storage operations are the main activities in the warehouse. It primarily identifies the locations where goods are deposited and held until they are in demand. The storage area design needs to consider the items characteristics and the storage equipments are important elements in this function.

4) Handling

The handling field includes operations which are relevant to the storage place. These activities mainly cover the aspect of the correct goods location in the stock area according to items turnover to achieve the time and error minimization.

5) Expediting

Expediting is making the operation processes happen more quickly from the storage system to the business environment. Thus, it requires preparing all information documents connected with expediting

6) Packing

Packing is used to explain the contents, application and preparation to the end users. Its operations are one of most important elements in the warehouse.

3.1.2 Methodology

Knowing the concept of warehousing, its methodology is required to be clearly kept in mind since the right methodology choice leads to the efficient warehouse operation. Chorafas (1974) also offered his arguments on this aspect. He pointed out

that *"warehousing methodology concerns the orderly execution of physical storage and retrieval activities and the processing of information needed about the goods stored."* He further noted that the warehousing methodology should "*focus on correct evaluation, identification, classification, and quantification of the goods to be stored and retrieved"* as well as "*on the ways and means of handling information."*

3.1.3 Issues in the Warehouse Solution

After discussing the warehousing methodology, Chorafas (1974) further generalized 6 issues should be taken into account on the warehouse solutions as well as offered the detail explanations subsequently.

1) Items of materials and inventory accountability

This issue aims to eliminate lost inventory, prevent costly production line from shutdowns and avoid lost sales.

2) Expense reduction

The warehouse solution needs the management to take more emphasis on the cost-efficient during the decision making. As a result, it requires them to reduce cost on materials handling labor, ease the warehousing problems, decrease the storage space, enhance layout efficiency, and reduce inventory amount as well as decrease its obsolescence and deterioration.

3) Customer service

Good warehouse solutions also demand the quick responsible to customer order and, at the same time, avoid the damage of goods during the shipment.

4) Manufacturing cost improvement

This issue requires the warehouse to keep the certain amount items to buffer the production under certain circumstance to realize the optimum product rate and better equipment utilization.

5) Improve delivery performance

The attentions should be placed on the internal and external delivery performance while formulating the warehouse solution. Thus, the delay of shipment must be eliminated.

6) Improve quality control

The quality of the goods is another issues should be considered. Inspection should be conducted after the reception and before delivery of goods. Additionally, appropriate storage after inspection must be done and any damage during the items handling should be avoided.

3.2 Warehouse Design

3.2.1 Objective

Warehouse is designed to handle a variety of items possessed by the organization. *"The objective of warehouse design is to develop an effective combination of people, space and equipment to meet the project storage and throughput requirement of the facility."* (Firth 1988)

3.2.2 Strategy and Design Process

Phillips (1983) considered that picking and storage are two functions with opposing requirements in the warehouse. One function dominating the other has different impacts. On basis of this, he developed a strategic model for warehouse design according to the measures of picking activity and storage requirement, which is illustrated in Figure 3.1 below.

Observed from the Figure 3.1, the model consists of 4 quadrants with regard to the picking and storage frequency. Accordingly, the warehouse design strategy for each quadrant is correspondently noted in the Figure.

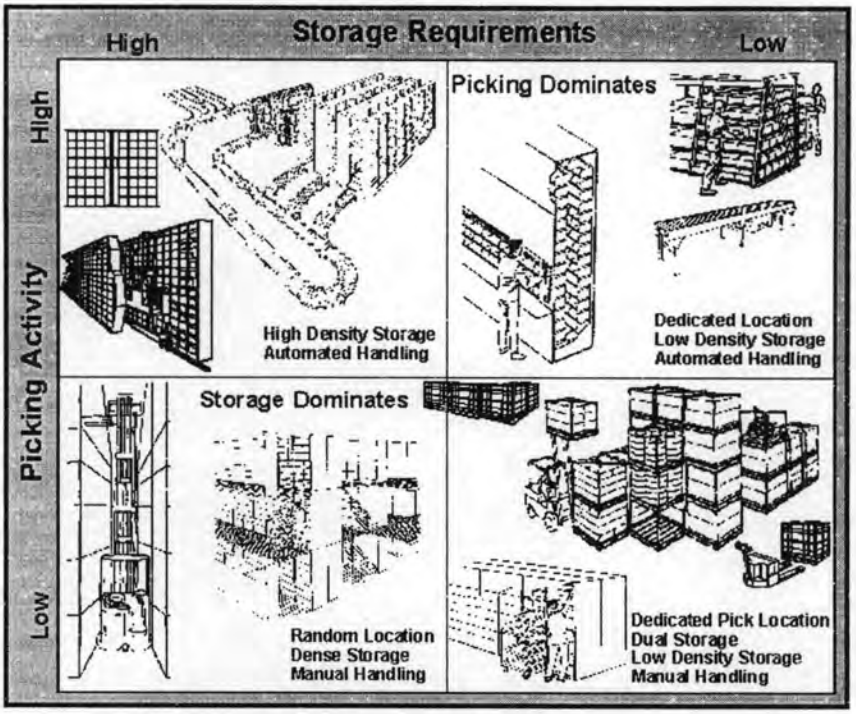

Figure 3.1: Warehouse design strategy

(Source: Phillips, 1983)

For the warehouse design process, Firth (1988) offered a five-step framework as a reference, which is shown as follows.

1) *"Identify the functions within the warehouse"*
2) *"Gather data and make projections to define the requirements for each function"*
3) *"Develop alternative methods for satisfying the requirement of each function"*
4) *"Combine functional alternatives into a single materials-flow system. This step must be repeated to generate several total system designs to compare with one another"*
5) *"Select the total system, that meets the projected requirements at the lowest annualized cost"*

3.3 Warehouse Layout Setup

The layout setup is one of the most important aspects in the warehouse

design. There is no doubt that the appropriate warehouse layout avoids a lot of inventory problems and enhances its operational efficiency accordingly.

3.3.1 Principles and Considerations

Many academic scholars have contributed their efforts to the researches of warehouse layout. Murphy and Wood (2003) pointed out that the warehouse layout is determined by the materials flow. They further offered four principles as guides to plan the layout, which is summarized below.

1) The receiving and shipping docks should be located on one wall and materials flow should be set as the U-shape
2) The small parts are ought be placed close to the docks
3) Fastest-moving materials should be placed nearest to the dock to shorten the distances
4) Link functions in the straight-through flow to minimize the time delay and space utilization as well as reduce materials-handling steps.

Caron, Marchet and Perego (2000) argued that the warehouse layout influences the picking system productivity which is ***"calculated as*** the ***ratio between the number of line items on a set of orders and the picking time required to collect them."*** Based on this concept, they suggested ***reducing the distance of picking orders*** during the warehouse layout design is able to increase the picking productivity.

3.3.2 Framework

One researcher, Hassan (2000), formulated a 14-step framework of warehouse layout design by considering major design requirements and offered the deep discussion on it, which is stated as follows.

1) Specifying the type and purpose of the warehouse

Prior to the start of layout design, the designers must explicitly identify the type and purpose of the warehouse to be or being used. This is because that clear specification will basically feedback the designers with the information of the design

requirements and expected warehouse operations level.

2) Forecasting and analysis of expected demand

After specifying the purpose of warehouse, the capacity of the warehouse and the information of the inventory level, equipments and the allocation of items in the storage area should be decided and prepared subsequently. All of these decisions are based on the demand amount. As a result, forecasting and analyzing the expect demand must be done at the second step.

3) Establishing operating policies

The warehouse layout design is also influenced by its daily operations which contain the activities being preformed and their sequences. As a result, an operating police has to be established at the early stage to direct all of the warehouse activities. This aspect will be specific discussed in the following warehouse operation section.

4) Determining inventory levels

The inventory level should be determined in this step with the information of demand estimation and forecast from step 2. This is because that the inventory levels affect the size or space requirement of warehouse. Simultaneously, space allocation and items assignments in the warehouse are impacted by the level of inventory.

5) Class formation

Class formation is used to category the items and should be made in the early decision for the sake of reducing picking time and distance. This decision is made on the basis of demand, physical characteristics, compatibility and geographic destination.

6) Departmentalization and the general layout

A warehouse may have several departments which are responsible for

different tasks, such as receiving, storage and picking. Based on this, how many departments in a warehouse being required to commit what functions or activities should be identified at this stage. After the departmentalization, the management and arrangement of these departments can be established and the general warehouse layout can be done accordingly.

7) **Storage partition**

Storage is one of most important functions in the warehouse and is usually divided into two areas, reserve and picking, for the reasons of easy operation, short movement. Storage partition is based on the demand, size and type of items. Additionally, two separated areas may be further divided into sub areas respectively, but depend on the equipments, items size and so on.

8) **Design of material handling, storage and sortation systems**

This activity is a critical and tough task and could not be finished until the rest steps have been done as there are various complex interrelationships between them. During the design, considerations should be taken into storage approach, dimension and size of storage equipment, type and capacity of handling equipment, total quantity of equipments and geographic assignment etc. The equipments to be designed should be compact if high efficient operations and space requirement reduction being expected to be achieved.

9) **Design of aisles**

Number, location, orientation, length and width of aisle are ought to be designed and decided at this stage since it directly relates to the space requirement and outcomes of step 8. Different aisles, such as narrow, wide, long have their own advantages and disadvantages and design should refer to warehouse actual situation and be suitable to other warehouse elements. One tradeoff of aisles design is to consider whether use more aisles to consume space or few to causes congestion. As a result, the designers have to think over importance weight between the space and

congestion in terms of the facts to make a better choice or make a balance between two factors.

10) Determining space requirements

After the design of aisles, storage and handling equipment and other factors in the previous steps, the space needs can be determined in this step. Since the space is affected by many factors and some of them may vary in future, the consideration should be put on this aspect as well.

11) Determining the number and location of I/O points

I/O points are necessary for the warehouse since its location influence some elements such as time and picking distance. They are placed at various locations across the warehouse for the sake of reducing movement and improving the accessibility.

12) Determining the number and location of docks

It is necessary for warehouse to set several docks to avoid congestion and speed up the movement. The placement of docks may be put on several sides of warehouse and must be in accordance of general operation flow.

13) Arrangement of storage

Arrangement of storage affects the time and cost being spent on movement and the productivity. Thus, at this stage, the items in the warehouse should be assigned properly to the storage area. The rule to be followed is the careful selection. Thus, the location of storage equipment and arrangement of item classification should be under consideration.

14) Zone formation

Zone formation implies that to divide the picking area into zones so that the picker pick only from an assignment zone. This aims to enhance the picking

efficiency and the flexibility of operations. Consideration should be placed on variation of the time, size and composition of zones.

3.4 Materials Storage

3.4.1 Concept

As indicated previously, storage is a major function in the warehouse operations and appropriate choice or design of storage equipments will enhance the operation efficiency, eliminate the potential problems and achieve the better space utilization. A variety of ready-made storage equipments are available and special ones could be made as well according to specification of inventory.

In today's warehouse, both the conventional (manual) and automatic storage equipments are in service and each one has its own advantages and disadvantages. Although there is a trend that more and more companies incline to install the automated equipments to improve the operations and control, Murphy and Wood (2003) argued that the conventional equipments are still considerable under certain circumstances from the angle of **cost** and **flexibility**.

The shape and appearance of conventional storage equipments also vary from place to place. However, Jessop and Morrison (1986) categorized them into the groups of Racks, Trays, Pallets, and Shelving on the basis of individual function. Among these types, Chorafas (1974) pointed out that the racks are the preferable storage equipments for the reasons of haphazard stocking of pallets and its own advantages.

3.4.2 Shelf

The Figure 3.2 illustrates a typical open shelf. Jessop and Morrison (1986) argued that open shelves are most suitable for storing package items such as small boxes of components.

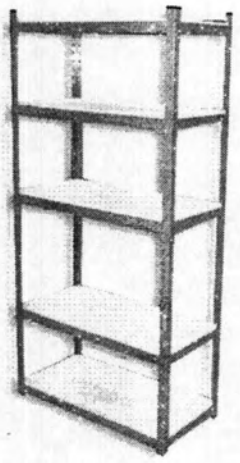

Figure 3.2: Open shelf

3.4.3 Rack

Rack is commonly used in the warehouse and different racks are used today. As the company in this case use steel bars and steel plates, the related racks related to these materials will be discussed.

- **Selective pallet rack**

Firth (1988) noted that the Selective pallet rack (See Figure 3.3) is regarded as the most universal and "bench-mark" storage and "***most storage systems benefit from the use of at least some pallet racks.***" He also mentioned its advantages of easy store and no structure and dimension limit for the loads.

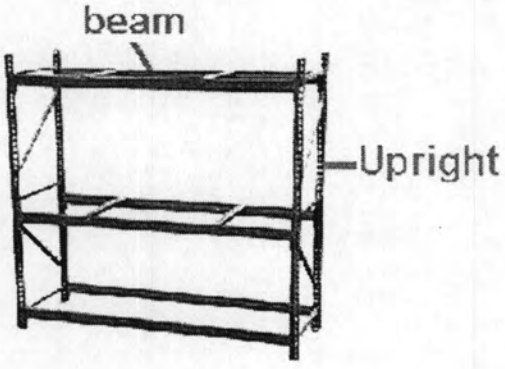

Figure 3.3: Selective pallet racks

- **Cantilever rack**

A typical cantilever rack is shown in figure 3.4 below. Firth (1988) additionally discussed that cantilever racks use the rows of load-bearing arms to support the storage. They consider that cantilever racks are very efficient for the items of long configuration such as bars since its important advantage of ***"providing long unobstructed storage shelves with no uprights to restrict the use of horizontal space"***.

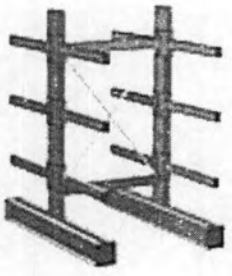

Figure 3.4: Typical double side cantilever rack

3.5 Materials Handling

The materials handling, one of the major activities in the warehouse, processes all movements of materials and goods. Although approaches, methods and equipments the company applied may vary one another depending on the type of business and materials, appropriate material handling can benefit the company in rewards, which is concluded by Jessop and Morrison (1986)

- Reduced handling cost
- Greater economy in use of space
- Reduced risk of damage to stocks
- Reduces labor requirement
- Less fatigue
- Increased safety

3.5.1 Principle

Meredith (1992) noted that the costs of materials handling occupy around 25 percent of factory payroll in the manufacturing industry. For this reason, the materials handling should be offered more considerations. He further generalized the basic principles from the perspective of minimizing handling and improving efficiency, which are grouped below.

- **Minimizing handling**
  1) If possible, do not handle the materials at all
  2) Minimizing handling by shortening travel distances
  3) Use gravity move materials whenever possible
- **Improving efficiency**
  1) Clearly identify materials
  2) Avoid partial loads
  3) Minimize pickup and delivery delays
  4) Use unit loads when feasible

3.5.2 Other Considerations

A large amount of other considerations shall be taken into account when selecting or designing the materials handling equipments. Jessop and Morrison (1986) generalized some points from the physical and financial angles, which should be given more attentions.

1) The position of the storehouse
2) Handle ability of materials
3) The case for manual handling
4) The method of packing incoming materials
5) Economy of movement
6) The selection of suitable machines
7) The storehouse layout
8) Training of operators

3.5.3 Alternative Approaches

Mechanical handling and manual handling are two main approaches being utilized in the warehouse operations. Each one has its own characteristics and is used under different circumstances. In order to achieve optimal choice, trade-off between efficiency and cost should be made as a result. Jessop and Morrison (1986) conclude the principle of choosing mechanical handling and manual handling.

- **Mechanical handling**

The major reason of selecting the mechanical handling is the loads are too heavy to be handled manually. Consequently, rather than the manual tools, the mechanical equipments should be preferred. The Besides this, the mechanical handling equipments also help save time, labor and space. If the company is constrained by the time, and employees and space, the mechanical handling equipments should be under consideration. Nevertheless, the mechanical handling is affected by the cost factor.

- **Manual handling**

Opposite to mechanical handling, the main reason to choose manual handling is the materials are not so heavy and can be moved by the manual tools. Also, the manual equipment is cheap to buy which avoids the high expense on the mechanical equipments. Thus, small and light items should apply this approach and mechanical handling is not economical in such a case.

3.5.4 Handling System

Efficient handling and movement of the materials is increasingly demanded in today's warehouse. In order to achieve this goal, thus, developing the efficient material handling system can be regarded as a straightforward approach. Although the forms might be different from place and place, developing a material-handling system normally include three main elements: ***selection of material equipment;***

selection of a unit load; assignment of equipment to moves and determining their routes. (Sule 1994) Based on this concept, therefore, two researchers, Sule (1994) and Apple (1977) formulated their respective frameworks to develop a material handling system, which is tabulated below.

Sule (1994)	Apple (1977)
1) State the intended function of the handling system 2) Collect the necessary data about the material 3) Identify the moves, their origin and destination, their path, and their length 4) Determine the basic handling system 5) Decide whether convey, truck or crane is best suited for the situation 6) Perform an initial screening of suitable equipment and select a set of candidate equipment 7) Select a set of suitable unit loads and match them with material and equipment	1) Understand the system concept 2) Review the system design criteria 3) Establish objective of the handling system 4) Obtain data required 5) Develop preliminary flow patterns 6) Identify activities and plan activity interrelationships 7) Determine space requirement and make area allocation 8) Establish material flow pattern 9) Identify and document move requirements 10) Analyze the material characteristics 11) Establish desired or existing building characteristics 12) Study basic handling systems 13) Determine feasibility and desirability of mechanization

Table 3.1: Two frameworks of developing a material handling system

3.6 Warehouse Safety

The safety issue is one of the eternal themes in almost all of industries. The slogan or banner of "Safety First" is often seen on the wall of a manufacturing plant

or a construction project site. Thus, importance of safety is beyond words. Unfortunately, the past experience proved that the safety issue did not receive sufficient attentions from the people since a lot of accidents and mishaps are frequently reported and heard. Due to its special function, warehouse turns up itself to be one of dangerous places in the whole organization and threats the companies' properties and employees' safety and health at any time. Consequently, the safety issue will be topic of this section.

3.6.1 Principle of Safety

Hammer and Price (2001) pointed out that one result generated from the safety field is the Occupational Safety and Health Act (OSHAct), which can be regarded as the safety principle or purpose. It ***"attempts to reduce the number and severity of accidents by making equipment and procedures safer by*** mandatory ***means as well as aims to ensure so far as possible every working man healthful working conditions and to preserve our human resources."***

3.6.2 People In Safety

Human beings are the important element in the safety aspect and play a determining role in the safety aspect. They are the makers of not only the safety but the accidents as well. From the top management to the shop floor workers, every one in the organization company is affected by safety. As a result, the safety decision and activities should involve everybody. Hammer and Price (2001) contribute a lot of researches on the people influence on and responsibility to safety. Their arguments will be summaries below.

- **Management**

For the management level, they point that the manager or should commit to setup safety policies for the whole organization and their influences should be apparent. They should pay attention to the accidents prevention and their concerns should be continuously and deeply impress the employees.

- **Supervisor and foreman**

The duties of supervisor and foreman are keeping close contact with workers and control all activities on safe operations. These people should keep their duties in mind at any time and ensure the safety to be not ignored.

- **Shop floor workers**

Due to danger of warehouse, worker's safety and health endlessly emphasized. Both new and experienced workers should be regularly trained, motivated and permanently supervised for safety operations. Also, the personal protective equipment is necessary for some hazard operations to avoid injury and safeguard worker in the vent of accidents.

3.6.3 Concept of Accident Avoidance

Accident is costly and sometime the loss might not be counted by currency. Hammer & Price (2001) noted that the accident could be caused by not only an error made by the operator, but also other personnel such as designers, manufacturers and managers who involved in the system. As a result, all potential hazards that might cause accidents should be studied in advance, and then eliminate those could be eliminated and control those could not.

3.6.4 Safety Approach and Related-Technique

- **World-Class approach**

Ansari and Modarress (1997) mentioned that safety performance affects the companies' outcome and Injure-free environment helps reduce cost and enhance quality. They introduced the Boeing approach as a world-class safety example by using Ishikawa diagram which is shown in figure 3.5 below.

- **Safety standard**

Hammer & Price (2001) consider standard contain technical information

and provide consistence. It lessens contentions between people and indicted safety measures to be taken. Thus, it can be used to prepare safety program to obtain improvement. If standard being meeting, cost and risk will be lower.

Figure 3.5: Boeing approach for safety

(Source: Hammer & Price, 2001)

- **Checklist**

Checklist, result from standard, is a technique used to measure the safety performance. Thus, the safety requirement can be made as items to be checked one by one to ensure the safety performance.

- **Safety information collection**

The formulation of safety standard and checklist and the safe designs for equipment and facilities need a large amount of information and feedback to support. Tarrants (1994) introduced a technique to collect information by interviewing the employees involved in hazard. He also concluded the questionnaires and hazard reports from agencies are alternatives to get the information.

3.6.5 Personal Protective Equipment

As noted previously, the employees' safety and health at the workplace should be given sufficient attentions. Thus, personal protective equipments should be correctly selected. For the heavy industries, the head protection should be placed with highest concerns.

For the head protection equipment, Hagan, Montgomery and O'Reilly (2001) suggested the helmet (See figure 3.6) as an ideal equipment to ***"protect against impact hazards and are typically used in heavy industries setting."***

Figure 3.6: Helmet

3.7 Safety Performance

Safety performance is required to be traced, measured and recorded. Petersen (1978) mentioned that frequency rate (the number of disabling injuries per million worker-hours) and severity rate (the number of days lost, or charged, per million worker-hours offered some safety performance measurements) are final measures used in the record system. However, due to the weakness of being individually used, Petersen further presented additional measurable ratios.

- **Frequency-severity indicator (FSI)**

$$FSI = \sqrt{\frac{F \times S}{1000}}$$

Where:

F stands for frequency rate whereas S stands for severity rate

- Cost factor

$$\text{Cost factor} = \sqrt{\frac{COST\ INCURRED \times 1000}{TOTAL\ WORKER - HOURS}}$$

Where:

Cost incurred means the actual compensation and medical costs paid for cases which occurred in a specified period plus an estimate of what is still to be paid for those cases

- Insurance Loss ratio

$$\text{Loss ratio} = \sqrt{\frac{INCURRED\ COST}{INSURANCE\ PREMIUM}}$$

- Nonindustrial disabling injury rate

$$\text{Rate} = \sqrt{\frac{no.\ of\ injuries \times 1{,}000{,}000}{312 \times no.\ of\ employees}}$$

3.8 Warehouse Security

Besides the warehouse safety, the security issue is another important aspect the company has to think over. Thus, how to prevent the stock from stealing and keep them in the secured condition will be discussed in this section.

Strobl (1973) noted some situations under which the stealing activities may occur and offered the corresponding solutions subsequently. They are generalized as follows

- Inspect the trash removal by security force
- Lend expensive hand tools to employees to avoid theft
- Packages carried by employees should be kept under their control point
- Scrap should be wrapped or boxed, rather than sell to employees
- Inspect the equipments used to move stock
- Inspect the theft time with security guard

Jessop and Morrison (1986) also pointed out the security issues and recommended certain solutions to keep the warehouse security.

- Secure the stockyards
- Keep the keys safe
- Control access to premises
- Marking the stores
- Segregate pilferable items
- Install electronic surveillance
- Use supervisors' inspection

3.9 Warehouse Operation Efficiency

Firth (1988) notes that ***"warehouse efficiency and accuracy are largely a function of the control system used to direct and track activity"*** To improve the warehouse operation efficiency, therefore, understanding the constitution of the typical warehouse operational activities and its sequences as well as carefully formulating the operating policy are essential. Furthermore, great attentions should also be drawn to the status of information in the operation.

3.9.1 Operating Policy

Warehouse operating policy affects not only the layout decision, but also the warehouse efficiency. It involves the activity such as storage, routing, batching etc... In most cases, nevertheless, storage policy and routing policy are two most critical elements receiving high concerns. Petersen (1999) defined storage policy as ***"assigning items to warehouse storage location"*** and routing policy as ***"determining the route of a picker for the picking tour, specifically the sequence in which items are to be picked."*** He further divided storage policy and routing policy into several categories which is illustrated in the following figure 3.7 and figure 3.8.

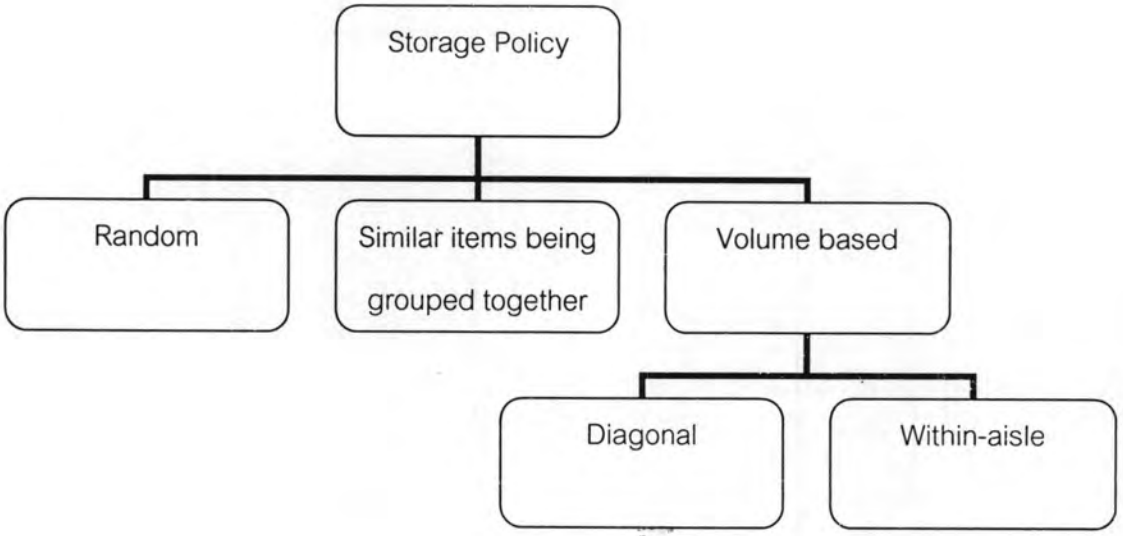

Figure 3.7: Storage policy

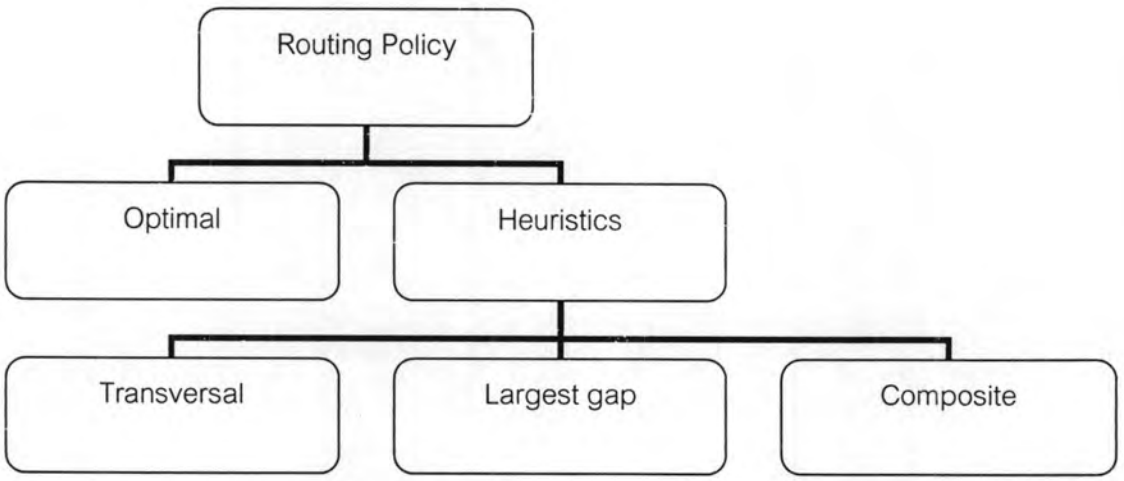

Figure 3.8: Routing policy

Based on the experiment, he concluded that within-aisle is relatively better than the diagonal for the storage policy and composite is the best solution among the heuristics routing policy. Additionally, since both heuristics routing policy and optimal routing policy have the respective advantages, he finally suggested that the management should tradeoff ***"the efficiency of optimal solutions and the easy implementation and use of heuristics procedures"*** before selecting the routing policy.

3.9.2 Receiving Operations

Figure 3.9 below depicts the activities flow during the receiving system transactions. Firth (1988) noted that "the most effective receiving system use layout and handling equipment to permit material flow through or past a receiving station." To realize this, he further pointed that the warehouse should achieve "immediate availability of information" and "capacity to handle peak demands".

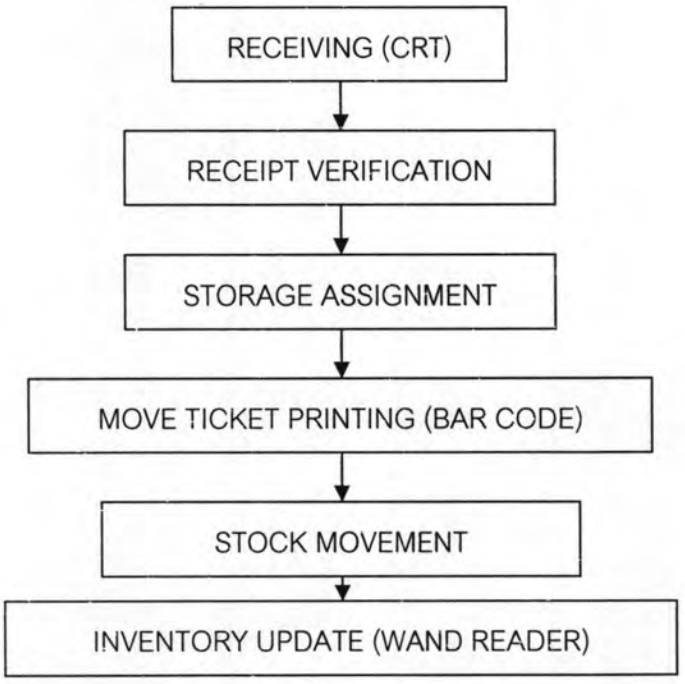

Figure 3.9: Receiving Systems Transactions

(Source: Firth, 1988)

3.9.3 Picking Operations

Figure 3.10 below displays the activities flow in the picking and shipping system transactions. Firth (1988) discussed that these activities need control if the high efficient picking operations are expected to be achieved.

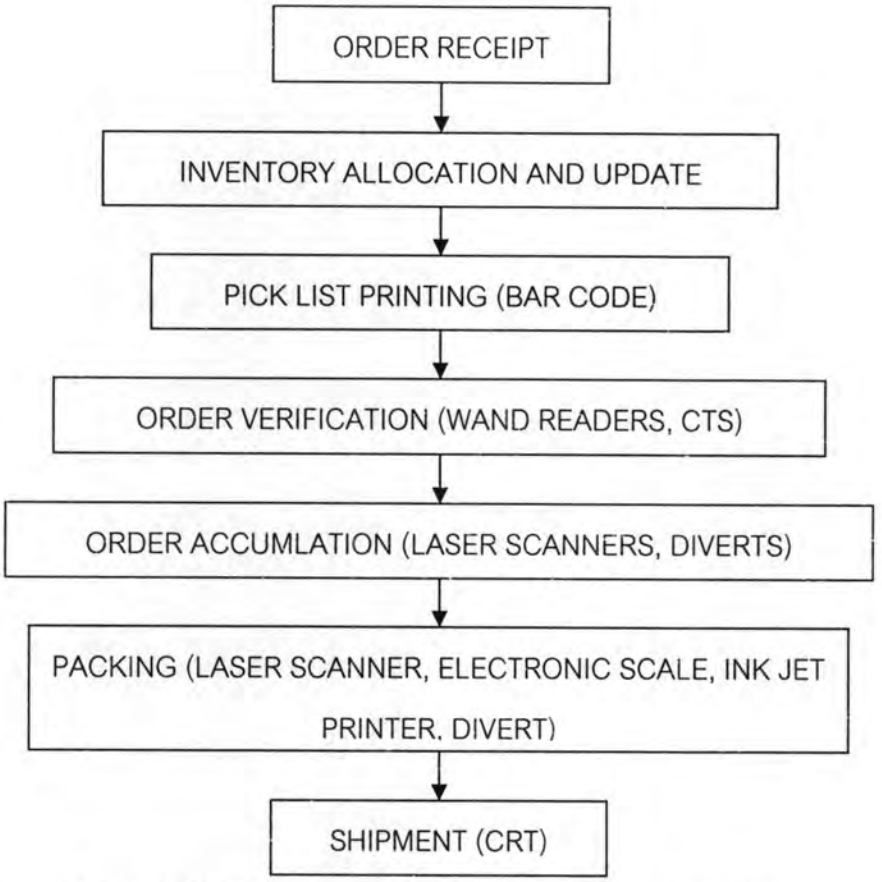

Figure 3.10: Picking and shipping systems transactions

(Source: Firth, 1988)

3.9.4 Model of Efficiency Improvement

Gunasekaran, Marri and Menci (1999) introduced a conceptual model for improving the efficiency o warehouse operations. This model is built on two perspectives application, JIT and TOM, in the warehouse operations and illustrated in Figure 3.11 below.

In their words, "JIT aims to bring certainty and smoothness to the flow of material through supply chain, while reducing the WIP, enabling the lowering of stock and thus reducing the lead time." On the other hand, "TQM is a management approach to organization centered on quality, based on the participation of all its members, and aiming at long-success through customer satisfaction and benefits to the members of the organization and to society." Both authors believed the combination of JIT and TQM can improve the warehouse operations efficiency and prove it through a case study.

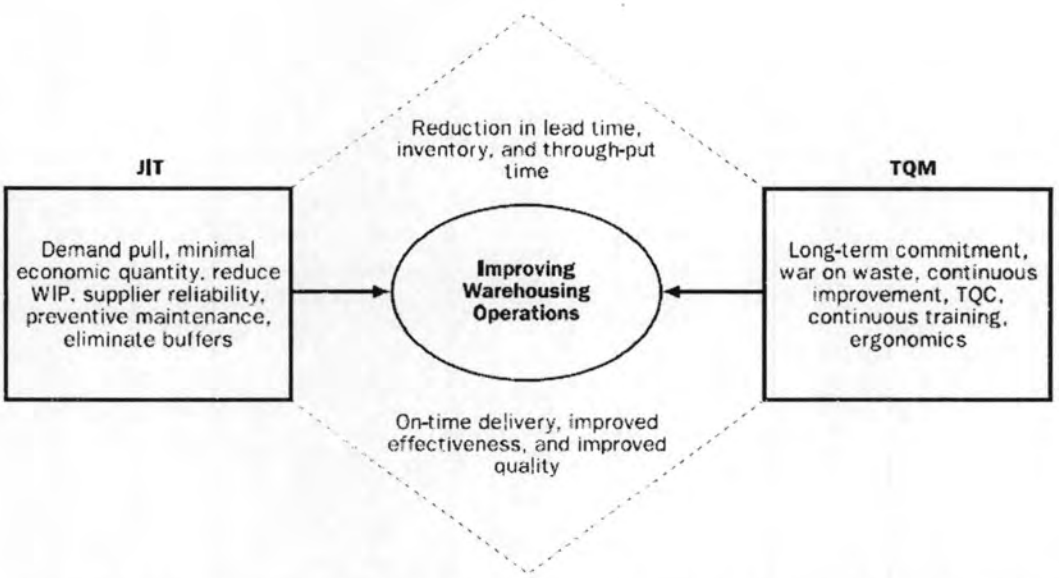

Figure 3.11: A concept model for improving the efficiency of warehousing operations (Source: Gunasekaran, Marri and Menci, 1999)

3.9.5 Information Flow

Information flow, to certain extent, plays a determining role in the efficient warehouse operation. Schroeder (1993) categorized information flows into two types: *"typical production of operation"* and *"usage for management of control material flow."* He emphasized the latter type and insisted that analysis of information flow should be keep up with the analysis of materials flow, since ***"materials flow may be improved but the management control of process may still be lacking."***

Ballard (1996) echoed this argument by pointing out that ***"materials flow and information flow must go hand in hand."*** His viewpoint is erected on the basis of ***"warehouse management system requiring being linked to an inventory control system."*** For this reason, he figured that ***"effective warehouse management should monitor the progress of goods and materials as they are processed through the warehouse."*** He further divided the stock information required to be monitored and measured into three types: fixed information, variable information and derived information. Their relationship is displayed in the figure 3.12 below.

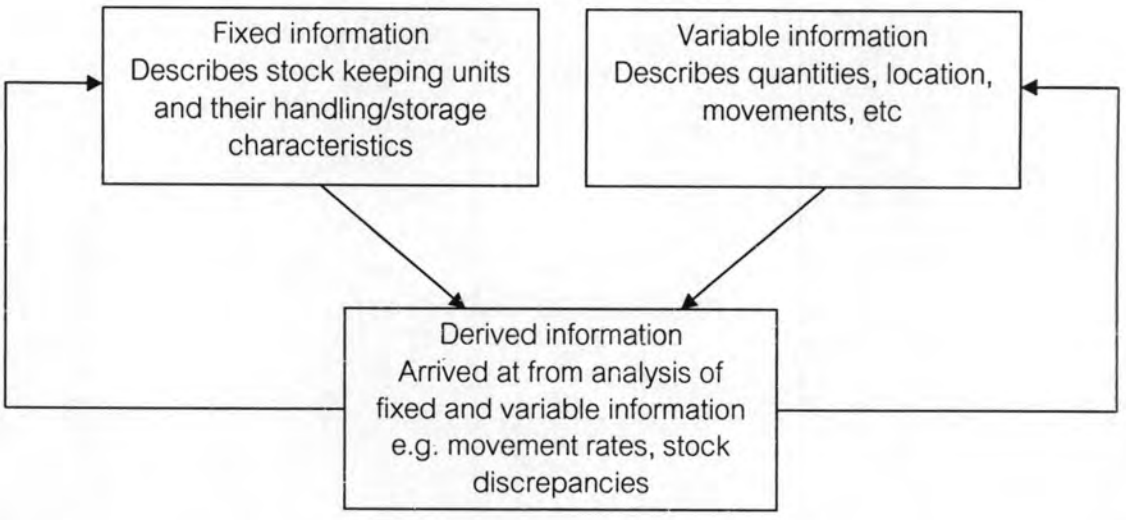

Figure 3.12: Inventory information

(Source: Ballard, 1996)

3.10 Improvement Technique

Appling the correct technique into the implementation stage will facilitate the procedure and enhance the final results of improvement. At the workplace, 5S's technique is commonly and widely used across the world and regarded as a most effective and efficient technique to improve the physical condition.

3.10.1 Concept of 5S's

5S's practices, originating and being developed from Japan companies, is a useful tool to improve both work and life. To apply this technique properly, thus, first to understand the meaning and implication of 5S's is a must. The word used to interpret the 5S's may vary from place to place, but the fundamental principles are exactly same. Hirano (1995), one representative 5S's researcher, who contributed a great deal of literatures in this field, interpreted the 5S's as **Organization**, **Orderliness**, **Cleanliness**, **Standardized Cleanup** and **Discipline**. He further explained its implication in detail as well. He also noted, 5S Practice relate to corporate health and survive and is the foundation for improvement. He also diagrams the meaning of 5S in the Figure 3.13.

1) Organization

The concept of Organization is clear identifying what is necessary and what is unnecessary. In another word, sort out the things to be kept and throw out the unnecessary things. Sometime, it is difficult to decide whether or not the target is still necessary. Hirano's suggestion is ***"When in doubt, throw it out."*** This is because useless things may result in future's errors and problems.

2) Orderliness

The meaning of Orderliness is keep things in an organizing way so that every one can use and find them easily. This is important for everyone in the workplace to keep how things are kept in their mind.

3) Cleanliness

Cleanliness implies that the floors are swept and things are keep in order. It helps find the problems concealing under the dirty, dust and debris and make the improvement of workplace or machines through clean state.

4) Standardized Cleanup

Standardized Cleanup means maintain the previous three steps: Organization, Orderliness, and Cleanliness. Maintenance can also be improved by preventing the dirt from occurring.

5) Discipline

Discipline means keeping following the standardized procedure. Without Discipline or maintaining 5S conditions, 5S campaign will stop soon. The best way of maintaining 5S is that managers or 5S formulators set themselves as the pioneers to maintain the 5S.

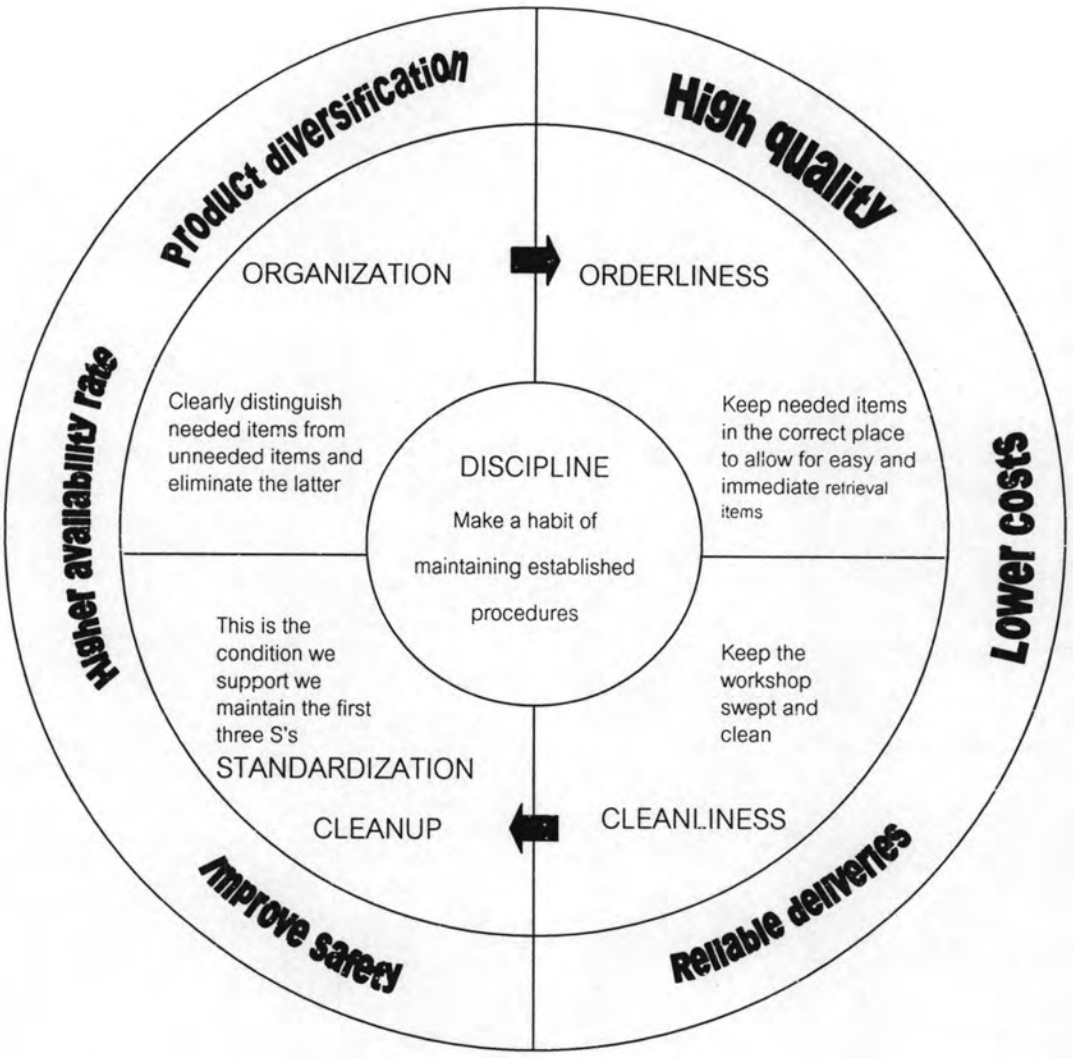

Figure 3.13: the meaning of 5S's

(Source: Hirano, 1995)

3.10.2 Introduction Steps

Hirano (1995) also provided a framework of 5S introduction to the workplace, which is illustrated in figure 3.14. Interpretation will be given to red-tag strategy and signboard strategy.

Red-tag strategy is a simple method to easily recognize and identify between what is needed and what is not. Its step is shown as follows

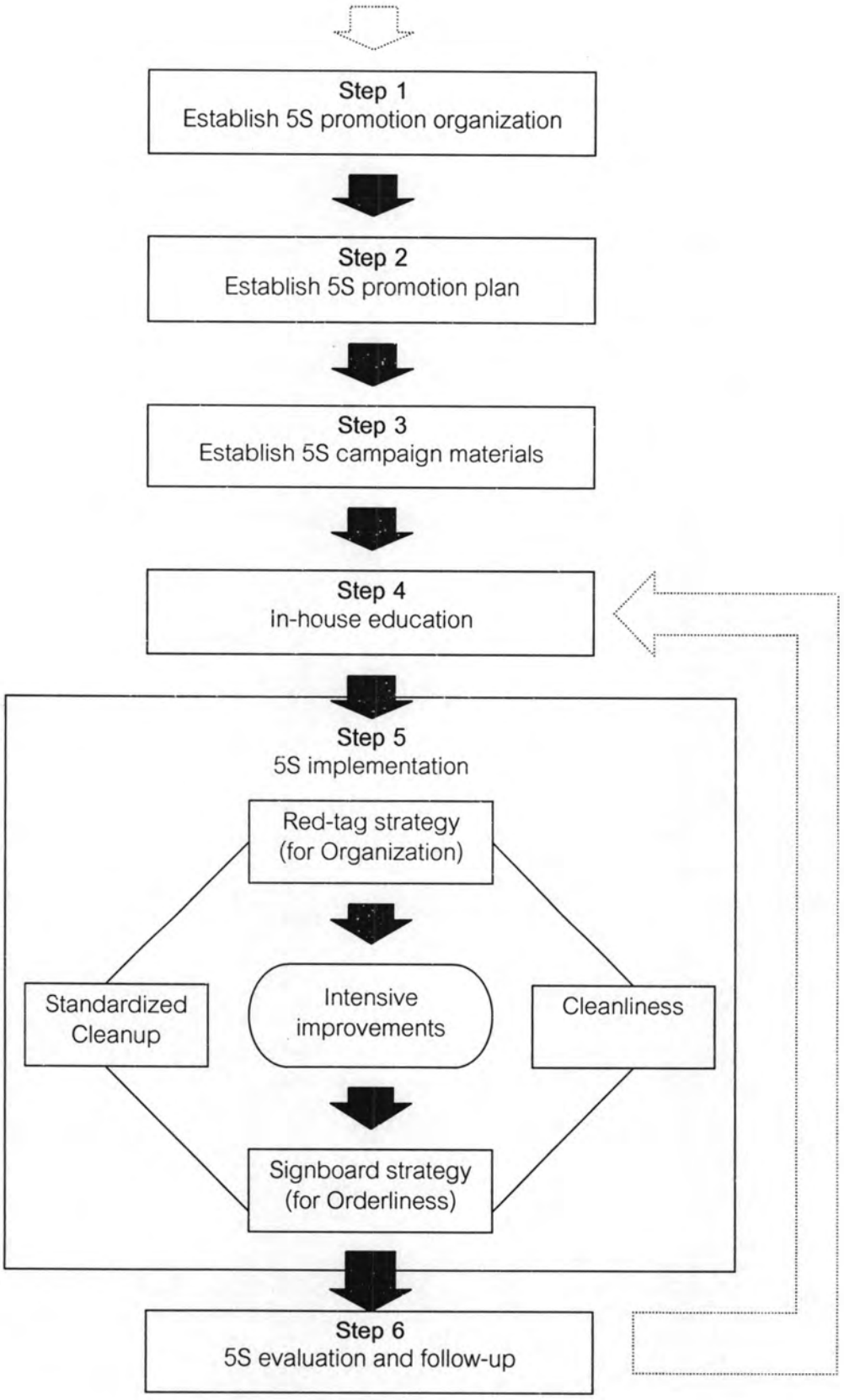

Figure 3.14: 5S Introduction steps

(Source: Hirano, 1995)

1) Launch the red-tag project
2) Identify red-tag targets
3) Set red-tag criteria
4) Make the red tags
5) Attach the red tags
6) evaluate the red-tag targets

Signboard strategy is a tool that "makes orderliness a more visual place." "The most important ones are inventory signboards that clearly indicated where each inventory items belongs and in what amount" Its step is shown as follows.

1) Determine locations
2) Prepare locations
3) Indicate locations
4) Indicate items name
5) Indicate amounts
6) Make orderliness a habit

3.10.3 Implementation Principle

There are a lot of academic textbooks and researches pointing out the techniques and practicability of 5-S in the improvement of factories. Ho (1999) is another scholar who has done a lot researches on 5-S techniques and illustrated some important points for efficient 5S implementation. He points out that, before the implementation, a good plan has to be prepared. Also the implementation needs commitment and accountabilities from both the top management and everyone in the organization. Moreover, he considers that having a 5-S champion to lead the whole organization towards the implementation step-by-step is critical.

3.10.4 Human and Culture Issues

O'hEocha (2000) researched the influence of company culture and employees' attitude on use of 5S in his case study as the human facet is the key factor

in 5-S implementation. This related to anther important issue: Working Culture. Whether the employees are willing to change their working attitude will directly determine the success of 5-S implementation. According to Hofstede (2001) who groups the culture differences into five categories: Power Distance, Uncertain avoidance, Individualism and Collectivism, Masculinity and Femininity, Long-Term and Short-Term orientation based on the IBM data set, Thai employees show their strong loyalty to their managers and the top managers incline to solve problem by the help from the technology and prefer to the long term perspective.