INCREASING EFFECTIVENESS OF A WAREHOUSE BY KARDEX STORAGE MACHINE: A CASE STUDY

by

Mr. Chatchawan Kitisomprayoonkul

A Final Report of the Three-Credit Course
CE 6998 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
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Project Title	Increasing Effectiveness of a Warehouse by Kardex Storage Machnine: A Case Study
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The Graduate School of Assumption University has approved this final report of the three-credit course. CE 6998 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

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ABSTRACT

This project had studied on the increasing effectiveness of warehouse by Kardex storage machine by surveying of existing warehouse system of company A and company B. The analysis was conducted in terms of technical and benefits aspect. The appropriate measures were selected with each warehouse to set saving target, leverage the efficiency, effectiveness, and plan for implementation.

The surveys of two case studies were conducted to analyze the storage area in order to develop that area to escalate effectiveness in storage management. These case studies displayed the system of Kardex machine and how it saved cost.

According to the case studies, the Kardex machine helped saving the storage area and cost in warehouse. It would help the manager to consider using new storage machine and its software to develop the warehouse management and the company to increase efficiency, effectiveness and earning more benefit.

ACKNOWLEDGEMENTS

I was indebted to the following people and organizations, without them, this project would not have been possible.

I wished to express sincere gratitude to my advisor, Mr. Smith Tungkasmit. His patient assistance, guidance and constant encouragement have advising me from the project inception to the project completion. I would like to express appreciation to my project Advisory Committee members; Prof.Dr. Srisakdi Charmonman (Chairman), Dr. Chamnong Jungthirapanich (Dean), Assoc.Prof. Somchai Thayarnyong (MUA Representative) for their comments and advice throughout the project.

I would like to thank Mr. Chaiwat Kasetsiri, Managing director of Vertical Carousel International Corporation for his contribution. Mr. Suraphol Nilabon, Store Specialist of AMD(Thailand) Ltd., in the help of some essential documents.

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INTRODUCTION

In recent year, warehouses had been subjected to technological development on a large scale. This was particularly true of mechanical and electrical equipment. The degree of sophistication of such equipment previously seen in manufacturing departments had currently been extended to warehouses applications. There had been a revolution in the mechanization of the warehouses operation, resulting from the very wide range of highly specialized equipment available on the market. The wide variety of materials were transported or moved ranges from large heavy items to lighter fragile ones. Goods had to be lifted and lowered or sometimes moved from one floor to another. Economic operation of warehouses were defined as optimizing the uses of floor space.

More and more warehouse facilities were using automated material handling equipment. For example, the automated storage was used to improve the efficiency and effectiveness of warehouse such as Kardex automated storage.

1.1 Kardex Company Background

Kardex Systems Limited was part of the International Kardex AG Group based in Switzerland which had representation in all the Major Countries in Europe, together with the USA, The Middle East, Far East and Australia.

The company had grown from the acquisition of part of the Remington Rand organization in the mid-seventies to being world leaders in automated retrieval using the vertical carousel concept. Over 2000 people work for Kardex world wide in it's various manufacturing and marketing companies.

The name Kardex had always been synonymous with innovation and never more than these days. From the first commercial typewriter at the turn of the century to robots and computer-controlled inventory handling at the present time, Kardex led the way in new technology in the International market place.

1.2 Kardex's Product Overview

Kardex's product could be separated into 2 categories according to area sector as following:

Industrial Products

Industriever, Shuttle and **Horizontal** had been specially designed to meet storage and retrieval requirements in the industrial sector.

Kardex Industriever

Kardex Industriever was a heavy-duty, dynamic storage and retrieval vertical carousel designed for the industrial sector, to improve efficiency in stores and on the shop floor.

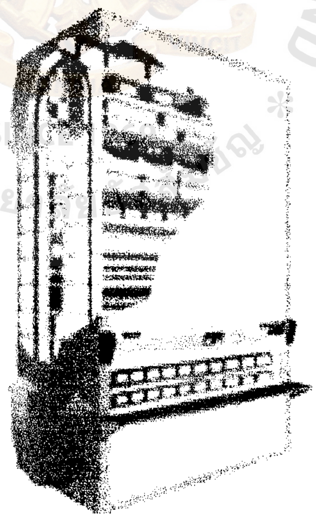


Figure 1.1. Industriever.

Kardex Horizontal

Kardex Horizontal was a horizontal carousel in which the ideal principle "goods to person" had been realized. Wherever rapid and efficient picking was required, the Kardex Horizontal was the ideal solution to reduce costs and increase productivity.

Figure 1.2. Horizontal.

Kardex Shuttle

Kardex Shuttle was a vertical lift module designed for industrial storage purposes (tower block system).

The shuttle is a computer controller automated vertical lift, storage, and retrieval system.

Stock remained stationary within the shuttle on front and rear tray locations

On request, a movable extractor unit traveled vertically between the two columns of trays and pulls the requested pallet from its location and took it to an access point.

Alternately, the selected tray could be automatically placed onto a stub conveyor, robot or AGV for onward dispatch.

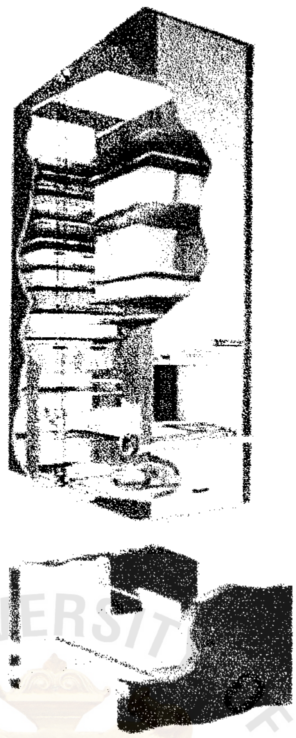


Figure 1.3. Shuttle.

Office Products

The Lektriever was a vertical carousel optimized for use in the office sector.Figure

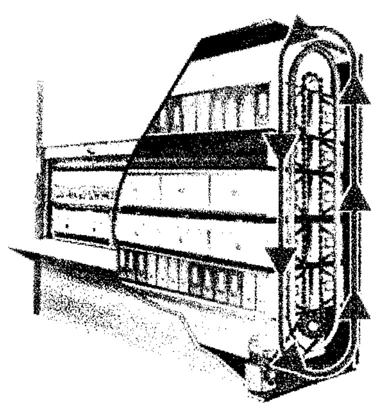


Figure 1.4. Lektriever.

1.3 Storage Problems

In current situation, each organization faced the storage problem in stores, warehouse and in office environment, which mainly caused from:

(1) Storage Area Size: Land cost was more expensive and storage space was limited that let stores and office needed the systematic storage machine to solve these problems.

(2) Accuracy and Processing Time: Man operation usually occurred imperfect result on storing, picking/distribution, recording and controlling that absolutely effected with organization cost.

As above reason, this project was improved to eliminate oriented problem by using new advanced technology "Storage machine" to save cost and cutting down operation failure.

1.4 Project Objectives

The objective of this project was aiming at studying using Kardex's storage machine especially Vertical Carousel (Industriever and Lektriever) for optimum use of storage space and also the strength and weakness point of Vertical Carousel.

In addition, this project would illustrate the real two case studies in using Kardex's technology to increase work efficiency on existing system and guidelines to use Kardex's technology to improve working system in the future.

1.5 The Basic Concept of Vertical Carousel (Industriever and Lektriever)

Industrievers

The vertical carousel was a concept pioneered by Kardex over 30 years ago. Currently, with the Industrievers available in eleven different models this concept is enabling customers worldwide to achieve savings space, time and effort throughout a wide range of industrial sectors.

In simple terms, the Industriever brought in the product to be picked to the operator thereby reducing substantially the time taken to walk from picking point to picking point. Coupled to this was the fact that the items were always presented to the picker at the optimum picking height so that effort; bending, stretching and climbing ladders were entirely removed. This led to the reduction of non-productive picking time, the reduction of operator fatigue, whilst increasing productivity with higher rates of throughput on each shift.

The range of Industrievers could be broken down into three basic sub-ranges; the 100 series and the 500 series. This was by no means a static set of ranges, new models were regularly introduced. For example, the 1000 series would shortly be available to further broaden the range of offerings.

The 100 series comprised of five models with a carrier loading of up to 175kgs. There were three models in the 300 series each with a carrier loading capacity of up to 350kgs. And 500 series also offered 500kgs loading per carrier on three models.

The 1000 series would break through the 1 ton per carrier loading capacity with the opportunity to carry 1200kgs on each carrier.

Lektriever

Information was the cornerstone of professional management and the basis for decision-making. Whilst computers retained substantial volumes of data in digital form, hard copy records-documents, files, printouts, card indexes — performed a vital role in retaining information in readable format.

The Lektriever concept was based upon a vertical carousel system, which fully utilize. The vertical dimension, the overhead office space, which was inaccessible and normally wasted with traditional manual systems.

Hundreds of thousands of records could be accommodated in a single unit, yet any document or group of documents could be summoned within seconds. When the document location code was keyed into the electronic keypad, the Lektriever carriers rotated automatically selecting the shorter route and presented the required records to the operator at a convenient working height. The Lektriever system was equally efficient when randomly retrieving a single document as it was for workstation operation, when the operator could rapidly process substantial volumes of records from a comfortable seated position.

It was estimated that traditional manual filing systems dissipated as much as 60% of effort non productively — walking up and down rows of cabinets, pulling and pushing filing drawers, or bending and stretching to upper and lower levels. Lektriever eliminated this wastage by bringing the records to the operator, not vice-versa. Not only was this faster, it substantially reduced fatigue and disinterest but increasing productivity.

In practical terms the vertical carousel concept could only be realized fully if the equipment was designed, constructed and maintained fully and accurately, provided the operator fully protected.

All Kardex Industrievers and Lektriever were designed and manufactured to the most exacting standards and where applicable were built to comply with SUVA regulations; the most exacting standards in Europe.

IL LITERATURE REVIEW

2.1 Material Handling

2.1.1 Definition of Material Handling

It was not easy to formulate a good definition for material handling. Defining material handling merely as "handling materials" was largely unsatisfactory because it involved s moving, packing, and storing as well as controlling activities.

From an engineering point of view, material handling might be defined as "the art and science involved in picking the right system, composed of a series of related equipment elements or devices designed to work in concert or sequence in the movement, packaging, storage and control of materials in a process or logistics activity." Each system had to be designed to serve in its specific operating environment and for specific materials. Although the possible contexts for the material handling systems varied a lot, the basic principles of sound material handling applied for each of them. It was also important to note that there was a strong interaction between material handling and other facilities design aspects such as building layout, storage methods, order picking concepts, etc. Tompkin and White gave a rather descriptive definition of material handling, which covered all the important objectives: "the best material solution from the host of alternative solutions that usually existed used the right method to provide the right amount of the right material at the right place, at the right time, in the right sequence, in the right position and at the right cost."

Several definitions were available for material handling. The most comprehensive was the one provided by the Material Handling Institute (MHI), which stated: "Material handling embraces all of the basic operations involved in the movement of bulk, packaged, and individual products in a semisolid or a solid state by means of machinery, and within the limits of a place of business."

Even a cursory examination of the statement revealed that material handling involved much more than just moving the material by using machinery; several additional functions were implied in the system.

First, material handling involved the movement of material in a horizontal (transfer) and a vertical (lifting) direction, as well as the loading and unloading of items. Second, specifying that the movement of materials was " within a place of business" implied that the movement included raw materials to work stations, semifinished product between workstations, and removal of the finished products to their storage locations. It also distinguished material handling from transportation; the latter involves moving materials from supplies to places of business or from places of business to customers.

Third, the selection of handling equipment was another activity in designed material-handling systems. Fourth, the term *bulk* indicated that the materials were to be moved in large, unpackaged volumes such as sand, sawdust, or coal. And fifth, using machinery for handling material was the preferable method even though the initial cost might be high.

The use of human beings on a continuous basis was inefficient and could be costly; material-handling equipment soon paid for itself, especially in societies in which the cost of labor was high.

2.1.2 Objectives of Material Handling

The need of study and careful planning of a material-handling system (MHS) could be attributed to two factors. First, as was mentioned before, material-handling costs represented a large portion of production cost. Second, material handling affected the operations and design of the facilities in which it was implemented. These led to the major objective of MHS designed that of reducing production cost through efficient handling or, more specifics.

(1) To increase the efficiency of material flow by ensuring the availability of materials when and where they were needed.

(2) To increase productivity in manufacturing (plant) or in distribution (warehouse).

(3) To increase space and equipment use.

(4) To improve safety and working conditions.

(5) To reduce material handling costs.

(6) To avoid too high capital requirements.

(7) To ensure a high level of system's flexibility, reliability, availability, and maintainability.

(8) To improve integration between material and information flow.

(9) To smooth the flow of materials through the logistics pipeline (from supplier to final customer).

2.1.3 Degrees of Mechanization

A material-handling system could be completely manual or fully automated; different degrees of mechanization also existed between these two extremes. Classification of a handling system according to its level of mechanization was based on the source of power for handling and the degree of involvement of humans and computers in operating the equipment. The levels of mechanization could be classified as follows:

(1) Manual and Dependent on Physical Effort: This level also included manually driven equipment such as hand trucks.

(2) Mechanized: Power instead of physical effort was used for driving the equipment. Some trucks, conveyors, and cranes fell into this level. Here

operators were needed for operating the equipment as opposed to proving the power.

(3) Mechanized Complemented with. Computers (an extension of the second level): The function of the computers was to generate documents specifying the moves and operations.

(4) Automated: Minimal human intervention was used for driving and operating the equipment, and computers performed most of these functions. Examples include conveyors, automated guided vehicles, and AS/RS (automated strong/retrieval system). The equipment usually received instructions from keyboards, push buttons, and tape or card readers.

(5) Fully Automated: This level was similar to the fourth level, but computers performed the additional task of on-line control, thus eliminating the need for human intervention.

The cost and complexity of designing the system increased as the degree of mechanization increase. However, efficiency of operations and labor saving could result.

The advantages of using mechanized and higher level systems include an increase in speed of handling operations, which in turn might decrease the overall production time, a reduction in fatigue and an improvement in safety: better control of material flow; lower labor cost; and better record keeping regarding inventory status of the material.

There were also some disadvantages as the degree of mechanization increased. For example, mechanization required a high investment cost, training of operators and maintenance personnel, and specialized equipment and personnel, which reduced flexibility. It was therefore necessary to weigh advantages and disadvantages carefully before deciding which system to be used. Changing from one mode of operation to another was always expensive and time consuming.

2.1.4 Basic Principles of Material Handling

The principle equation of material handling system design was often formulated as follows: Materials + Moves + Methods = Best System

The underlying idea was that the best handling is the least handling. Therefore, the emphasis was on a critical attitude toward the whole material handling process, i.e., the "why" of material handling. Supporting questions might be the "what," "where," "when," "how," "who," and "which," aiming to establish the type of materials to be moved, their main characteristics, the quantities to be moved, the units to be handled, the sources and destinations for each move, the frequencies and speed at which the moves had to be made, the methods that could be used to execute the moves, the party responsible for the handling process (physical and information flow), equipment alternatives with their specifications, etc. The materials Handling Institute, Inc., synthesized the experiences of many practitioners into a list of 20 material handling principles. Table 2.1 was a slightly modified list. This list presented rules of thumb that might be helpful in remembering most of the important issues concerning material handling systems. Based on the list, many checklists had been developed and were available in the literature.

Relationship between Material Handling and Plant Layout

In a manufacturing system, no to other activities affected each other as plan layout and material handling. The relationship between the two involved data required for designing each activity, their common objectives, the effect on space, and the flow pattern. Specifically, plan-layout problems required knowledge of equipment operating cost in order to locate the department in a manner that would minimize the total material handling cost. At the same time, in designing the material handling system the layout should be known in order to have the move length, move time, and resource, and destination of the move. Because of this dependency, many designers stressed to need to solve the two problems jointly. However, the only feasible way was to start with one problem, using its solution for solving the other, then going back and modifying the first problem on the basis of the new information obtained from the second, and so on until a satisfactory design was obtained.

Table 2.1. Basic Material Handling Principles.

1. Planning. Study the problem thoroughly to identify potential solutions and constraints and to establish clear objectives.
2. Flow. Integrate data flow with physical material flow in handling and storage.
3. Simplification. Try to simplify material handling by eliminating, reducing, or combining unnecessary movements and equipment.
4. Gravity. Use gravity to move material wherever possible, while respecting limitations concerning safety and damage.
5. Standardization. Standardize handling methods and equipment wherever possible.
6. Flexibility. Use methods and equipment that can perform a variety of tasks.
7. Unit load. Handle product in as large a unit load as possible.
8. Maintenance. Plan maintenance carefully to ensure high system reliability and availability.
9. Obsolescence. Make a long-range plan, taking into account equipment life cycle costs and equipment replacement.
10. Performance. Determine the efficiency, effectiveness, and cost of the material handling alternatives.
11. Safety. Provide safe material handling equipment and methods.
12. Ecology. Use equipment and procedures that have no negative impact on the environment.
13. Ergonomics. Take human capabilities and limitations into account while designing a material handling system.
14. Computerization. Consider computerization wherever viable for improved material and information control.
15. Utilization. Try to obtain a good use of the installed capacity.
16. Automation. Consider automation of the handling process to increase efficiency and economy.
17. Operation. Include operating costs (energy) in the comparison of material handling alternatives.
18. Integration. Integrate as much as handling and storage activities into one coordinated system, covering receiving, inspection, storage, transportation, production, packaging warehousing, and shipping.

Table 2.1. Basic Material Handling Principles. (Continued)

19. Layout. Keep in mind that layout and material handling are closely linked and that an interactive procedure is often needed to obtain their best coordination.
20. Space use. Choose the material handling equipment so that effective use is made of all (cubic) space.

There were several important interrelationships between layout and material handling; storage issues such as selectivity and density, and material handling; and order picking and material handling. Table 2.2 compared some common order-picking systems. The pick-to-cart and man aboard vehicle systems were "human-to-goods" solutions, whereas the carousel was a "good-to-human" solution.

Table 2.2. Order-picking System.

Characteristic	**Pick-to-Cart**	**Man-aboard Vehicle**	**Carousel**
Pick rate	Low	Medium-high	Medium-high
Cost/square foot	Low	Medium	High
Picking Accuracy	Medium	Medium	High
Maintenance requirements	Low	High	Medium
Reconfigurability	High	Low	Low

Plant layout and material handling had the common objective of cost minimization. Arranging closely related departments such that the material moved only short distances could minimize the material-handling cost.

Additionally, material handling and plant layout influenced each other in terms of space requirements and utilization. Overhead equipment did not occupy any space on the floor of the layout. Stacking items as high as possible by using the appropriate unit load would help to reduce the space taken by these activities and best utilize the cube. It could also be achieved by using mezzanines, carousels, and high-rise storage for storing material.

Finally, the physical characteristics of building, such as aisle width, ceiling height, and columns, would affect equipment selection and its routing.

2.2 Analyzing an Existing System

2.2.1 Quantitative Analysis

Nowadays managers of all company levels faced a wealth of information in many different subjects. This abundance of data was sometimes difficult to cope with. Often information was presented to the manager in a rather broad way and incorrectly included, outdated, and incomplete data. Apparently, the last step in the information system was often omitted: The information was available but unfriendly to the users. An additional processing step was required to discriminate between important signals and routine infonnation. Perfoiniance indicator (PI) systems were a means for this purpose, because they allowed large amounts of data to be summarized into a few relevant key numbers. Although PIs were not fundamentally new, a recent renewed interest in this idea might be noted in many business areas, especially in logistics, of which handled material systems from an important component. Figure 2.1 illustrated the PI cycle. Note that the purpose of the PI cycle was not only to report on past perfoitnance but also to anticipate problems and to try to correct them in a continuous improvement program. The target-setting process, if difficult in an situation dependent, e.g., the ratio of the time for material handing to the total operating time would preferably below in a workshop but might be high in a warehouse; moreover, in the latter situation, the target depended on the degree of automation applied in the warehouse. The targets should be carefully determined to motivate people to work toward them. Setting targets too high would demotivate people ("We can never reach them any way") as well as setting them too low.

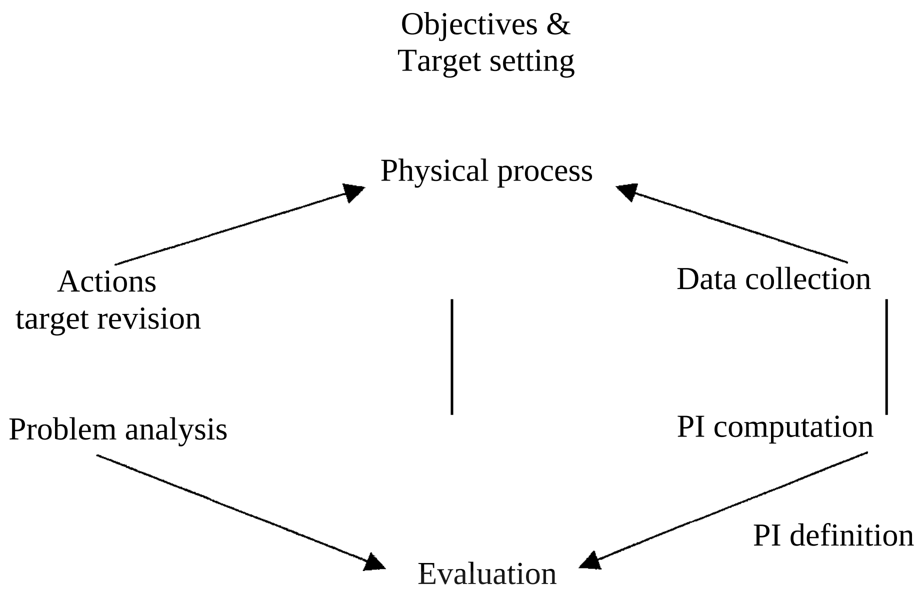


Figure 2.1. Performance Indicator Cycle.

The PI definition process was a crucial aspect in the PI cycle. It was time-consuming process in which PIs were suggested, critically analyzed, and redefined until there was a consensus about their usefulness. The computation and data collection methods should be carefully defined for each PI. Data integrity and timeliness were, of course, required features for the PIs.

Three basic types of PIs might be distinguished: measuring efficiency, effectiveness, and productivity. Efficiency ratios would report on how well resources had been used. An effectiveness of ratio would report on how well the objective was reached, and productivity ratio related input needed to achieve out-put. Figure 2.2 gave generic definitions for each of those types. Reporting on the material handling process, some further general indicators might be useful to complete the performance picture (e.g., the number of product in the warehouse). Table 2.3 illustrated performance measures in each category for material handling systems. Note that although most PIs were ratios, this was not absolutely necessary.

Input → Process → Output

$$\text{Efficiency} = \frac{\text{Computed input (theoretical)}}{\text{Consumed input (actual)}}$$

$$\text{Effectiveness} = \frac{\text{Achieved out put (actual)}}{\text{Expected output (theoretical)}}$$

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

Figure 2.2. Basic Performances Indicator (PI) Types.

Table 2.3. Material Handling Performance Indicators.

Performance	Example	Illustration of PI
Effectiveness	Throughput time	Order cycle time, i.e., time between Material handling job request and its completion.
	Accuracy-reliability	Service level, i.e., number of okay jobs per total numbers of jobs.
	Scrap	Damage ratio, i.e., number of damaged loads per total number of loads.
Efficiency	Space	Warehouse space use, i.e., storage space occupied to available storage space.
	Equipment	Lift truck use, i.e., items moved per hour vs. theoretical capacity.
Productivity-General	Material handling vs. context	Material handling labor ratio, i.e., material handling personal to total operating personal.
	Material handling vs. process	Movement ratio, i.e., number of moves to number of productive operation.

Related to these PI issues were the increasingly popular competitive benchmarking techniques. The main idea of competitive benchmarking was to compare one's own performance with that of the competitors to detect one's weaknesses and strengths. From there, the area for improvement might be identified. Benchmarking in general was a technique used to establish world-class performances in certain processes (e.g., manufacturing performance).

2.2.2 Qualitative Analysis

A qualitative material handling system analysis or a material handling audit might be conducted on different levels: strategic, tactical, and operational. A strategic audit would be geared toward the contribution of the material handling system in supporting the corporate goals. A typical question to be answered here was, "Does the company need its own warehouse or should it rent outside storage space?" A tactical audit would try to answer questions concerning medium-term investment and operating costs. A typical issues addressed here was the useful economic life of the material handling equipment.

An operational audit emphasized the daily operation of the warehouse and thus concerned the flow of material and info'ivation.

Analyzing an existing material handling system was meant to determine whether the system was functioning efficiently and smoothly (without creating bottlenecks) and transporting the unit when and where it was needed. Using a good checklist would help to avoid this while it was saving valuable time. By a "good" checklist we meant a checklist based on experience in any different companies and taking into account the principle areas of the material to handle system. The concept of such a checklist was illustrated in Table 2.4.

e.g., warehouse or shop floor. In step B. a detailed analysis was concerning with the requirements for handling, storing, and controlling was made.

The next step was a crucial one, because in step C all the alternatives that would be considered in the study were developed. The existence of a large variety of equipment with different capabilities and limitations made this step a tough one. The rapidly changing technology in some areas added to this complexity. Also factors such as available funds, building characteristics and management philosophy concerning automation might influence this step.

Figure 2.3 illustrated several degrees of automation and their suitability for different throughput levels. Notice that several elements would favor more automation, while others would favor less automation. Among the elements that favored automation were centralized distribution, better space use, increasing labor cost, nonavailability of labor, improving work conditions, with smaller size and therefore more handling units. One element favoring less automation was the tendency toward shrinking inventories, i.e., smaller warehouses.

However, the primary benefit of automation was system discipline, resulting in increased accuracy, better ergonomics, and fewer returned shipments.

In step D in Table 2.5, the alternatives from the previous step were evaluated. Different methods might be used. Note, however, to obtain the necessary data was not always an easy task.

Besides these quantifiable measures, there was also a number of intangible aspects to be taken into account, e.g., reduced scrap, better quality of work life, and preparation for more integration.

Table 2.5. Steps in Designing a Material Handling System.

A.	Define the intended function of the material handling system.
B.	Analyze the requirements for handling, storing and controlling.
C.	Generate alternatives.
D.	Evaluate alternatives.
E.	Select preferred design.
F.	Implement the selected design.

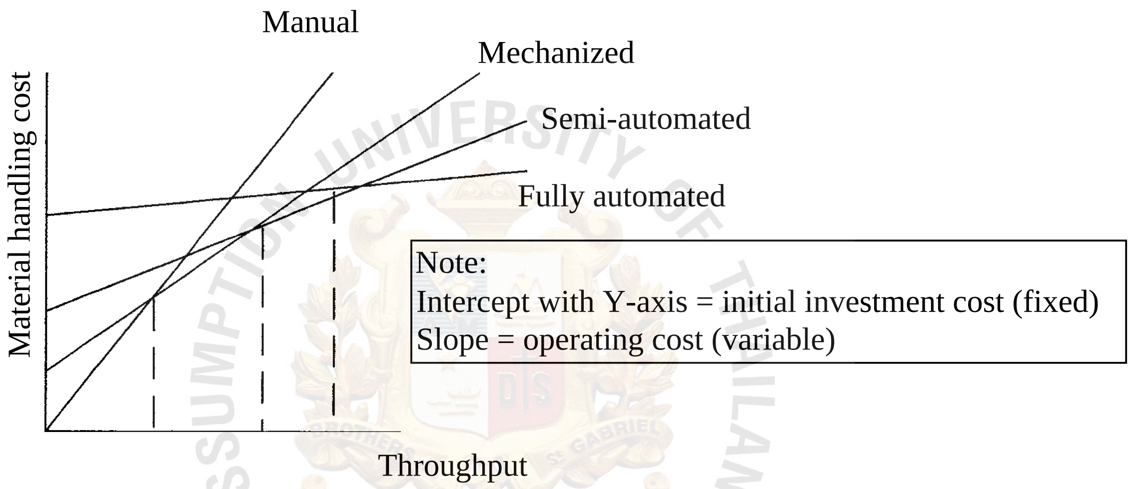


Figure 2.3. Levels of Automation.

2.4 Automated Equipment

Vertical and horizontal carousels could be treated much like bins, with the exception that only one person could work an aisle at a time. Carousels, in fact, were often grouped with a single material handle to work in two or more. In this arrangement, each carousel was usually considered to be an aisle and the single-person limitation was modified to apply to the carousel group.

The sequencing of transactions in a carousel environment could be important to productivity. Typically, when a single operator used several carousels, transaction alternate among the carousels and those for a single carousel were sorted by section. This allowed some carousels to be rotating while others were being used. It also limited the rotation time required for each carousel to move from one pick or put-away transaction to the next.

Productivity and accuracy considerations often required that the inventory control system should be directly connected to the programmable controller that operated the carousels. The link was used to pass transactions to the carousel controller in real time and to rotate them automatically as needed. The inventory system had to be also able to communicate the exact picking location and quantity to the material handler. It had to be able to receive a signal from the material handler denoting the completion of each transaction. And, there had to be a means by which the material handler could enter exceptions such as unplanned shortages or incorrect carousel rotations as they occurred. A translation table was often needed to convert between the location numbers understood by the inventory system and those understood by the carousel controller.

Real-time communication between the carousel and the inventory system could be handled by an intermediate computer. Personal computers had been successfully used for this. Batches of work, such as a picking wave, were downloaded to the PC. The PC managed the carousels and the picking process. Validated results were uploaded to the inventory system on completion of the wave.

Automated storage and retrieval systems (AS/RS) were similar to carousels except that the mechanism for moving the load to the operator was different. While a carousel rotated the entire "aisle" until the appropriate bin was in front of the operator, an AS/RS extracted individual bins or unit loads and carried them to the operator. Most automated storage and retrieval systems were capable of moving one load while the operator was working an another.

Link carousels, automated storage and retrieval systems were often interfaced with the inventory system to reduce key entry requirements. Like carousels, the interface was almost always done through a programmable controller to handle the digital to analog conversion. And, in many cases, a personal computer was placed between the programmable controller and the main inventory control system to assure fast real-time response.

Moveable aisle systems consisted of high-density storage in which an entire row of locations was mounted on wheels and could be moved laterally. When an operator needed access to a location, rows were moved until an aisle was created. Moveable aisle systems were often best suited for slow-moving items in long-term storage and, therefore, were not often found in inventory facilities with sophisticated control systems. They could be useful however, in instances where physical security was concerned.

The rack and flow rack could be semiautomatic with the addition of a pick-by-light system. These systems included small LED displayed at each location that were used to display a picking quantity and, sometimes, an order number. They often enhanced picking productivity by eliminating paperwork. Accuracy was also improved because the pick quantity was displayed at the picking location and the picker did not need to figure out which location to pick from.

Pick-by-light systems required a significant degree of integration with the inventory system. As always, the picker had to have the ability to signal completion of a pick or a group of picks, often by pressing a button. Methods of recording and acting on exceptions were also needed.

The term "pick-by-light" implied that these systems were intended for picking. While they were most commonly used to control pickers, they could also be used for storing material and for other tasks. In the case of a put-away, for instance, a material handler could scan a bar code on a pallet of mixed items to be put away. The inventory system could determine the location for each of the items and signal the location by displaying the put-away item number and quantity on each one.

2.5 Vertical Carousel (Industriever and Lektreiver) System

Kardex Industriever and Lektriver were vertical carousels working on the "goods to man" principle. This system was an industrial-grade heavy-duty system of vertically rotating shelves, which were powered up and down in response to operator commands.

Key Components

The small-item powered vertical carrousel transportation concept consisted of several key components:

(1) Carrier which could have dividers;

(2) Two endless closed-loop chains

(3) Electric motors, drives, and sprockets;

(4) Start and stop controls, carousel chain command entry device or key pad, and access door;

(5) Structural support upright posts, horizontal support members, and shell (shroud or housing).

The first small-item vertical carousel transportation component was the carrier. Carriers for material storage were attached to heavy duty roller chains at both ends. The special design of the Vertical Carousel enabled high storage density as it eliminated wasted unusable height between individual carriers.

Most small-item vertical carousel manufacturers permitted a minimum weight per carrier load-carrying surface. This minimum load weight was the combined weight for the product, load-carrying surface (carrier), and containers. Also, most small-item

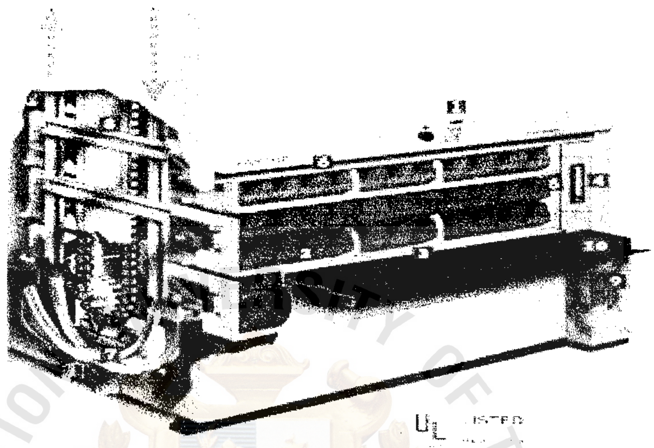


Figure 2.4. Unit Component.

(a) Electronic Control Panel: Integrated microprocessor controls chose shortest route to selected shelf

(b) Maximum load per carrier of 600 lbs

(c) Upper and lower safety bar

(d) Infra-red safety eyes

(e) Safety status panel

(f) Optional full width fluorescent light

(g) Four-point tracking in the arc allowed for maximum carrier support

(h) Freestanding end frame allowed greater unit payload capacity

(i) Variable Speed DC drive allowed optimum efficiency

(j) Handcrank allowed manual operation of the unit vertical carousels had a weight limited to the total number of load-carrying surfaces.

The next important vertical carousel concept component consisted of the two closed-loop chains. These endless closed-loop chains were the major components that moved the load-carrying surfaces (carrier) between the two floor workstations. The side of the carrier load-carrying surface was attached on each chain side.

The third component of the vertical carousel concept consisted of the motors, drives, and sprockets. These carousel components provided the power to move the two closed-loop chains over the travel path of each chain. The shaft with a sprocket was connected to the electric motor. One of the chains of the carousel and the dual sprocket with a chain was located at the base of the vertical carousel unit. All of these components plus all of carrier were enclosed within the shell or enclosure.

As the electric motor turns the shaft, the gear at the end of the shaft was its tooth sprocket.

Most vertical carousel manufacturers had several standard size motors. These decimators' sizes were 1.5 hp, 1/3 hp, and 3 hp. The appropriate motor was matched the vertical carousel application, based on the number of carrier and the carrier load — carrying capacity.

Another feature on some vertical carousel units was the guide rollers and sleeves. These guide rollers and sleeves improved the rotation of the vertical carousel carrier over the travel path and minimize vibration.

The next major component of the vertical carousel consisted of the controls that moved the series of carrier, emergency stops, manual movement of the carrier chain up or down, and other switches and indicators, such as OFF/ON and carrier number.

Most vertical carousel manufacturers had two carrier movement control actions: (1) keypad and (2) computer controlled.

The manual control option was the keypad data-entry device. Most keypads had several features:

(1) 10 buttons with number from 0 tog

(2) An industrial quality membrane keyboard with graphic LCD-display and pull-down menus, which could be switched to other languages.

(3) A digital industrial control with integrated variable speed drive guarantees a high degree of safety and quiet, vibration-free operation.

(4) A digital readout

(5) Emergency stop

(6) Keys that caused the carousel chain to bring the required carrier over the shortest route (forward or reverse travel path) and with positioning accuracy to the workstation opening.

The manual control keypad had the flexibility to be mounted at any location above, adjacent to, or in front of the access door opening.

The second manual control option was the hand-held bar code scanner that reads the required carrier identification into the automatic vertical carousel control system.

The next vertical carousel control option was an interface with a PC of computer-controlled, system.

A key part of the control area was the opening area of the vertical carousel access station or workstation. The vertical carousel access station permitted your employee to per form the required deposit and withdrawal product transactions. Other features included in the workstation were:

(1) The access opening, ergonomically designed for good visibility and easy access to the stored material, ensured optimum working conditions.

(2) A full-length bi-parting sliding door protects the stored goods against

unauthorized access, dirt and dust contamination.

(3) The workstation was fully lit by an integrated lighting system.

(4) A work bench covered the full length of the unit, offering sufficient working space.

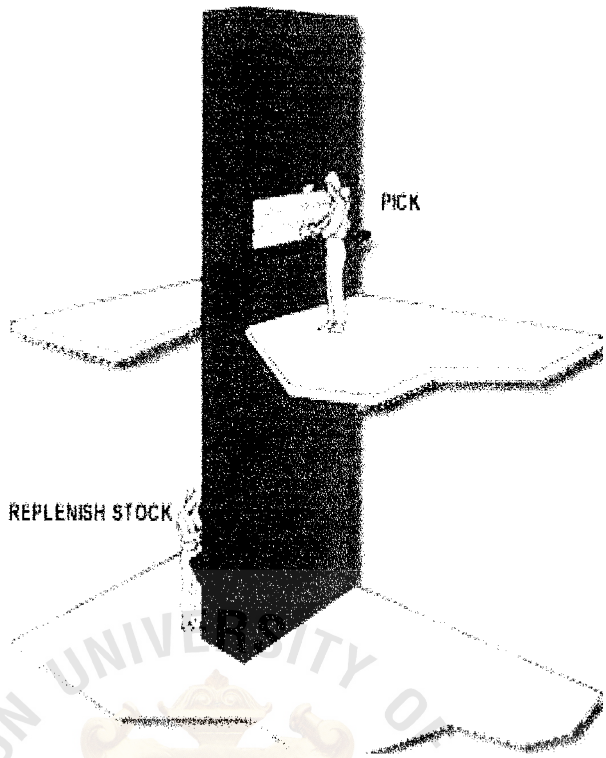
All vertical carousel transportation concepts had two accesses (workstation) openings per carousel unit. With dual-access openings in the vertical carousel, the vertical carousel controls had to be interrelated to control the carousel chain movement. The interrelated controls were required to limit the chain movement so that as the vertical carousel chain moved, only one access door could be open. When an employee at one access opening was performing a product transfer transaction, the interrelated vertical carousel controls shut the door at the other access opening to prevent an employee the other access opening from accessing the carousel, which could cause employee injury, product damage, or equipment damage.

The second vertical carousel dual-access station feature was the location of the access workstations (door). The two location options were: (1) the C configuration and (2) the Z configuration.

In the vertical carousel C dual-access station configuration (see Figure 2.5a), the two vertical carousel access doors (stations) were located on the same side of the vertical carousel travel path. In this C dual-access door configuration, the upper-level door was above the lower-level door.

In the vertical carousel Z dual-access station configuration (see Figure 2.5b), the two access stations were located on different sides of the vertical carousel travel path.

There were several vertical caroused dual—access station design factors that affected the selection of the C or Z dual-access configuration: (1) available floor space and (2) manufacturers standard.



Configuration

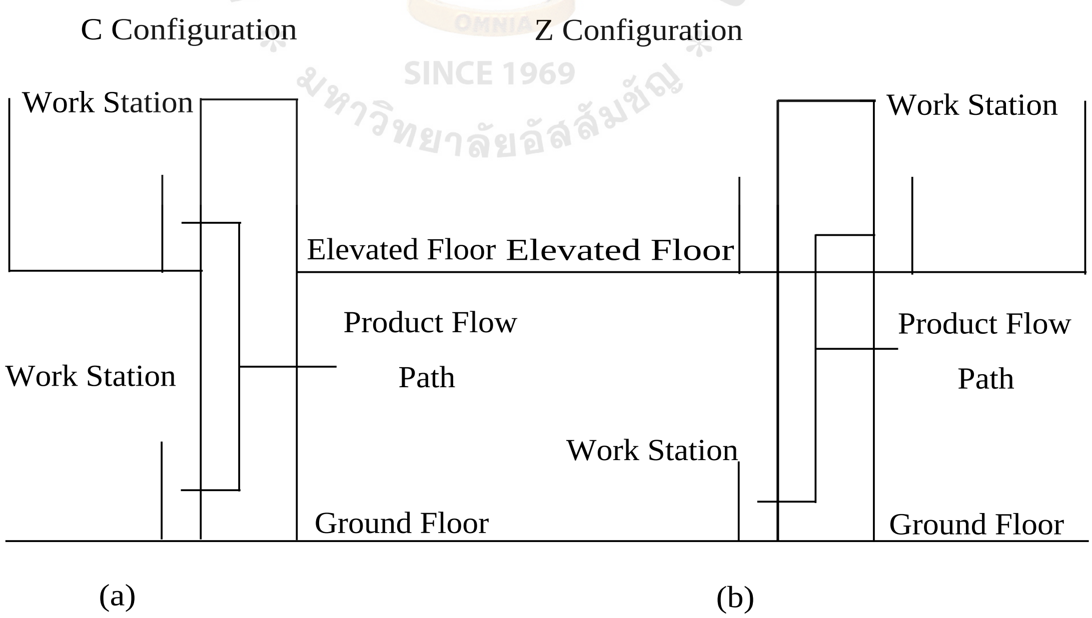


Figure 2.5. (a) C Configuration (b) Z Configuration.

The next major component of the vertical carousel transportation concept group consisted of several parts: (1) structural support upright posts; (2) horizontal support members; and (3) the shell, housing, or enclosure.

The structural upright posts and horizontal support members were the metal members that serve two purposes: (1) provide support to the endless closed-loop chain, carrier guide track and access workstation or counter and (2) provide support to the housing or shell. The housing or shell was a solid-coated sheet-metal surface.

The solid sheet-metal surface exterior enclosed the entire vertical carousel's moving parts. The exterior shell had the appropriate number of workstation (door) access openings and a maintenance access door. The exterior surface (shell) minimized risk of employee injury and reduces any noise from the vertical carousel's moving parts.

The key to the construction of Vertical Carousel was the side frames which not only have to be strong enough to support the full, loaded weight of the Vertical Carousel but also have to be engineered with sufficient accuracy that the chains (on which the carriers were supported), the guidance equipment and the motor and gearbox assembly could all run smoothly with minimal wear year-upon-year. A stable, self-supporting structure with integrated reinforcing frames guaranteed maximum safety.

The care taken over construction could be illustrated by the fact that each side frame was pre constructed fully in the factory and comprehensively checked and tested. Once passed by inspection the side frame units were immediately packed ready for shipment. Strength and accuracy were two essentials built into every Kardex Vertical Carouse.

Kardex Vertical Carousel was an industrial-grade design available in a variety of abrasion-resistant, environmentally friendly paint finishes.

Description of Operation

The design of the vertical carousel as a small-parts vertical transportation concept required that the vertical carousel had two carousels access opening or workstations. One of these vertical carousel doors was located on the lower floor level and the other carousel opening (door) was the located on the upper floor level.

If the lower level was considered the inbound or receiving location, the upper level was the outbound (pick or processing) area. After the inbound product was delivered by the floor-level horizontal product transportation concept to the lower-level access door or opening workstation, the employee activated the controls to access the opening (door) and to have the upper-level vertical carousel access opening (door) lock-out (shut). The employee entered the vertical carousel command so that the appropriate carrier revolved to the access door opening. When the carrier arrived at the access door, your employee transferred the product from the workstation counter to the carousel carrier location. With the completion of the product transferred, the vertical carousel carrier movement commands were repeated for the remaining inbound product. After the entire product was transferred from the lower-level workstation to the appropriate vertical carousel carrier, the lower-level access door was shut. When the lower floor level access door shut, the upper-level employee could open the vertical carousel upper-level door. The upper level door in the open position served two purposes:

(1) It permitted the outbound (pick or process) employee access to the vertical carousel trays or pans. After the upper-level employee entered the vertical carousel movement commands into the carousel control system, the appropriate carrier traveled to the upper-level access door (opening). When the appropriate carrier arrived at the opening (door), your employee removed the appropriate product and quantity from the carrier. The product

removal completes this product transportation and transfer transaction.

(2) It locked or shuts the lower-level vertical carousel access door or opening.

Safety

Safety was of paramount importance to all operators of Vertical Carousel and Kardex had pioneered the incorporation of multilevel safety features as standard. These included; photoelectric cutout switches, both in-line and crossover configurations, elector-mechanical trip bars in the door assemblies and emergency stop switches. Safety cutout and covered all access points, for servicing and manual winding.

Kardex Vertical Carousel complied with international regulations, e.g. BG, RAL, SUVA, VDE, CE, UL etc.

Security

Stock integrity was a further important consideration and mention had already been made concerning the ease by which fire-fighting systems could be introduced into the Vertical Carousel unit. Equally important was the security aspect and all Vertical Carousels were fitted with steel, center-close doors complete with a lock. Extra facilities were available to increase protection including reinforced door panels, double locks and fully electronic combination locking devices.

Unit Chart

UNIT CHART

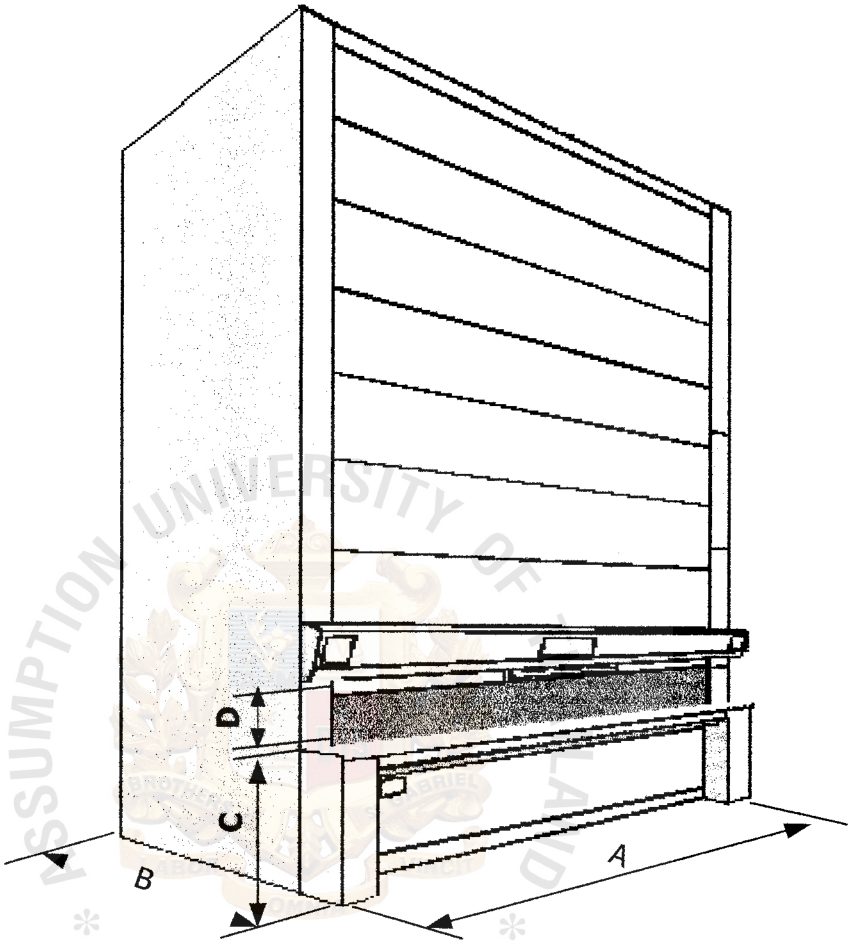


Figure 2.6. Unit Chart.

Table 2.6. The Dimension of Unit Chart.

<table>
<tr><th>SYSTEM</th><th colspan="2">A
Unit Width</th><th>B
Unit Depth</th><th>C
Posting Board Height</th><th>D
Access</th></tr>
<tr><td>120</td><td>2560</td><td>2947 3265</td><td>1155/1175</td><td>1000/750</td><td>493/743</td></tr>
<tr><td>180</td><td colspan="2" rowspan="3">2935/3385</td><td>1180</td><td rowspan="3">1000/750</td><td rowspan="3">493/743</td></tr>
<tr><td>181</td><td>1635</td></tr>
<tr><td>182</td><td>1535</td></tr>
<tr><td>350</td><td colspan="2" rowspan="3">3070/3620</td><td>1312</td><td rowspan="3">1000/750</td><td rowspan="3">543/793</td></tr>
<tr><td>351</td><td>1755</td></tr>
<tr><td>352</td><td>1560</td></tr>
</table>

Technical Data

Technical Data of System 180-182

Req. Room Height	=	Unit Height	20 mm.
Cycle Speed:		SYS 180	5.86 inch / sec.
		SYS 181	4.88 inch / sec.
		SYS 182	4.88 inch / sec.
Total Load Incl. Carrier Dead Weight:			Max. 6100 kg.
Max. Load per Carrier with 40 kg. Own Weight:		SYS 180	220 kg.
		SYS 181/182	180 kg.
Max. Imbalance Load:			700 kg.
Max Carrier Depth With:			
SYS 180 Carrier Pitch	7.5" — 8.75"	=	380 mm.
SYS 180 Carrier Pitch	10" — 16.25"	=	410 mm.
SYS 181 Carrier Pitch	10" — 16.25"	=	620 mm.
SYS 182 Carrier Pitch	10" — 16.25"	=	520 mm.
Carrier Width:			2500 / 2950 mm.
Stop Tolerance at Balance Load About:			ca. +/-15 mm.
Noise Level About:			ca. 60 DB (A)
SYS 180	Drive DC-Bevel Gear Motor		1.8 KW
SYS 180-182	Drive DC-Bevel Gear Motor		1.8 KW
Intermittent Duty:			60%
Average Power Consumption:			1.2 KVA
Max. Power Consumption:			3.0 KVA
Power Supply:			3 * 380 V 50/60 Hz
Power Supply:			3 * 220 V 50/60 Hz

Fuse:	3 * 16 A
Operators Safety Features:	Mech. safety bars (doors)
Safety Switches for:	Lower front access panel and hand crank opening.
Operators Safety Regulations:	BG according to ZH 1/428 Testing Specification VBG 4/1 1977, VBG 4/4 1979, SUVA.
Safety Against Fracture of Carrier Chains:	7 — shelf
Ambient Temperature Max.:	
Operating:	+ 5°C --- +40°C
Non Operating:	-20°C --- +70°C
Permit. Rel. Humidity:	10% --- 90%
Ambient Temperature Max.:	
Operating:	15°C / hour
Non Operating:	10°C / 5 MM.

Condensate must be removes before operating.

Access for service from front.

Unit can be placed directly side by side.

Hand crank for installation of carriers and service.

Technical Data of System 350-352

Req. Room Height	= Unit Height	20 mm.
Cycle Speed:		4.60 inch / sec.
Total Load Incl. Carrier Dead Weight:		Max. 12290 kg.
Max. Load per Carrier With 40 kg. Own Weight:		SYS 350-352 350 kg.
Max. Imbalance Load:		2000 kg.
Max Carrier Depth With:		
SYS 350	=	410 mm.
SYS 351	=	620 mm.
SYS 352	=	520 mm.
Carrier Width:		2500 / 3050 mm.
Stop Tolerance at Balance Load About:		ca. +/-15 mm.
Work Place Related Continuous Sound Intensity Level:		ca. 60 dB (A)
Drive AC — Bevel Gear Motor	SYS 350 — 352	3.0 kw
Intermittent Duty:		60%
Power Consumption:		4.5 KVA
Power Supply : (Standard)		3/N/PE 400 V 50/60 Hz
Securing of the Power Supply Cable:		3 * 16 A
Power Supply Cable		2.5 mm^2 CU
Safety Switches for:		Front access panel and hand crank opening.
Safety Against Fracture of Carrier Chains:		7 — shelf
Ambient Temperature Max.:		
Operating:	+ 5°C	+ 45°C
Non Operating:	- 20°C	+ 70°C
Permitt. Rel. Humidity:		10% --- 90%

Ambient Temperature Max.:

Operating: 15°C / hour

Non Operating: 10°C / 5 MM.

Condensate must be removes before operating.

Access for service from front.

Unit can be placed directly side by side.

Hand crank for installation of carriers and service.

Type Number

Example: SYSTEM XXX — 18 10.5 —)O(

_____ Height no.

_____ Carrier pitch in inch

_____ Number of carrier

_____ Unit type

III. METHODOLOGY

3.1 Research Methodology

The project research methodology can be divided into four steps as following;

(1) Data Collection

Collected the necessary data about the company background, previous storage system such as material characteristics, storage equipment, and storage layout, and problems of the existing system.

(2) Selecting and Propose System

Selected and proposed a set of suitable Kardex storage machine to solve the problems of the previous system concerning to material handling concept and customer requirement.

(3) Data Analysis

Analyzed the new storage system by compare with the previous system in terms of technical and value-add benefits aspect such as increasing capacity, floor space saving, access time saving, and labor cost saving.

(4) Conclusion and Recommendation

In the last step, the result of data analysis in the both case studies would be concluded by compare between previous system and Kardex system in terms of quantitative and qualitative analysis. Moreover, the result of both case studies analysis would be showed the percentage of saving in bar chart.

From the previous information, the Kardex system could be concluded in terms of advantage and disadvantage of the vertical carousel and guideline to improve working system in the future.

3.2 Company A

3.2.1 Business Activities

Company A was the largest specialized agency in the United Nations system and the lead agency for agriculture, forestry, fisheries and rural development.

A specific priority of the company was encouraging sustainable agriculture and rural development, a long-term strategy for increasing food production and food security while conserving and managing natural resources. The aim was to meet the needs of both present and future generations by promoting development that did not degrade the environment and technically appropriate, economically viable and socially acceptable. The activities of this organization show as following:

(1) Development assistance

The company gave practical help to developing countries through a wide range of technical assistance projects.

(2) Information

The company collected, analyzed, interpreted and disseminated information relating to nutrition, food, agriculture, forestry and fisheries.

(3) Advice to government

The company provided independent advice on agricultural policy and planning and on the administrative and legal structures needed for development.

(4) Natural forum

The company provided a natural forum where all nations could meet to discuss and formulate policy on major food agriculture issues and approved international standards.

3.2.2 Background

According to many problems of storage system such as low storage capacity, the cause of it came from significant increase of hard copy records-documents and project files, and high access time which was the result of improper working environment.

To correct the problems, company A's Registry Section was looking for a storage system that had high-density storage capacity with reasonable investment. A simple but impractical idea was to double stack 4-drawer cabinets on top of the others, using the mezzanine floor for access to the upper tier of 4-drawer cabinets. The idea was rejected by the operators due to the danger of working under such precarious conditions. Expansion or renovation of existing building was just not possible.

3.2.3 Previous System

Lateral folders and suspended pockets were kept in 4-drawer cabinets in document storage room 3.95 meters wide by 6.90 meters long, with the ceiling height 5.50 meters. 50 units of 4-drawer cabinets occupied the entire room. One row each was placed against both side of the wall and two rows, back to back, in the middle of the room. Process of storage and retrieval were unpleasant and created a difficult time in finding a required file. Moreover, the aisles were uncomfortably narrow to access. See Figure 3.1.

3.2.4 Solution

Using the advantage of ceiling height, two units of KARDEX SYSTEMS, VERTICAL CAROUSEL, were installed. One unit at height 5200 mm. with 29 carriers. The other unit at height 4700 mm. width 26 carriers due to the obstruction by an upper beam. See Figures 3.2, 3.3.

The specification of vertical carousel would show in the proposed system document as following:

SYSTEM PROPOSED: COMPANY A

<u>Vertical Carousel No.1</u> (See Appendix A)

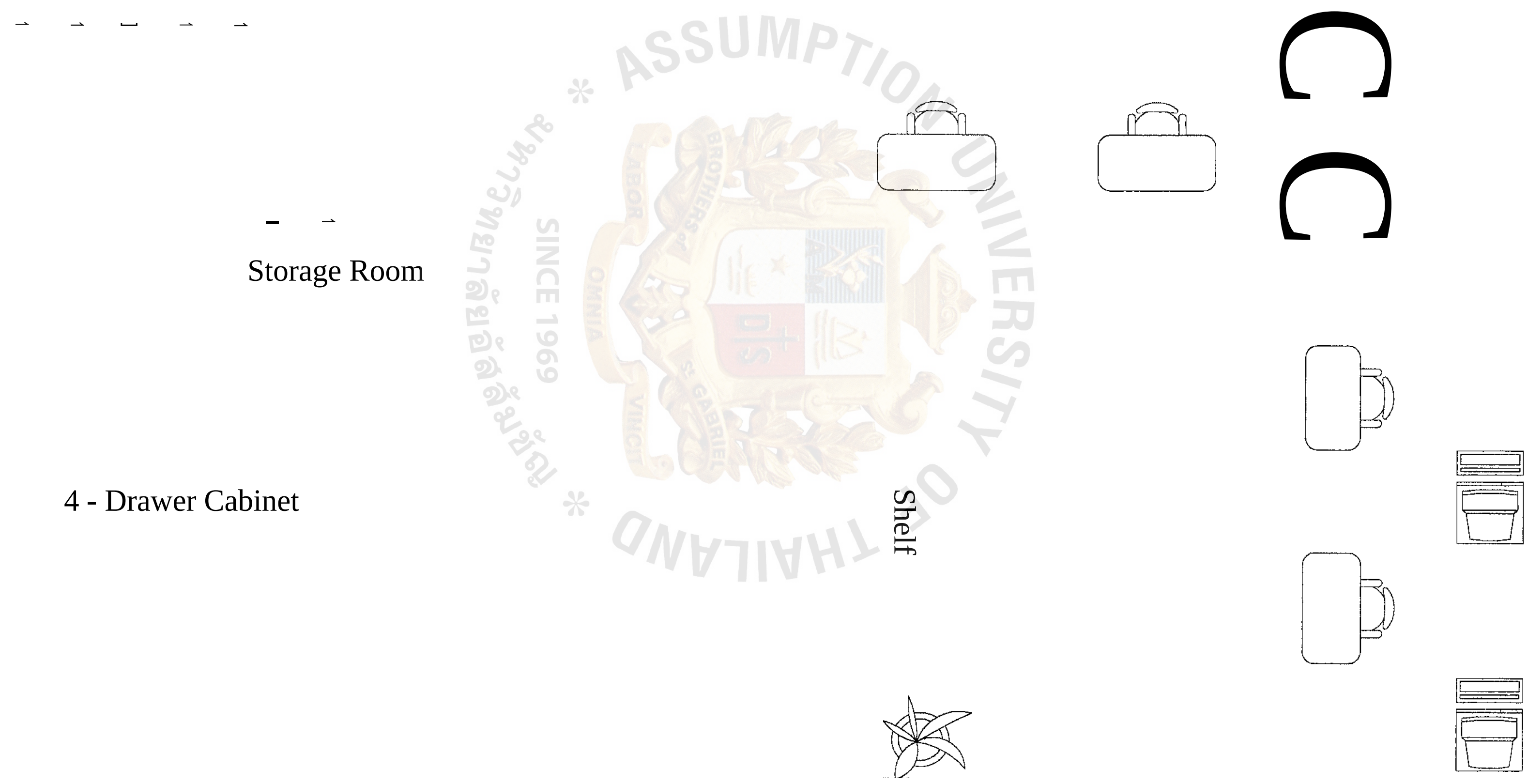
System	SYS 180 — 2612.5 — 50
Unit Dimension	H 4700 * W 3385 *D 1180 mm
Number of Carrier	26 carriers at
	Clear width 2950 mm
	Clear depth 410 mm
	Clear height 278 mm
Suspension Arms Load	206 kg
Carrier Max. Load	220 kg
Average Access Time	13.5 sec
Storage Capacity	76.7 linear meter
Price (Grand Total)	1,058,000 bath

<u>Vertical Carousel No. 2</u> (See Appendix A)

System	SYS 180 — 2912.5 - 60
Unit Dimension	11 5200 * W 3385 *D 1180 mm
Number of Carrier	29 carriers at
	Clear width 2950 mm
	Clear depth 410 mm
	Clear height 278 mm
Suspension Arms Load	184 kg
Carrier Max. Load	220 kg
Average Access Time	15.51 sec
Storage Capacity	85.55 linear meter
Price (Grand Total)	1,104,000 bath

OFFICE LAYOUT 1st FLOOR
(Previous System)

6.95 m



Office Layout Company A (Previous System).

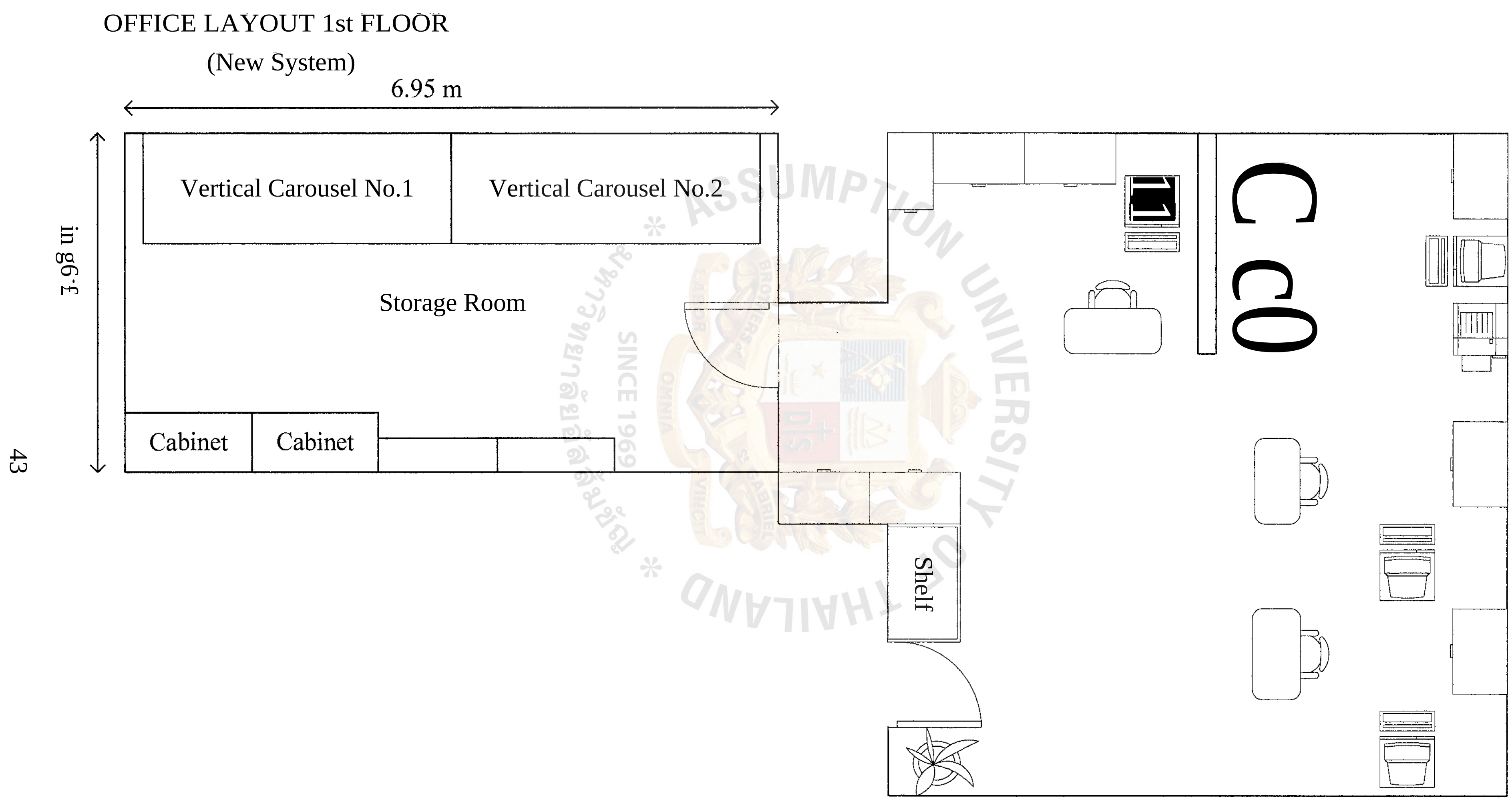


Figure 3.2. Office Layout Company A (New System).

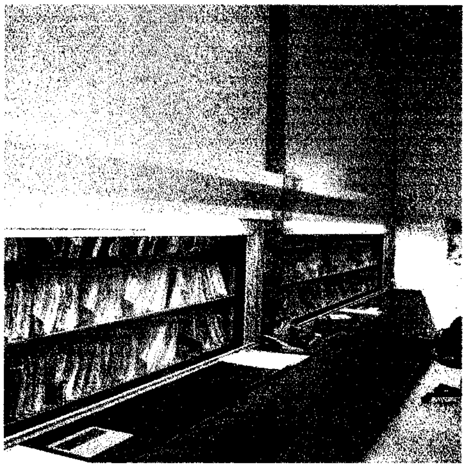
 

Figure 3.3. Vertical Carousel.

3.3 Company B

3.3.1 Business Activities

Company B was currently the supplier of Microsoft Windows compatible PC processors, and a leading supplier of non-volatile (flash) memory. With employees and facilities worldwide, Company B provided the world with processing and flash memory solutions.

Company B was headquartered in Sunnyvale, California

2000 Revenue: $4.6 billion	2000 Net Income: $983 million
Total Assets: $5.7 billion	Number of Employees: 14,435

Creating Technology for Life

Computation Products: company B had produced a family of processors for personal computing, notebook computing, and a processor for servers and workstations. It produced the processor was among the world's most powerful engines for PC computing, and represents the industry's first seventh-generation x86 micro architecture, provided an optimized solution for the most demanding value conscious business and home users, without compromising their budgets, created high-performance notebook computing.

Non-Volatile (Flash) Memories

Flash memory was the brains behind many of today's technology appliances, such as cell phones, pagers, and personal digital assistants. For over two decades the company had been providing the world with non-volatile (flash) memory devices. These devices could be found in computers and peripherals, wireless communications, public and private communications, automotive control, consumer applications, scientific instrumentation, and medical devices. Whether chips for adapter cards, embedded applications for hubs and switches, Ethernet controllers, or interfaces for digital subscriber lines, the company was dedicated to the task of improving bandwidth and connectivity for the business.

3.3.2 Background

Confronted with an expanding number of orders to process as business volume steadily increased, an increase in storage capacity was required. The company needed the storage system that would address the following operation conditions:

(1) A growing store of electrical parts stored on static shelving occupying 64.8 square meters of picking area at the second floor.

(2) The average pick time was too high and stock was open to thief, loss, and damage.

(3) A new store building addition to an existing facility could not do because the store had not enough areas for expanding.

As above conditions, the store specialist of company B needed a new storage system to improve space utilization, maximizing the use of their store space and increasing productivity.

So, vertical carousels were an important tool to facilitate an efficient physical consolidation. Vertical carousels were automated storage systems consisting of a number of shelves, or carriers, that moved on an endless track, to bring stored items to the operator level, or "golden zone".

3.3.3 Previous System

Previously, the store division stored their spare parts and electrical parts about 4,000 items on static shelving at the 12 static shelving at the 2" floor occupying an area of 23.04 square meters of actual storage space. Low ceilings, only 3.5 meters clear, prevented higher storage. Consequently, the static shelve were spread out over an area of 64.8 square meters in the 2" floor of company's store.

The operators were responsible for complete fulfillment of the store system such as storing, picking, and distribution. In a typical day, the operator spent much of their time walking up and down between the 1st floor to pick the parts at the 2" floor and searching for items. See Figure 3.4.

3.3.4 Solution

Using the advantage of the main aisle at the 1St floor was 7 meter height, 10 meter length, 4 meter width of warehouse, which was to setting up two units of KARDEX SYSTEMS, VERTICAL CAROUSEL, were installed. One unit at height 5050 mm. width 3620 mm. and depth 1560 mm.. The another unit, which had all specification same with the first unit. See Figures 3.5, 3.6.

The specification of vertical carousel would be shown in the proposed system document as following:

SYSTEM PROPOSED: COMPANY B

Vertical Carousel No.1 (See Appendix A)

System	SYS 352 — 1818 — 50
Unit Dimension	H 5050 * W 3620 * D 1560 mm
Number of Carrier	18 carriers at Clear width 3050 mm Clear depth 520 mm
Number of Additional Shelves	36 additional shelves
Number of Storage Level	18 carriers with 2 ADS = 3 storage levels at each level clear height 126 mm

Total 18 carriers = 54 storage level

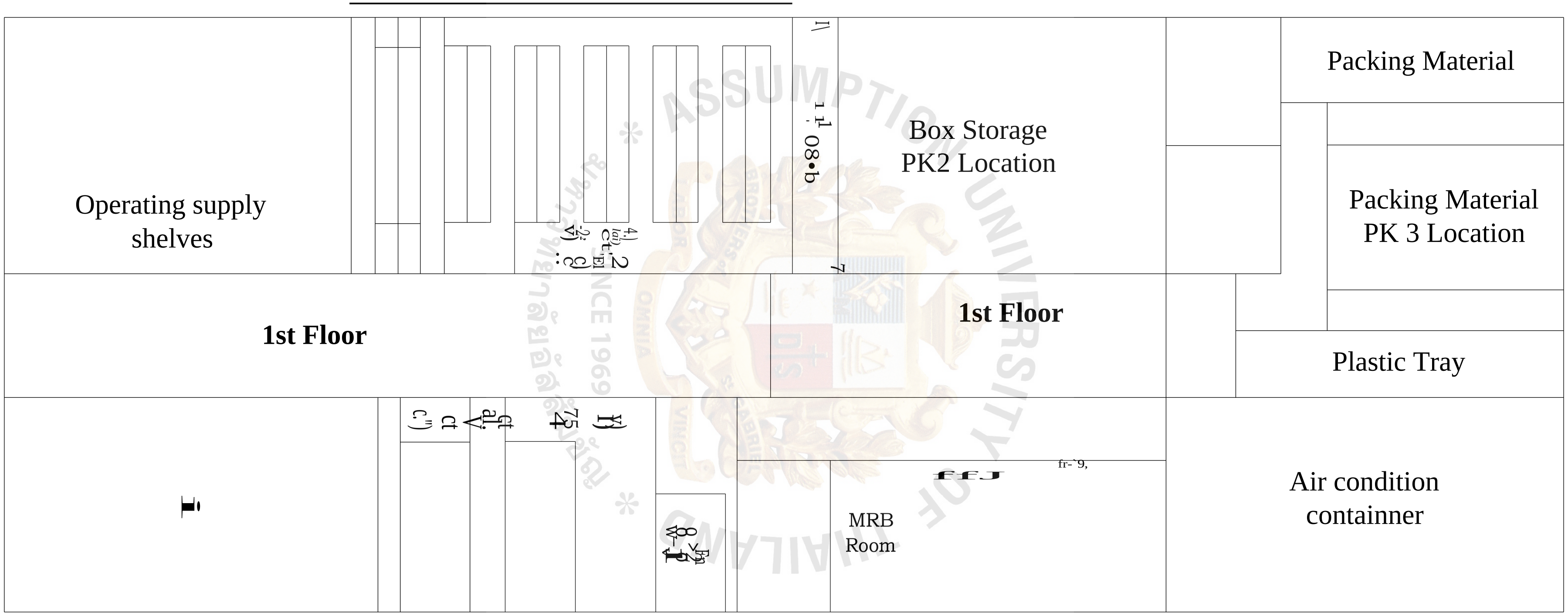
(18 carriers * 3 storage level)

Suspension Arms Load	420 kg
Carrier Max. Load	350 kg
Average Access Time	17.6 sec
Storage Capacity	164.7 linear meter
Price (Grand Total)	1,600,000 bath

Vertical Carousel No.2 (all spec. of it same as Vertical Carousel No.1)

STORE LAYOUT 2nd FLOOR

(Previous System)

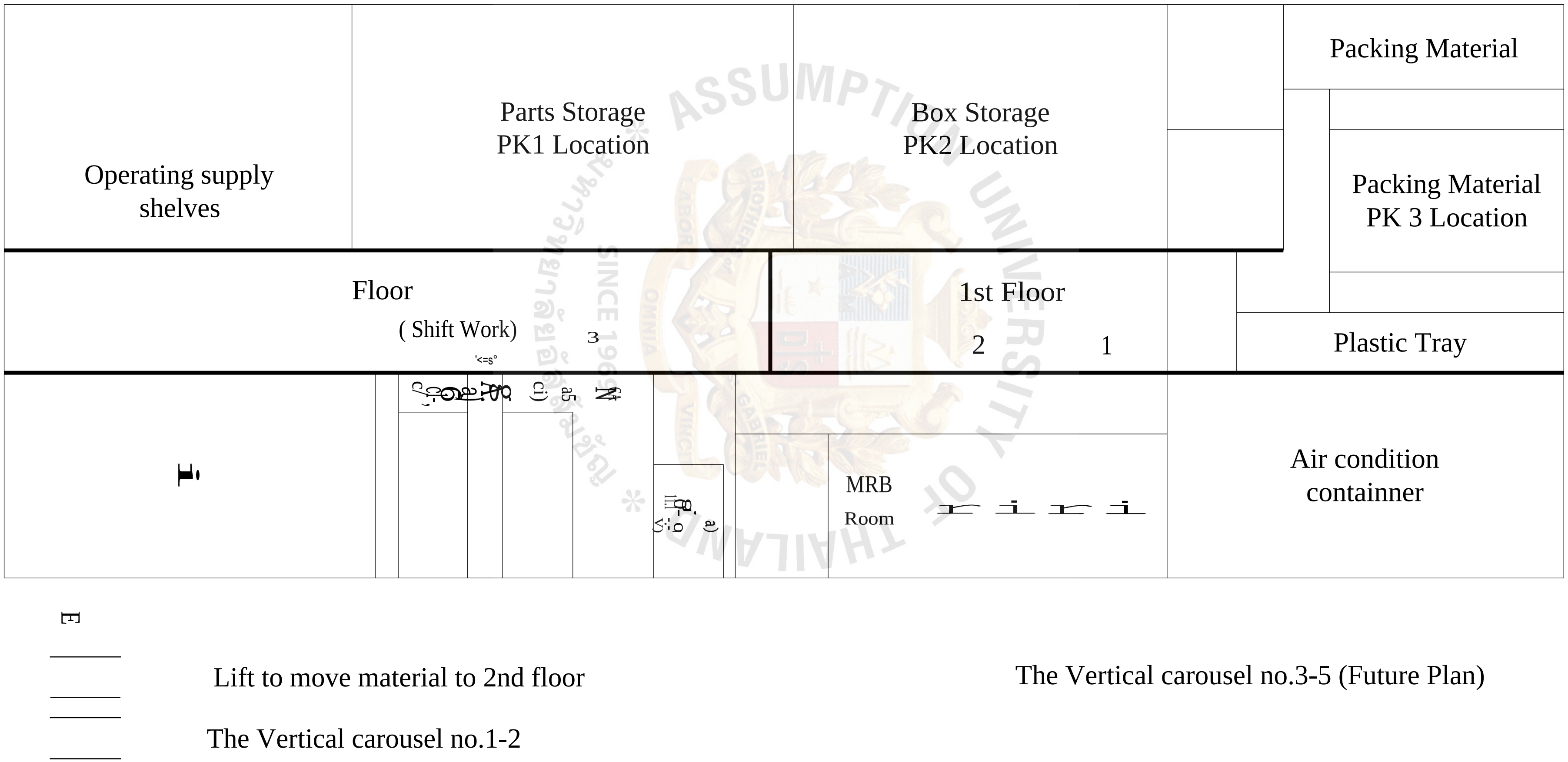


Lift to move material to 2nd floor

Store Layout Company B (Previous System).

STORE LAYOUT 2nd FLOOR

(New System)



Store Layout Company B (New System).

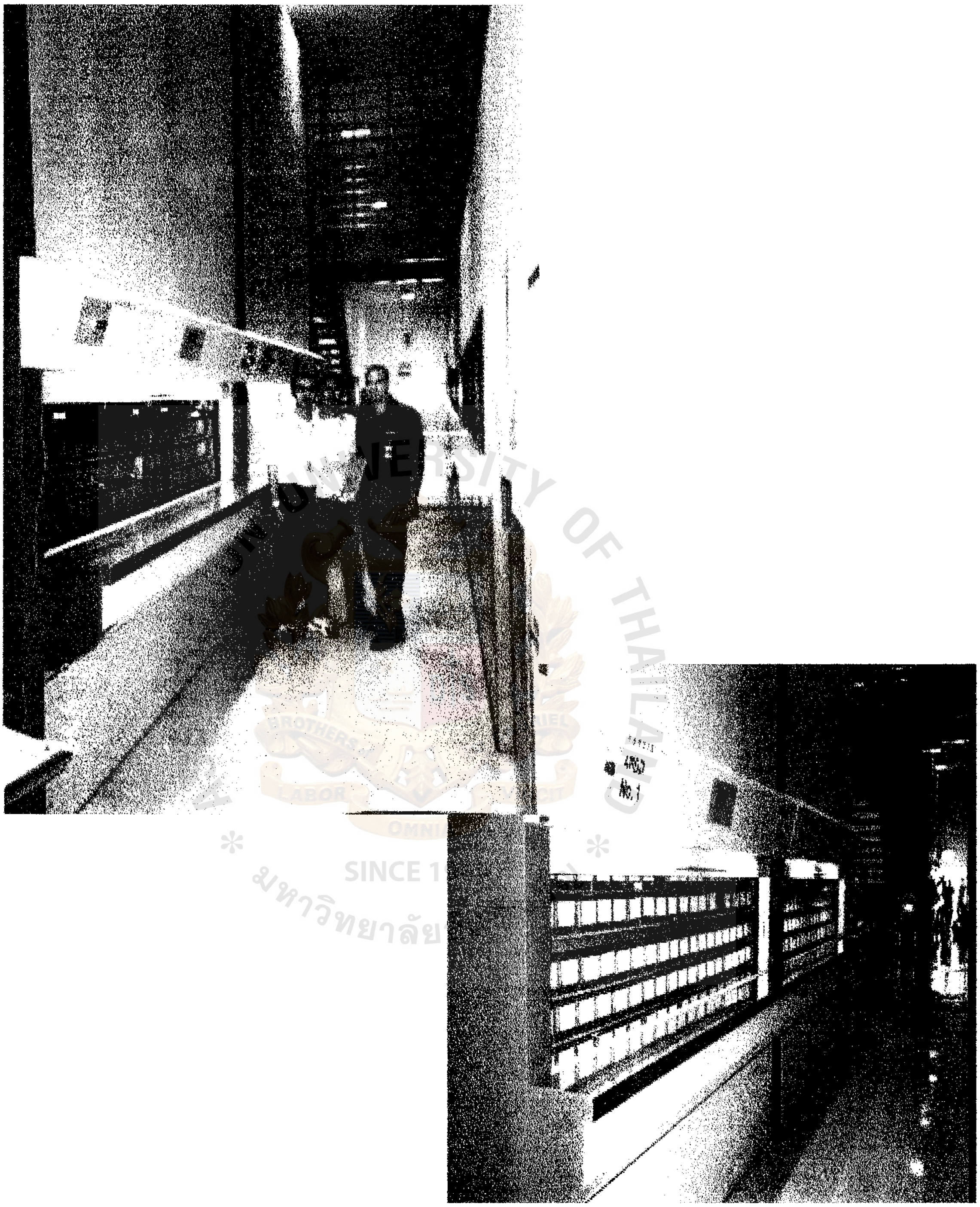


Figure 3.6. Vertical Carousel.

IV. DATA ANALYSIS

4.1 Company A

According to the survey data of Company A, the cost saving can be considered on the following:

Storage Capacity Increasing

<u>Previous System</u>

Storage size of Drawer Cabinet : W * D * H

= 390 * 550 * 270 mm.

Storage capacity of 4 — Drawer Cabinet : 550 * 4 = 2.20 linear meters

Storage capacity of 4 — Drawer Cabinet 50 units : 2.2 * 50 = 110 linear meters

<u>Kardex System</u>

Storage Size of Carrier : W * D * H

2950 * 410 * 295 mm.

Total Number of Carrier : Vertical Carousel No.1 + Vertical Carousel No.2

= 26 + 29 = 55 Carriers

Storage Capacity of 2 Vertical Carousel = 2950 * 55 mm.

162.25 linear meter

Then,

Storage Capacity of 2 Vertical Carousel = 162.25/2.2 = 73 4—Drawer Cabinets.

4-Drawer Cabinet 50 units replaced by 2 Vertical Carousel and remain storage capacity = 162.25 —110 = 52.25 linear meter or 32.2 % of total storage capacity.

These two units of VERTICAL CAROUSEL had a combined storage capacity of 162.25 linear meters, equivalent to 73 units of 4-drawer cabinets. Not only the two units of VERTICAL CAROUSEL could replace all existing 4 - drawer cabinets but also provided a reserved storage capacity of 52.25 linear meters or 32.2% for future expansion.

Free Floor Space of Storage Room Saving

Storage Room Area = 6.95 * 3.95 = 27.45 m^2

Previous System

Storage Floor Space of 50 4-Drawer Cabinet = 470 * 620 * 50 = 14.57 m^2

Free Floor Space of 50 4-Drawer Cabinet = 27.45 — 14.57 = 12.88 m^2

or 46.92% of storage room space

Kardex System

Unit Size Vertical Carousel No. 1: 3385(W) * 1180(D) * 4700(H) mm

Vertical Carousel No. 2: 3385(W) * 1180(D) * 5200(H) mm

Total Floor Space of 2 Vertical Carousel = 3385 * 1180 * 2 mm^2

7.9 m^2

Free Floor Space of 2 Vertical Carousel = 27.45 — 7.9 = 19.55 m^2

or 71.22% of storage room space

Then,

Free Floor Space Saving of Storage Room = 19.55 — 12.88 = 6.67 m^2

or 51.78 % of Previous System Free Floor Space.

According to the previous system, the registry section could not expand the storage capacity of storage room because it already used full storage capacity.

After the company used new storage system, the free storage space would increase about 6.67 m^2 or 51.78% of Previous System Free Floor Space. The company had free space for adding the Vertical Carousel 2 machines or storage capacity about 4,000 files in the future.

Access Time Saving

Previous System

According to the survey data, the access time was about 120 second.

Kardex System

According to the **Table A.1.** in appendix A, the access time of Vertical Carousel No.1 and No.2 were 13.5 sec and 15.1 sec respectively.

Then,

Access Time Saving was about 120-15 = 105 sec or 87.5%

Labor Cost Saving

The reduction in storage floor space rather than being a detriment to operations, became an opportunity to reduce the amount of traveling operators had to do each day searching for records, and the time they spent going through drawers and files.

In addition, the controller automatically searched for the file, performs a shortest route calculation, and brought the correct carrier to the work surface. So an operator could stand in one place and retrieve information, rather than walking to several different file cabinets and shelves.

As above reasons, the registry section could cut in personnel requirement in the file storage room by 1 person or labor cost saving about 60,000 baths/year.

4.2 Company B

Storage Capacity Increasing

Previous System

Storage Size of Static Shelving:	W * D * H
	= 3200 * 600 * 220
Storage Capacity of Static Shelving:	3200 * 4 level/carrier = 12800
	= 12.8 linear meters

Storage Capacity of 12 Static Shelving: = 12.8 * 12

= 153.6 linear meters

Kardex System

Storage Size of Carrier: W * D * H

= 3050 * 520 * 403

Storage Size of carrier (2 divider/carrier): W 3050 * D 520* H 126

These is carrier carousels utilize or split shelf design to provide 54 level of storage capacity.

Total number of storage level: 18 carrier * 3 level/carrier

= 54 storage level.

Storage capacity of Z vertical carrier = 3050 * 54 * 2

= 329.4 linear meters

Then,

Static shelving 12 unit replaced by 2 vertical carousel and remain storage capacity = 329.4 — 153.6 = 175.8 linear meters. or 53.37% of total storage capacity of vertical carousel.

In addition, the two vertical carousels used 1,954 plastic bins to store the 4,000 parts items of the previous system and remain the storage capacity for store parts roughly 2,000 items.

Free Floor Space Saving

Storage Area (PK1) = 13.5 * 4.8 = 64.8 m^2

Previous System

Static Shelving Size: W * D * H

= 3200 * 600 * 220

Storage Floor Space of 12 Static Shelving: = 3200 * 600 * 12

= 23.04 m²

Free Floor Space of 12 Static Shelving: = 64.8 — 23.04 = 41.76 m^2

Kardex System

Vertical Carrousel Size: = W 3620 * D 1560 * H 5050

Storage Floor Space of 2 Vertical Carousels = 3.62 * 1.56 * 2

= 11.29 m^2

Free Floor Space of 2 Vertical Carousels : = 64.8 — 11.29 = 53.51 m^2

Then,

Free Floor Space Saving = 53.51 — 41.76 = 11.75 square meter or 28.13 % [11.75 * 100 / 41.76] of previous system free floor space.

Storage Floor Space Saving

Previous System

Static Shelving Size: = W 3200 * D 600 * H 220

Storage Floor Space of 12 Static: = 3200 * 600 * 12

= 23.04 m^2

Kardex System

Vertical Carrousel Size: = W 3620 * D 1560 * H 5050

Storage Floor Space of 2 Vertical Carousels = 3.62 * 1.56 * 2

= 11.29 m^2

Then,

Storage Floor Space Saving = 23.04 — 11.29 = 11.75 m^2 or 50.99 % [11.75 * 100 / 23.04] of previous system storage floor space.

As above data, the store divisions floor space requirement from 23 square meters to just 11.29 square meters — a reduction of 50.99 percent. The 11.75 square meters thus freed up was turned over to store.

Access Time Saving

Previous System.

According to the survey data, the operator used the access time about 3 min for walking up and down the aisles and stairs of static shelves for access parts.

Kardex System

According to the **Table** A.3. in Appendix A, the access time of vertical carousel is 17.5 sec.

Then,

Access time saving is about 180 — 17.5 = 162.5 sec or 90.27%

Labor Cost Saving

The Kardex's system eliminated the loss time to research the parts on shelf, and dramatically increased efficiency by eliminating the climbing, stretching and bending required to pick those same parts from shelf before installation of vertical carousel.

So now instead of walking up and down between the 1St floor to pick the parts at the 2nd floor, an operator could stand in front of the vertical carousel, and use the keypad at the vertical carousel to key in parts storage location. The carousel then rotated until that location appeared in the pick window. A light bar identified the location of parts and the picker selected the items.

The Kardex's system could cut the distances worker had to walk between picks the parts about 20 meters and reduced the average picking time for a part from 10 min to 30 sec. As a result, it cuts in personnel requirements in the store department by 1 operator / shift.

Then,

Company B had 4 workers per shift and had 3 shifts. The company could reduce 1 worker per shift or 3 persons from all of them, which is 25% of workers.

Labor Cost Saving	=	5000 bahts / shift / month
		5000 * 3
		15000 Bahts / month (3 shift)

V. CONCLUSIONS

In the conclusion, this project studied about the problems of storage system especially the usage space in the store. The Vertical Carousel was a best way to solve this problem because the concept of it was using the limited area to keep the parts or files document that helped to increase the productivity, which we could explain deep in detail as following:

5.1 Comparing between Previous System and Kardex System

According to the Previous system and Kardex system of both company A and company B, we could see the differentiation of the previous system and Kardex system which these actual information would help easy to understand the both system. These information would help to understand why the companies changed from the previous system (man-to-goods) to implement the Kardex system (goods-to-man) although the machine is expensive.

Comparing between the Previous System and Kardex System

Table 5.1. Comparing Quantitative.

Previous System	Kardex System
- Required wide - spread area to store the items, or products.	- Required limited area to store the items, or products.
- Employ many people.	- Employ only few persons
- It used a lot of areas to store the items, which no more space to expand the warehouse.	- Kardex machine was small footprint ensures maximum storage density using minimum floor space, so it had more space to expand the warehouse, which it was not to buy the new plant or rent other warehouse.
- Was low picking and dispatch speeds.	- Was high picking and dispatch speeds.

Table 5.2. Comparing Qualitative.

Previous System	Kardex System
- Was slowly to access and deliver the items	- Was fast to access and deliver the items.
- Was low accuracy.	- Was increase the accuracy.
- Was high quality parts/goods damaged.	- Was low quality parts/goods to damaged.
- Was less performance.	- Was high performance.
- Was difficult to control the amount of accession, waste parts, loss and damaged.	- Was easy to control the quantity and quantity of parts because it has collecting data system which can record both quantity and quality of them.
- The operator low level of job satisfaction.	- The operator high level of job satisfaction
- Was low level security and protection from dust contaminated.	- Was high level security and protection from dust contaminated.
- Was low level savety system.	- Was low level savety system.
- Was low ergonomical design.	- Was better ergonomical design to reduce operator fatigue.

5.2 Advantages and Disadvantages

The vertical carousel concept as a small — item vertical transportation concept had several advantage and disadvantage as following:

Advantages

(1) Uses of all the cube or vertical facility space

(2) A small foot print requirement

(3) A storage area function

(4) Excellent product security and minimum employee injury.

(5) Fully mechanized computer based system

(6) Maximize floor space saving

(7) Increase of storage capacity

(8) All items were stored and retrieved within the "GOLDEN ZONE

(9) Reduction of access time

(10) Increase speed and efficiency in location time

(11) Eliminate wrong position

(12) Enhance office environment

(13) Multi-floor storage possibility

(14) Supervision was much easier because the picker was in clear view all the time

(15) The flow of material through the store was smoother because picking and replenishment took place at different locations, thus avoiding congestion.

Disadvantages

(1) Move only small product quantity,

(2) Travel distance is short,

(3) Requires a high capital investment,

(4) Only one floor at one time could be accessed by the vertical carousel carriers,

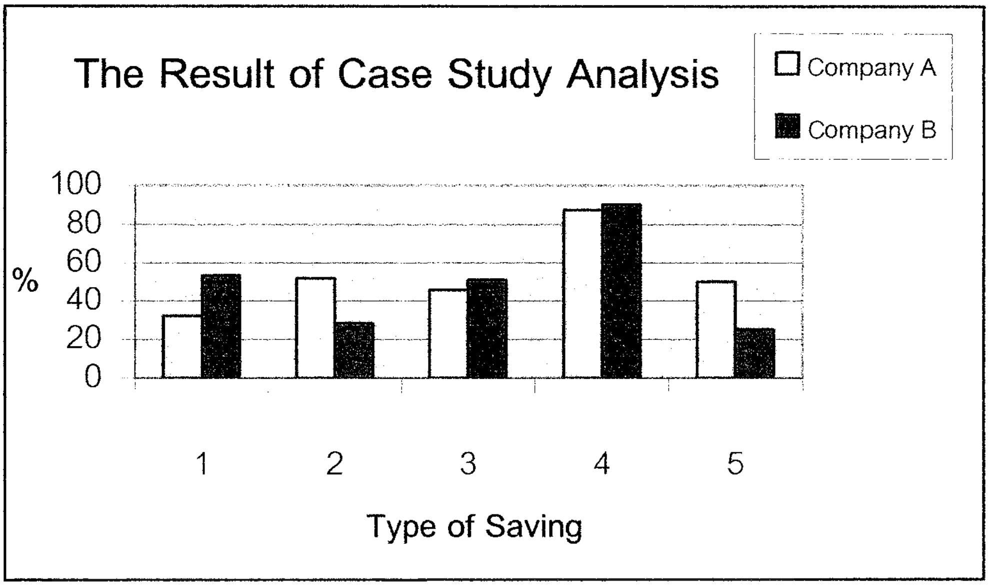
(5) Handling a limited product mix, and

(6) With downtime it was difficult to transfer and move the product.

5.3 The Conclusion of Case Study

From the studying, big problem of the companies was the storage area of the store and inexpandable. So they used the Vertical Carousel to solve the problems.

According to the result of case study analysis, it was illustrated as in the graph followed:



Remarks: 1. Increasing Storage Capacity 2. Free Floor Space Saving

3. Storage Floor Space Saving 4. Access Time Saving

5. Labor Cost Saving

Figure 5.1. The Result of Case Study Analysis.

From Figure 5.1, after the company implemented the Kardex System, it was found that the company could increase the storage capacity at least 30% and saves the storage floor space about 50%.

According to the result of studying, this system could help the company to increase the greater space efficiency by using the overhead space and maximize storage density using minimum floor space.

In addition, this system helped to increase the operator efficiency by more simplifying to work and faster in access parts, which helped the store system worked smoothly and got the higher productivity with lower labor cost.

5.4 Suggestion to Improve Working System in the Future

Vertical carousel was designed to conjunction with software (option), which it could help to improve the warehouse system as the following features:

(1) Manually controlled movement of vertical carousels.

(2) Article master data creation, editing and deletion.

(3) Manual stock input and output.

(Stock input allows operators to either accept the storage location suggested by the system or manually define the location themselves)

(4) Quantity management inc. stock control and administration of minimum stock

Vertical carousels can be effectively operated through an electronic interface with the inventory system by allow the information flow from the host computer to the vertical carousel via a local PC.

For example, company B plan to use computerizes carousel operation. The plan is to tie all two to the center's central computer, which can then download daily orders automatically. When the stage of plan is completed between picks, saving even more order picking time at the center. In addition, the software helps the warehouse accuracy with reports available at any time. FIFO warehouse is automatically accomplished as well, without any operator interference.

From above reason, company B can reduce warehouse division staff from three to two people per shift. At the same time the efficiency and effectiveness is increase too.

APPENDIX A

SYSTEM DATA

Table A.1. System 180 (Basic Units 12.5").

Id - No.	Type Cat. No.	Height (mm)	Height No.	Average Access Time(sec)	Suspension Arm Load (kg)	Weight End Frames (kg)
38153.3	1112.5	2350	3	5.7	260	555
38154.1	1212.5	2500	6	6.2	260	580
38155.8	1312.5	2650	9	6.7	260	604
38156.6	1412.5	2800	12	7.3	260	328
38157.4	1512.5	2950	15	7.8	260	653
38158.2	1612.5	3150	19	8.3	260	382
38159.0	1712.5	3300	22	8.8	260	706
38160.8	1812.5	3450	25	9.3	260	730
38161.6	1912.5	3600	28	9.9	260	755
38162.4	2012.5	3750	31	10.4	260	779
38163.2	2112.5	3950	35	10.9	258	808
38164.0	2212.5	4100	38	11.4	245	832
38165.7	2312.5	4250	41	11.9	234	857
38166.5	2412.5	4400	44	12.5	224	881
38167.3	2512.5	4550	47	13.0	215	905
38168.1	2612.5	4700	50	13.5	206	930
38169.9	2712.5	4900	54	14.0	198	959
38170.7	2812.5	5050	57	14.6	191	983
38171.5	2912.5	5200	60	15.1	184	1007
38172.3	3012.5	5350	63	15.6	177	1032
38173.1	3112.5	5500	66	16.1	171	1056
38174.9	3212.5	5650	69	16.6	166	1080
38175.6	3312.5	5850	73	17.2	160	1110
38176.4	3412.5	6000	76	17.7	155	1134
38177.2	3512.5	6150	79	18.2	151	1158
38178.0	3612.5	6300	82	18.7	146	1182
38179.8	3712.5	6450	85	19.3	142	1207
xxx	3812.5	6650	89	20.2	138	1236
xxx	3912.5	6800	92	20.8	134	1260
xxx	4012.5	6950	95	21.3	131	1285
xxx	4112.5	7100	98	21.9	127	1309
xxx	4212.5	7250	101	22.4	124	1333
xxx	4312.5	7400	104	22.9	121	1357
xxx	4412.5	7600	108	23.5	118	1387

xxx = Price on request

Table A.2. System 180 Multipurpose Carrier.

Max. Carrier Load 220 kg.

Carrier				Additional Shelf and Deviders					Carrier Weight (Max. Carrier Load) (kg)
Pitch	Id - No.	Clear Depth LT (mm)	Clear Width B (mm)	ADS with BRF LH (mm)	ADS with BRF Id.No. Dividers	No. ADS	ADS without BRF LH (mm)	ADS without BRF Id. No. Dividers	
7.5"	154148.1	380	2500			0	155		31 (220)
				66	37629	1	72	37631.9	
	154156.4		2950	151		0	151		36 (220)
				64	37709	1	70	37630.1	
8.75"	154149.9	380	2500	187		0	187		33 (220)
				82	37637	1	88	37639.2	
	154157.2		2950	183		0	183		38 (220)
				80	37635.0	1	86	37638.4	
10"	154150.7	410	2500	219		0	219		37 (220)
				98	37644	1	104	37647.5	
	154158.0		2950	215		0	215		42 (218)
				96	37643	1	102	37646.7	
11.25"	154151.5	410	2500	250		0	250		39 (220)
				114	37653	1	120	37655.8	
				68	37629	2	76	37633.5	
	154159.8		2950	246		0	246		44 (216)
				112	37652	1	118	37654.1	
				66	37629	2	74	37632.7	
12.5"	154152.3	410	2500	282		0	282		41 (219)
				130	37661	1	136	37663.2	
				78	37634	2	86	37638.4	
	154160.6		2950	278		0	278		46 (214)
				128	37659.0	1	134	37662.4	
				78	37634	2	84	37637.6	

Remark: BRF bottom reinforcement = 12.5 mm.

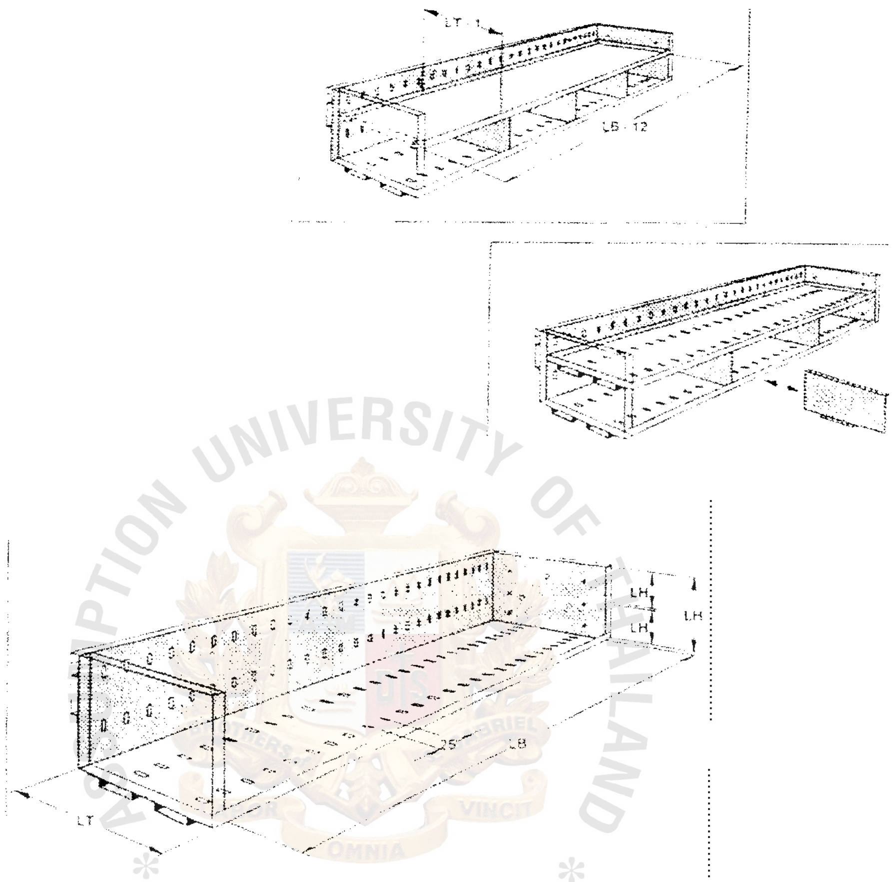
Table A.3. System 352 (Basic Units 18").

Id - No.	Type Cat. No.	Height (mm)	Height No.	Average Access Time(sec)	Suspension Arm Load (kg)	Weight End Frames (kg)
-	818	2750	4	7.8	420	860
-	918	2950	8	9.6	420	898
-	1018	3200	13	9.7	420	938
-	1118	3450	18	11.7	420	977
-	1218	3650	22	11.7	420	1040
-	1318	3900	27	13.9	420	1080
-	1418	4100	31	13.6	420	1118
-	1518	4350	36	16.0	420	1157
-	1618	4550	40	15.6	420	1195
-	1718	4800	45	18.2	420	1235
-	1818	5050	50	17.6	420	1300
-	1918	5250	54	20.3	420	1338
-	2018	5500	59	19.5	420	1377
-	2118	5700	63	22.5	420	1415
-	2218	5950	68	21.5	420	1455
-	2318	6200	73	24.6	420	1495
-	2418	6400	77	23.4	420	1533
-	2518	6650	82	26.7	420	1597
-	2618	6850	86	25.4	420	1635
-	2718	7100	91	28.9	420	1675
-	2818	7300	95	27.3	420	1713
-	2918	7550	100	31.0	405	1752
-	3018	7800	105	29.3	391	1792
-	3118	8000	109	32.3	378	1855
-	3218	8250	114	31.3	365	1895
-	3318	8450	118	35.3	354	1933
-	3418	8700	123	33.2	343	1972
-	3518	8900	127	37.5	332	2010
-	3618	9150	132	35.2	323	2050
-	3718	9400	137	39.6	313	2114
-	3818	9600	141	37.1	305	2152
-	3918	9850	146	41.7	296	2192
-	4018	10050	150	39.1	288	2230
-	4118	10300	155	43.9	281	2270
-	4218	10550	160	41.0	274	2309
-	4318	10750	164	46.0	267	2372
-	4418	11000	169	43.0	261	2412
-	4518	11200	173	48.2	254	2450

Table A.4, System 352 Multipurpose Carrier.

Carrier				Additional Shelf and Deviders					Carrier Weight (Max. Carrier Load) (kg)
Pitch	Id - No.	Clear Depth LT (mm)	Clear Width LB (mm)	ADS with BRF LH (mm)	ADS with BRF Id.No. Dividers	No. ADS	ADS without BRF LH (mm)	ADS without BRF Id. No. Dividers	
10.5"	124343.5	520	2500		-	0			49 (350)
				66	73625.6	1	104	96551.7	
	124344.3		3050	151	---	0	212	---	57 (350)
				64	96654.9	1	100	96656.4	
12"	124345.0	520	2500	187	---	0	259	---	51 (350)
				82	96660.6	1	123	74684.2	
	124346.8		3050			0			59 (350)
				80	96658.0	1	119	96661.4	
13.5"	124347.6	520	2500	297	---	0	297	---	53 (350)
				135	83877.1	1	142	96669.7	
				81	74691.7	2	91	42923.3	
	124348.4		3050	289	---	0	289	---	61 (350)
				131	96665.5	1	138	96667.1	
				78	42929.0	2	88	96653.1	
15"	124349.2	520	2500	335	---	0	335	---	55 (350)
				154	96674.7	1	161	74680.0	
				94	96655.6	2	103	83878.9	
				63	96646.5	3	74	96651.5	
	124350.0		3050	327	---	0	327	---	64 (350)
				150	96672.1	1	157	81206.5	
				91	42923.3	2	101	96656.4	
				61	96645.7	3	72	96650.7	
16.5"	124351.8	520	2500	373	---	0	373	---	57(350)
				173	96679.6	1	180	96681.2	
				106	96657.2	2	116	96660.6	
				73	96650.7	3	84	96652.3	
	124352.6		3050	365	---	0	365	---	66 (350)
				169	42926.6	1	176	96680.4	
				104	96651,5	2	113	96658.0	
				71	83772.4	3	82	74685.9	
18"	124353.4	520	2500	411	---	0	411	---	59 (350)
				192	96685.3	1	199		
				119	96661.4	2	129		
				82	74685.9	3	93		
				60	96645.7	4	72	---	
	124354.2		3050	403	---	0	403		69 (350)
				188	96683.8	1	195		
				116	96660.6	2	126		
				80	74691.7	3	91		
				59	96644.0	4	71		

MEHRZWECKTRAGER MIT 10 MM VORDERER A UFKANTUNG UNDSCHLITZSTANIZUNGEN
MULTIPURPOSE CARRIER WITH 10 MM FRONTLIP AND SLOTS



S'r'STEM	TRAGERZU! CARRIER LOAD (kg)	ANZAHL DER S TU TZBLECHE I NO. OF DIVIDERS: TRAGERBR 2500-2740 CLEAR CARRIER WIDTHS 00-274; mtt BVS wrth BRF	ANZAHL DER S TU TZBLECHE I NO. OF DIVIDERS: TRAGERBR 2500-2740 CLEAR CARRIER WIDTHS 00-274; *ohne* BVS without BRF	LICHTE TRAGERBR. 2750-3050 CLEAR CARRiER 'NIDTH 2750' 3050 mit BVS with BRF	LICHTE TRAGERBR. 2750-3050 CLEAR CARRiER 'NIDTH 2750' 3050 ohne BVS without BRF
350-352	350	2	4	2	5

Remark: BRF bottom reinforcement = 12.5 mm.

Figure A.1. Multipurpose Carrier.

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