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IMPLEMENTATION OF THE BAR-CODING SYSTEM IN MATERIAL MANAGEMENT FOR AN AUTOMOTIVE PART INDUSTRY

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for the Degree of Master of Engineering Management
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ศิริวัฒน์ จิตต์หรรษา: การประยุกต์ใช้สัญลักษณ์รหัสแท่งในการบริหารวัสดุคงคลังของอุตสาหกรรมการผลิตชิ้นส่วนรถยนต์ (IMPLEMENTATION OF THE BAR-CODING SYSTEM IN MATERIAL MANAGEMENT FOR AN AUTOMOTIVE PART INDUSTRY) อ.ที่ปรึกษา: ศ. ดร. ศิริจันทร์ ทองประเสริฐ, อ. ที่ปรึกษาร่วม: คุณ เศรษฐศักดิ์ เชาวนาจิน; 106 หน้า. ISBN 974-333-509-9.

การศึกษาเรื่องนี้เป็นการพัฒนาระบบการจัดการสินค้าคงคลังโดยการประยุกต์ใช้ระบบคอมพิวเตอร์ที่สามารถทำงานร่วมกับ ระบบสัญลักษณ์รหัสแท่ง หรือ Barcode ได้ โดยมีวัตถุประสงค์ที่สำคัญ คือ เพื่อแก้ปัญหา เกี่ยวกับระบบการบริหารสินค้าคงคลังที่มีอยู่ในปัจจุบันใน บริษัท ทีบีเค กรุงเทพ จำกัด ยอดคงเหลือที่บันทึก และยอดคงเหลือที่มีอยู่จริงนั้นมักไม่ตรงกัน

ในช่วงแรกนั้น ได้ทำการศึกษาเกี่ยวกับระบบการบริหารสินค้าคงคลังที่ใช้อยู่เดิม และศึกษาการใช้ และแลกเปลี่ยนข้อมูลของแต่ละขบวนการในงานวัสดุคงคลังโดยใช้ Data Flow Diagram (DFD) เป็นเครื่องมือที่ช่วยในการเขียนแผนผังการไหลของข้อมูลในงานวัสดุคงคลังนั้น จากนั้น แผนภาพดังกล่าวได้ถูกใช้เพื่อหาข้อบกพร่องของการไหลของข้อมูล แล้วทำการปรับปรุงเพื่อแก้ปัญหาดังกล่าวข้างต้น โดยคำนึงถึง ความถูกต้องของข้อมูล และความรวดเร็วของทั้งระบบเป็นหลัก

ระบบการไหลของข้อมูลใหม่นี้ได้ถูกใช้เป็นหลักในการออกแบบฐานข้อมูลและโปรแกรมคอมพิวเตอร์ที่ทำงานร่วมกับผู้ใช้และฐานข้อมูลที่ออกแบบขึ้น ระบบบริหารสินค้าคงคลังใหม่นี้สามารถแทนที่ระบบเก่าได้ทันที โดยสามารถทำการบันทึกการรับวัสดุจากผู้ขาย และการเบิกวัสดุของ ฝ่ายผลิต รวมถึงการออกรายงานการรับ-จ่าย วัสดุได้ด้วย นอกจากนี้ระบบยังสามารถนำข้อมูลที่เก็บไว้มาวิเคราะห์ จัดกลุ่มวัสดุ ตามหลัก ABC analysis และยังสามารถคำนวณหา จำนวนการสั่งซื้อที่ประหยัดที่สุด หรือ Economic Order Quantity (EOQ) ได้อีกด้วย ซึ่งสามารถนำไปใช้เป็นข้อมูลประกอบในการกำหนดนโยบายการสั่งซื้อวัสดุ

จากการที่ได้ทำการทดลองใช้งานจริงของโปรแกรมที่ออกแบบขึ้นใหม่นี้ โดยให้ทำงานพร้อมๆ ไปกับระบบเดิมตลอดเดือน พฤศจิกายน 2542 กับ บางวัสดุ พบว่า ไม่มีความผิดพลาดของข้อมูลในระบบใหม่เลย ในขณะที่ระบบเก่านั้น มีความผิดพลาดเกิดขึ้น เท่ากับ 5% ของปริมาณทั้งหมด ระบบใหม่ยังสามารถทำการบันทึกการรับจ่ายได้รวดเร็วขึ้น โดยลดลงจาก 49.65 วินาที เหลือ 25.85 วินาทีต่อการดำเนินการแต่ละครั้ง และเมื่อได้นำข้อมูลที่บันทึกไว้แล้วในเดือน พฤศจิกายน 2542 มาใช้ในการจัดกลุ่มวัสดุ ตามหลัก ABC Analysis แล้วนำวัสดุในกลุ่ม C มาใช้ค่า EOQ ในการสั่งซื้อวัสดุนั้นๆ ในเดือนธันวาคม 2542 พบว่า ปริมาณวัสดุคงคลังเฉลี่ย มากกว่า 20% โดยประมาณเมื่อเทียบกับ ระบบการสั่งซื้อวัสดุเดิม

ภาควิชา ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต ลายมือชื่อนิสิต .....

สาขาวิชา การจัดการทางวิศวกรรม ลายมือชื่ออาจารย์ที่ปรึกษา .....

ปีการศึกษา 2542 ลายมือชื่อที่ปรึกษาร่วม .....

4171628021: MAJOR ENGINEERING MANAGEMENT

KEY WORD: Inventory Control / Inventory Management System / Barcode Application

SIRIWAT JITHUNSA: IMPLEMENTATION OF THE BAR-CODING SYSTEM IN MATERIAL MANAGEMENT FOR AN AUTOMOTIVE PART INDUSTRY. THESIS ADVISOR: PROF. DR. SIRICHAN TONGPRASERT. THESIS COADVISOR: MR.SETTASAK CHOWWANAJIN. 106 pp. ISBN 974-333-509-9.

In this study, a computer-based inventory management system application that can work with a bar-coding system for an automotive parts industry, TBK Krungthep Co., Ltd, has been developed. This application deals with material updating (updating stock status), material issuance activities, and inventory reports.

A general description about the organization, including organization structures and general production processes has been delineated. First of all, the existing inventory system has been studied, using the data flow diagrams (DFD) in order to identify problematic areas, data, and information flow at first place. Then, additional system requirements determination has been surveyed. After that, a barcode system and codes for the warehouse have been set.

Finally, a computer-based inventory management system and inventory database has been designed under a client/server environment. The system allows warehouse operator to input the data of the receiving and picking transactions, using a barcode scanner. Moreover, the system also provides real-time reports for supervisors or managers including summary of receiving, picking, EOQ and ABC analysis. The average amount of parts per year in the Economic Order Quantity (EOQ) and ABC analysis reports are estimated using the recorded picking amounts in the inventory database.

In the implementation process, the new system is compared with the existing system in three areas, which are accuracy, timeliness, and overstocking, using a sampling set of selected parts. As a result, the errors in the database of the studied parts is decreased from 5% to 0%, while the timeliness of inputting data is improved from average 49.65 seconds to 25.85 seconds. Finally, the average on hand per day of type C items is reduced by more than 20% when using the EOQ model.

ภาควิชา ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต ลายมือชื่อนิสิต .....

สาขาวิชา การจัดการทางวิศวกรรม ลายมือชื่ออาจารย์ที่ปรึกษา .....

ปีการศึกษา 2542 ลายมือชื่อที่ปรึกษาร่วม .....

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CHAPTER I

INTRODUCTION

1.1 Background

Generally, a key objective of production and operation management in most manufacturing companies is to reduce the frequently occurring non-value-added activities (NVA). NVAs, for instance: moving of products or work-in-process, inspection for monitoring quality of goods, etc, are losses. One of the NVAs, which is always forgotten, is inventory. Nowadays inventory management is becoming more significant in the industrial sector for it can, by several means, gave the company a competitive edge. Below are some of the reasons why an efficient inventory management system is necessary.

First, cost reduction is what every company is striving for. Many companies are trying to cost justify their expenditure because of Thailand's economic crisis. If we deliberate on meaningful factors that affect the cost of products, we will find that excess of inventory comes in at the top of the list. In some companies, more than one-third of a company's assets is inventory[1]. So if they have an appropriate system to control their stock, they will have more liquidity and higher efficiency as well.

Second, due to the World Trade Organization is trying to open up the world market based on free and fair trade. On 1st January 2000, the Thai Government will allow car manufacturers to freely use imported parts and raw materials, instead of the current 60% use of domestic materials enforce by legislation. This means that, the number of competitors will increase, with more strength in new technologies, higher performance in the information system and higher efficiency in the production system in order to achieve customer satisfaction. Therefore, medium size manufacturers are forced to improve continuously in every area. Only those who are able to provide the customers the products they want at the right time and in the right amount will survive in this highly

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[1] http://www.picsnet.com/selfquiz.htm

competitive market. This means material should also be provided at the right time, the right places and in the right amount to ensure that the production line flows smoothly. An efficient and appropriate inventory control system is one significant factor that can help a company.

TBK Krungtep co., Ltd., a company which produces aluminum die cast auto parts for Toyota, Nissan, Mazda, Isuzu and Mitsubishi Motors, has also encountered inventory problems. For example, the company has no explicit stock policy, thus, they have overstocked in ingot aluminum (imported) and other materials. Moreover, most documents are done manually or managed by the spread sheet application (Microsoft Excel). Hence, a long time is spent on checking papers and errors between actual amounts in the warehouse and reported amounts in computers. For example, the inventory at the end of June 1998, for pinion gear on hand was recorded in the database as 602 units, while the actual amount in the warehouse was 420 units. These problems should not be disregarded because the company is losing money through them. Therefore, the company should plan to improve its inventory management, computerize itself and apply a bar code system for both higher effectiveness and efficiency in material control.

1.2 Statement of problem

TBKK is a member of EAN-Thailand (European Article Numbering Thailand) which registers members and issues EAN manufacturer numbers to members. The TBKK member number is 8851000, 885 means Thailand and 1000 is TBKK. Nowadays, TBKK is trading with international companies (ISUZU, Mitsubishi Motor, etc.) and is searching for new markets to which to export its aluminum die cast products. Thus, the company realized the necessity of the Article Numbering System. The company realized that Bar Code system is a universal system that can reveal the manufacturer's place of contact, therefore opening up marketing opportunities for the manufacturers and making it more efficient to use the information system in management especially sales and inventory information.

Now, the company's inventory system is mostly run by manual process and on paper documents, such as picking a raw material from a warehouse for a production line. This affects the accuracy and speed of the data that influence managers' decisions. Furthermore, there are more than 500 items in the inventory. The computerized inventory system is necessary for the company seeking higher precision and more rapid data. With the computerized system, many useful techniques, such as ABC or EOQ (Economic order quantity) method, can be applied to classify various materials in the warehouse and handle the numerous stores' documents. Moreover, it can integrate Bar-coding system that can identify products and materials, etc.

The price of effective inventory management software is very high (more than 300,000 baht[2]), while the price of computer equipment is reasonable. Moreover, there is no inventory management software that supports the bar-coding feature. Thus, in-house software is a better way for the company, especially in this period. It's more suitable for the company because it will be equipped with only the necessary features or tools to support the production line for the company's warehouse management and therefore achieve customer satisfaction. Furthermore, it can integrate the bar-coding system and also be user friendly.

In addition, Mitsubishi Motor (Thailand), a customer of TBKK, started to apply the UCC/EAN 128 bar coding system throughout the company from warehouse to distribution centers or dealers. In addition, the Electronic Data Interchange is required. Certainly, Mitsubishi's suppliers should initiate the use of the bar coding system when the Mitsubishi barcode system completes as well.

In conclusion, TBKK plans to improve the inventory system by introducing computers and software (run on WINDOWS95) with the bar code system to meet the manufacturing requirement and achieve customer satisfaction. This thesis will concentrate on the applications of the software. The following is the exhaustive list of the application: materials management from receiving, picking, serving, recording, checking, shipping, summarizing and issuing documents.

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[2] http://www.pcaim.com/

1.3 Objective of the Thesis

- The objective is to improve a material management system with bar-coding identification.

1.4 Scope of the Thesis

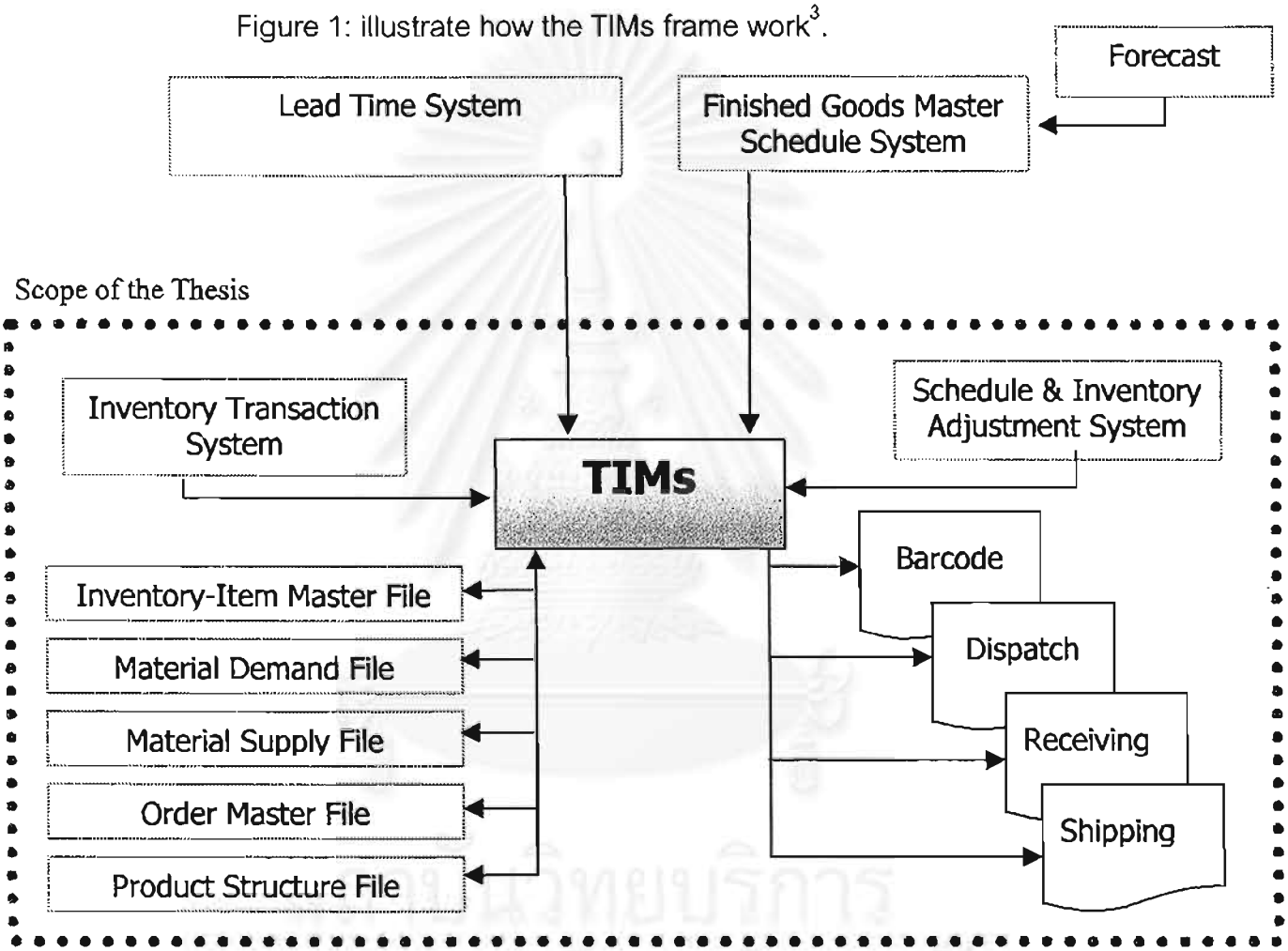
- Concentration of the study is on raw materials.
- To implement a new inventory control application with bar-coding system and necessary features to the inventory division.
- Bar-coding system is based on UCC/EAN 128 system as labeling and internal code.
- Software will be evaluated by:
  - The amount of overstocking
  - Time consumed in summarizing the stores' data
  - The differences between actual amount and record amount.
- User interfaces:
  - Receiving parts, check-ins
  - Picking parts
- An inventory databases which composes of parts, suppliers, customers, models, and employee table.

1.5 Expected Results

The applications of the software will assist general inventory work for higher precision, higher speed in data processing and data transaction and higher performance in analyzing warehouse data. The focus is on supporting process requirements or in other words: to meet the production satisfaction. This program calls "TBKK Inventory Management software (TIMs)", as shown in figure 1.

TIMs will receive the information of ordering from the purchasing department. It can answer the simple question in inventory management, for instance, how many we do have, when the next lot will come, when we should reorder, how we summarize the data to assist our decision, etc. Moreover, with the bar code system we can get rid of human errors in inputting data and/or in confusing over numerous materials in the store.

Figure 1: illustrate how the TIMs frame work[3].



[3] Modified from W.S. Donelson, "MRP-Who Needs Its" Datamation, Vol 25, No.5, May 1979, pp. 185,194.

- Inventory-Item Master File: status of products and raw materials. It composes of part numbers, part descriptions, qualities on hand, quantities on order, part locations.
- Order Master File: status of purchasing order and manufacturing order data. It composes of part numbers, order number, order quantity, due dates, vender number.
- Product Structure File: list and structure of components, which are assembled to finish goods. It composes of part numbers, parent part numbers, component part numbers, tools, lead time, production time.
- Material Demand File and Materials Supply File: contain finish goods and parts required by customers.
- Finished goods Mater Schedule: this has the lists of the kind of products to be produced, the amount needed and the required shipping date, amounts, and shipping date.
- Product Structure Explosion and lead-time System: is a bill of materials and lead-time.
- Inventory Transactions System: is the recorded parts data received and picked parts.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

According to the topic of the thesis, nowadays, there are many useful related sources of information that can be assorted into 5 major issues. Foremost, information technology and information system (IT / IS) have provided the general framework of forming IT strategies and selecting proper IT for a company in order to gain the maximum benefits. Secondly, automatic data collection (ADC) – barcode system, the primary important points in implementing an ADC project will be explained in this topic. Thirdly, the latest bar-coding system, the UCC/EAN 128, its documents and application, will be discussed. Fourthly, inventory control and management issue that deals with the manipulation of the materials in warehouses will be presented. Finally, trends of bar-coding system in warehouses and manufacturing will be the last topic to be studied.

2.2 Information technology

Cortada (1998) suggests that IT managers should be concerned with the benefits of using quality management tools and concepts in IT area such as benchmarking, Quality Function Deployment (QFD), Statistical Process Control (SPC), Just In Time (JIT), and Failure Modes and Effects Analysis (FMEA). In addition, other four classic ideas of quality management practices should be included:

- Continuous improvement
- Zero defects
- Doing it right the first time
- Reliance on employees closest to the situation to improve it

Nowadays, there are many enterprises that have gained the benefits of applying the quality concepts to the management of IT such as Monsanto's Fiber Division, IBM,

Black & Decker. Undoubtedly, all the tasks that IT has to carry out as collections of processes are also at the essence of a quality strategy.

Stair (1996) has defined that information is a collection of facts (data) organized using rules and that they have additional value beyond the value of the facts themselves. In the process of transforming the data into useful, valuable information requires knowledge, which is the body or rules, specifications and procedures used to select, organize, and handle data to make it suitable for a particular task.

Moreover, he has pointed out the characteristics of valuable information. Typically, valuable information should be simple, accurate, complete, reliable, verifiable, relevant and flexible information. In addition, useful information should be obtained economically and it should be delivered when it is needed.

An information system (IS) is a set of interrelated elements or components that collects (input), manages and stores (process), and distributes (output) data and information, and prepares a feedback mechanism.

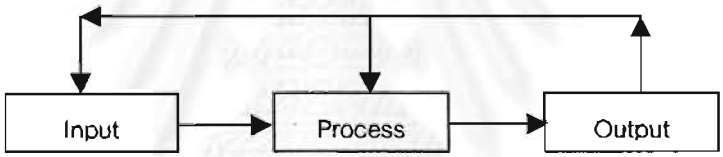


Figure 2.1: The components of an information system.

Haeckel & Nolan (1999) notice that modern successful organizations focus on sensing and responding to swiftly changing customer needs. In order to cope with the change, information technology is introduced due to its ability to largely reduce the constraints dictated by time and space in retrieving, interpreting, and working on information. Therefore, the managing by wire is a strategy that should be considered in order to survive in the sense-and-respond world. In dynamic environment, the ability to adapt will extremely differentiate the manage-by-wire strategy from the static make – and-sell strategies of the past.

The manage-by-wire is management by using the information on a console, like in the airplane to assist the managers to modify the business plan based on changes in external conditions, monitor the performance of employees and processes and give

directions to auxiliary units such as production and marketing. To achieve this goal, organizations inevitably have to invest some money in IT. However, rather than investing in isolated IT systems (such as inventory control systems, scheduling system, or e-mail), the company must invest in the IT capabilities that will be needed in managing by wire.

Date (1995) explains that a database system is basically a computerized recording system. In other words, it is a computerized system that is used to manipulate the information and provide that on-demand information. In a database system, there are four major components those are data, hardware, software, and end user(s).

Normally, the database systems can be based on many different approaches such as hierarchical, relational and object-oriented systems. Today, even though the trend is to move to the object-oriented database system for both economical and theoretical perspectives, the relational approach is still the most important system. In a relational system, the data is stored in the form of tables. The normalization and entity-relationship diagram are very important concept and tool for building an effective relational database.

2.3 Automatic Data Collection (ADC)

Lebow (1998) explains that automatic data collection (ADC) is a method of entering information into a computer system without manually typing it. The greater speed and accuracy, and the capability of allowing data entry without human intervention are obtained from the ADC. Nowadays, the most popular technology of the ADC is barcode system. Since bar-coding affects many different departments and can fundamentally change the way a company does business, bar-coding needs to be recognized as a strategic tool and needs the active commitment of management. Besides the bar-coding system, ADC covers a number of technologies and methods of data entry such as:

- Barcode system
- Magnetic stripe reading
- Radio frequency identification (RFID)
- Touch-screen terminals

- Pen-based computing
- Voice data entry
- Optical character reading (OCR)
- Touch memory devices.

As shown above, there are many different technologies for different applications. However, the design principles are all similar. In a barcode project, the keys to the success of the project are listed below:

- Team leader – should understand the technology, project management, and the company culture.
- Top management – should have a commitment for the project.
- Team members – have to have high commitment.
- End-users - should be involved early in planning.
- Resources – must be provided.
- System requirements – have to be well defined.

Smith (1996) says that in a barcode project, generally, hardware is focused, while software seems to have less significance to the project team. In fact, software has substantial effects to the entire system; therefore the barcode project team must pay great attention to the software as well as the hardware. For example, many companies had suffered when they did not have enough analysis of their software such as Bell Helicopter Textron and Lockheed Martin. As a result, everything from all the applications feeding WIP reports and hazardous materials tracking to ordering flu shots and opera tickets.

Today, it is a client/server era, thus software should be able to support the technology. Moreover, the user interfaces are essential today. This means that the forms on a screen have to be easy to operate with or user-friendly. A good alternative is Graphic User Interface (GUI) since it uses pictures, images, icons that are more meaningful and easier to understand than texts are.

A suggested solution for the software is to customize the interface and simplify the interaction with the user due to the fact that it will make the system easy to understand and use. Furthermore, training costs are reduced.

2.4 UCC/EAN 128 System (Uniform Code Council [UCC] and European Article Numbering [EAN], 1997)

Article Numbering or Barcode is a symbol of unique bar and space pattern used to identify products which are being circulated in the trade cycle such as manufacturer, wholesale, retail, exporter and importer chain. The barcode can be read by a scanner or by entering the access number via a keyboard. In short, the bar-coding system is based on two principles [11]:

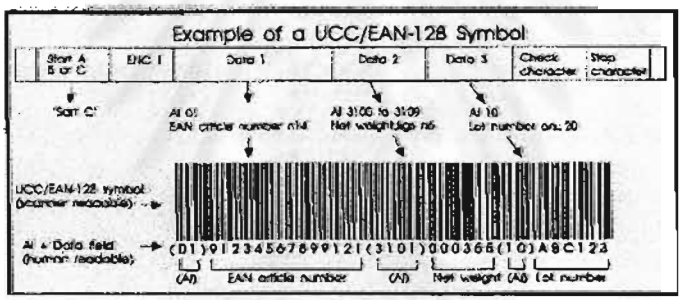
- The codes must identify, not classify, an item.
- The UCC or the appropriate EAN coding authority assigns codes to identify the supplier.

Nowadays, two organizations have the control over the barcode number. Those are European Article Numbering International (EAN) and Uniform Code Council (UPC). UPC barcode system is used only in Canada and America, while the EAN barcode system is currently implemented in more than 80 countries world wide including Thailand, Japan and Taiwan.

Presently, there are many useful barcode systems such as EAN8, EAN13, ITF14, Code3of9 and UCC. The barcodes from these systems are utilized as the key to access a database. That is, for example, printed barcodes on milk bottles or books in supermarkets and bookstores are used as identifiers to identify the location that contain the details of products in the database such as prices, weights, discounts, promotions. Normally, they compose of two sections, human readable digits and scanner readable symbols. The example barcodes are illustrated in figure 2.

EAN13 and EAN8: compose of 12 digits + 1 check digit, and 7 digits + 1 check digit respectively. Generally, they are used with consumer products in supermarkets in order to access an inventory database. The EAN13 and EAN8 are just the key entry, they do not contain any data.

ITF14: composes of 1 container digit + 12 EAN13 digits + 1 check digit. It is used for products that are contained in boxes or on pallets because it can be printed in larger size than that of the EAN13 system. So, it can be found and scanned easier. Again, it does not embody any data.



UCC/EAN 128: composes of Application Identifiers (AIs), which are the identifiers that show what the following data is. For example, as illustrated above, AI is 01 means the following data is SCC-14, Shipping Container Code that composes of 14 digits. Nowadays, it is a very useful bar code system because it can contain many effective data.

Figure2 [14]: Bar-coding Systems

UCC/EAN 128 standard system is the latest barcode system, established from the cooperation of the UCC and the EAN. The purpose of UCC/EAN 128 is to provide clear and precise information about products and shipments. Obviously, it differs from other systems because it is not just the key access but it can contain some useful data of a product by the prefix numbers, Application Identifiers (AIs). For example, serial shipping container code (SSCC), batch numbers, production date, weights, dimensions,

expiry date and destinations can be embedded in the UCC/EAN 128 barcode system, as shown in figure 2. The AIs are the codes that indicate what the following numbers are and what they represent. The AIs are illustrated in Appendix A.

In brief, AIs are prefixes of 2 to 4 digits, which indicate the meaning and format of following data. Each AI has its own specific rules on its length and formats of data. The data that follows the AI should be alphanumeric. Meanwhile, data fields have either fixed or variable lengths depending on each AI.

In addition, the AI is an internationally compatible standard, that is, it can be used throughout the trading chain worldwide. Moreover, companies can program their system to only accept the AIs that are of interest to them and ignore other AIs.

There are many benefits from applying UCC/EAN 128:

- Gain highly accurate inventory data.
- Improve productivity and lead-time.
- Enhance the logistics management.
- Apply with EDI (Electronic Data Interchange) based on UN/EDIFACT
- Gain the traceability.

[1]Moreover, it is a meaningful element that assists many concepts of inventory control. Those are:

- Efficient Customer Response (ECR)
- Supply Chain Management (SCM)
- Quick Response (QR)
- Electronic Commerce (EC)
- Category Management (CM)
- Vendor Managed Inventory (VMI)
- Flow thorough Cross Docking (CD)

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[1] EAN Thailand Newsletter, Vol.5 No.1 January-March, page 8-9.

UCC/EAN 128 Label

An important feature of UCC/EAN 128 is the use of it on labels. The structure of the international style label is shown in figure 3, as followed.

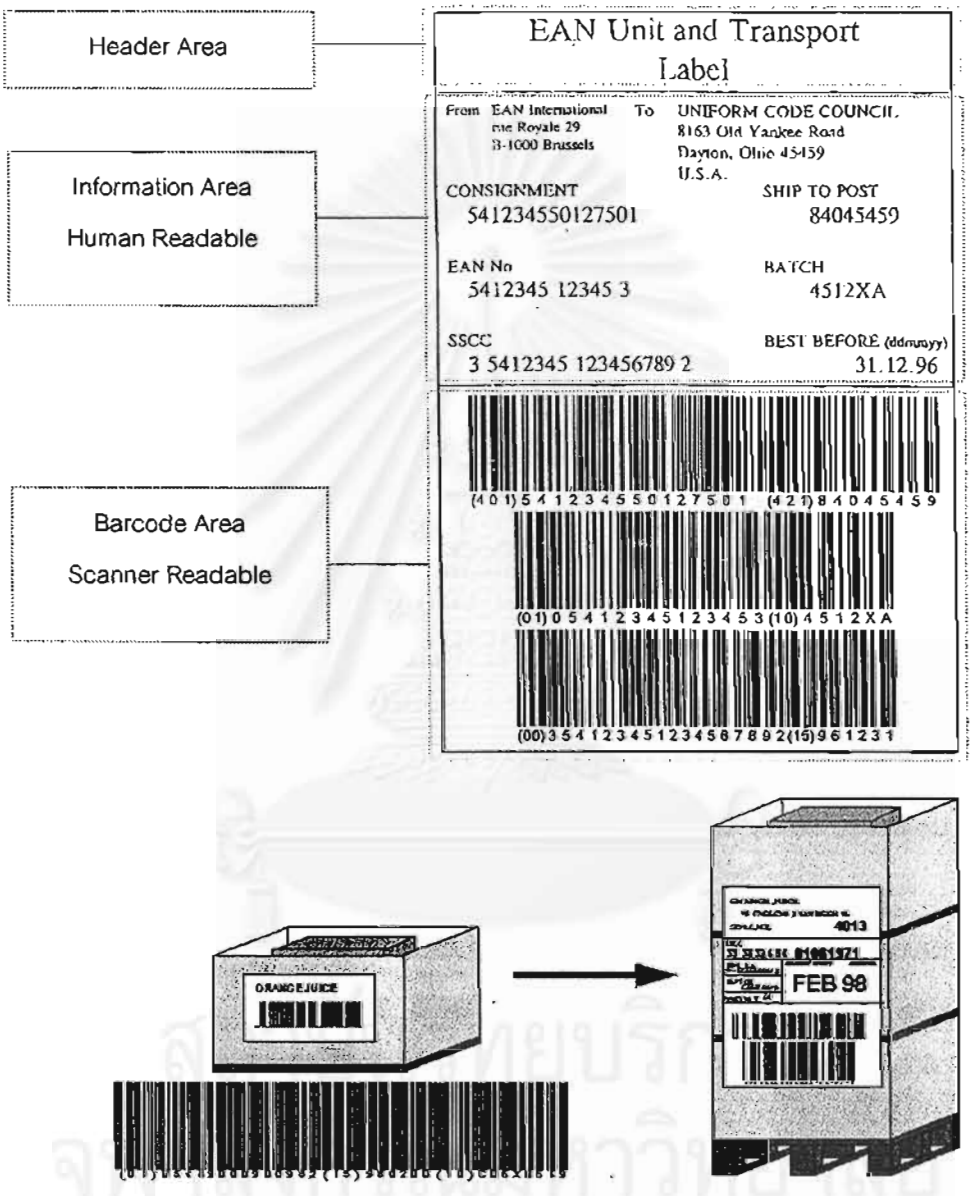


Figure 3 [13]: UCC/EAN 128 barcode Label and its application on a box and pallet

2.5 Inventory Control and Management System

Lambert & Stock (1993) divide inventories in to six primary types. All six groups are shown below.

1. Cycle stock is inventory that affects from the replenishment process and is required in order to meet under conditions of certainty.
2. In-transit inventories or pipe-line inventories are items in delivering processes. Normally, they can not be used to calculate the inventory carrying costs. They should be considered as inventory at the place of shipment origin since the items are not available for use/sale and/or later reshipment.
3. Safety or buffer stock is accounted as the excess of cycle stock. It is necessary for every warehouse to cope with the uncertainty in demand or lead-time, which is a fact of life.
4. Speculative stock is kept in a warehouse for reasons other than satisfying current demand. To illustrate, a large volume of a part may be ordered because there is a special discount for such amount.
5. Seasonal stock is quite similar to the speculative stock, while the seasonal stock is held for seasonal reasons in order to maintain a stable labor force and stable production runs.
6. Dead stock is inventory which is not in demand for some specified period of time

Because the inventories are the companies' assets that may cover more than 40% of the total assets, it should be properly managed and controlled. However, the managing and controlling of the inventory should have some objectives as followed:

- To rise company profitability.
- To evaluate the effect of company policies on inventory levels.
- To minimize the total cost of logistics activities.

Nowadays, there are many inventory management techniques that can be applied in many businesses such as Economic Order Quantity (EOQ), ABC analysis.

Economic Order Quantity (EOQ)

The technique is based on the concept that attempts to minimize the total inventory carrying costs and ordering costs, as shown in figure 2.2. The best ordering policy can be identified using the economic order quantity model (EOQ).

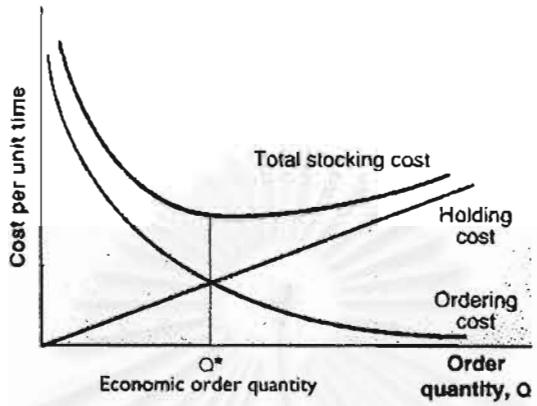


Figure 2.2: Holding, ordering, and total stocking costs

In a popular, simple EOQ model, there are four main parameters used, as illustrated below.

$$EOQ = \sqrt{\frac{2\ PD}{CV}}$$

Where

P = the ordering cost (Baht per order)

D = annual demand or usage of the product (units)

C = annual inventory carrying cost (value or a percentage of product cost)

V = average cost or value of one unit of inventory

Although EOQ is an interesting and well-known technique for managing the inventory under certain conditions, there are some limitations that should always be concerned before implementing it. The simple EOQ model is based on following assumptions.

1. A continuous, steady, and known rate of demand.
2. A consistent and known replenishment or lead-time.
3. A consistent buying price that is independent of the order quantity or time.

4. A consistent transportation cost.
5. No stockouts are allowed.
6. No inventory in transport (pipeline inventory)
7. Only one item in inventory.
8. An endless planning horizon.
9. No limit on capital availability.

Notice that, the EOQ formula does not cover the impact of the variation of transportation rates and quantity discount that are typical conditions in the real world. Therefore, the EOQ is refined in order to make its accounts the impact of quantity discounts and/or freight breaks.

$$Q^1 = 2\frac{rD}{C} + (1 - r)Q^0$$

Q^1 = the maximum quantity that can be economically ordered to qualify for a discount on unit cost.

r = the percentage of price reduction if a larger quantity is ordered.

D = the annual demand in units

C = the inventory carrying cost percentage

Q^0 = the EOQ based on current prices

Moreover, the noticeable symptoms of poor inventory management of companies are pointed out. The following list is the symptoms, observed from many companies, that should be improved.

1. Increasing numbers of back orders.
2. Increasing capital investment in inventory with back orders remaining stable.
3. High customer turnover rate.
4. Increasing number of orders being canceled.
5. Repeated insufficient storage space.
6. Wide variance in inventory turnover among distribution centers and among major inventory items.

7. Changing relationships with intermediaries, as typified by dealer revoking and downwardly orders.
8. Large quantities of obsolete items.

The problems of inventory management above can be reduced using the following solutions that are being used in the real world.

1. ABC analysis
2. Lead time analysis
3. Delivery time analysis
4. Elimination of low turnover and/or obsolete items
5. Analysis of discount structure and pack size
6. Analysis of returned goods procedures
7. Encouragement/ automation of product substitution
8. Installation of formal reorder reviews systems
9. Calculation of fill rates by stock keeping unit (SKU)
10. Analysis of customer demand characteristics
11. Development of a formal sales plan and source demand by a foregone logic.

In addition, in many cases, reducing order-cycle time by using advanced order processing systems is a good method of reducing inventory investment. However, there is a well-known and effective inventory management technique that can be applied on a wide range of areas.

ABC analysis was developed based on the concept of Villefredo Pareto in the 18th century. The Pareto's principal can be called 80/20 rule, which means that 20 percent of the firm's customers or products account for 80 percent of the sales and perhaps an even larger percentage of profit.

In inventory management, the items in a warehouse are classified into three groups, which are type A, B, and C items. The figure 2.3 shows an example of the grouping.

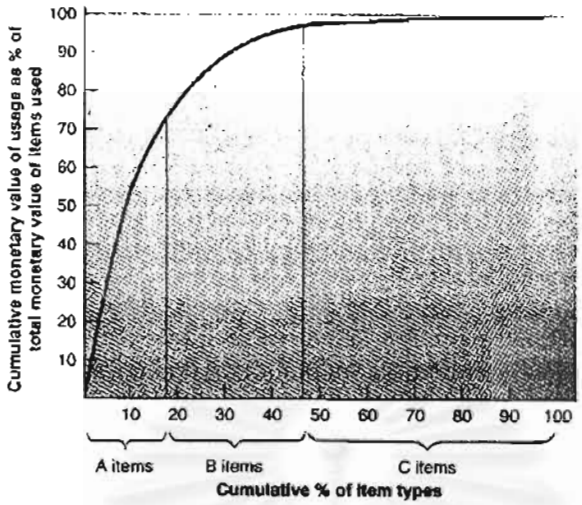


Figure 2.3: ABC Analysis.

Martinich (1997) recommends the management and control approaches for the three groups from the ABC analysis. For category A, the items should receive the greatest attention from companies because they have a large impact on a company when only a small percentage reduction in inventory costs. Consequently, the effective inventory management systems for category A items are demand forecasting module, the real-time inventory tracking module and the sophisticated ordering rules. In the same way, type B items should receive high level of attention as well, but before doing this, the companies must ensure that category A items are already under controlled. On the other hands, due to the fact that there are only small savings from substantial reductions in inventory costs of type C items, the simpler, lower cost methods are recommended such as two-bin systems and EOQ to control the type C items.

In addition, there are a few essential components of any materials management system that are accuracy and timely inventory records. For example, in some companies, errors of even 1% or 2% are very harmful for the companies, because the errors can cause costly stockouts of critical components. As a result, the American Production and Inventory Control Society (APICS) suggests accuracy levels of type A items for $\pm$0.2%, type B items for $\pm$1%, type C items for $\pm$5%.

To maintain the accuracy of inventories, firstly, "closed storerooms" are required to control the access to inventories with receipts and withdrawals from keeping areas are always recorded. With this system, only storeroom workers are able to accept or distribute materials. Furthermore, they are responsible for inventory record accuracy. Thus, in order to achieve the ultimate goal, they should be trained and motivated to record all transactions accurately because the major error is human's.

Secondly, other option to maintain the accuracy of inventory records in term of amount and location is to use barcode and optical scanning technology. Barcode labels can be attached to items when they enter the warehouse to indicate the type and number of items. Then, the labels will be scanned when the items are taken out of the warehouse to the next processes. If a company manages the barcode system properly, it can be used through the entire company.

Thirdly, a physical count of inventories is essential, although there is a good monitoring systems. The actual amounts will be compared with the recorded amount of the monitoring systems. While there are many cycle count strategies to choose from, there is one basic concept. After parts are grouped by using ABC analysis, type A items should be counted more often (two or four times per year) than B and C items. Cycle counting can also be made more efficient by selecting items to count during a cycle using the following guidelines.

1. Count items when inventory records show a small amount in stock, thereby reducing the number of objects to count.
2. Count items when inventory balances show a positive level but a stockout is reported.
3. Count items after an especially large amount of inventory movement (receipts and withdrawals) for that items.

Heizer, and Render (1997) emphasize on material management, which supports JIT methodology. Moreover, the author also presents to the reader the advantages of computer in inventory controlling in order to meet customer satisfaction. With the help of computer, the high accuracy and speed of data can be obtained, thus maximizing the efficiency of warehouse management.

Lancioni, and Howard (1989) divide the fundamental inventory characteristics into 7 parts: type, function, demand, usage, lead-time, cost and value-usage distribution. Furthermore, they describe some details about the characteristics for clear understanding of the inventory management. Moreover, the ABC analysis and Economic Order Quantity techniques and formulas are explained in depth. Then, they focus on customer service. The aim is to provide this service at the least cost, with a minimum investment in inventory. Finally, the outline of aggregate inventory management is defined based on conflicting objectives: assure customer satisfaction, maximum facilities utilization and efficient manpower utilization at the least cost. Tools called *Management Policy Variables* are available to manipulate inventory to meet inventory policy objectives.

Jerome (1978) mentions the implementation of computer in inventory control using database. The author describes from the construction of the database to the processing and the transaction needed. However, the bar-coding system is not discussed since the system did not exist then. Consequently, some features of the method are not of practical use nowadays.

2.6 Bar-coding system in productions and warehouses

Burke (1990) discusses about the solution of general inventory's problems by barcode system. First of all, parts in the warehouses should be labeled (item identification). In other words, barcode labels represent the addresses in computer databases. Next, location should be identified by using the barcode labels. They should show the general information of the locations. Moreover, loading trucks should have the identification codes as well so that the tracking of the parts on them is possible. In short, the system should show that which truck it is and what is on the trucks.

However, in order to gain the maximum benefits of using the barcode, there should be a universal code that can be recognized by the entire industry. He mentions that a standard system of barcode for automotive industry had been developed by

Automotive Industry Action Group (AIAG) since 1984. Code 3 of 9 was selected to be the base system because of its flexibility that the code can be generated by both alphabets and numeric without limited lengths. Moreover, the AIAG had recommended about the necessary areas for each label, which are:

- Part number
- Quantity
- Supplier number
- Serial number
- Special data

Olson (1996) illustrates a list of seven trends of millennium warehouses based on the basic concept that warehousing will continue to be a dynamic function, driven by market forces toward continuous improvement. The seven trends that will take industry into the next century include:

1. Focusing on the customer

Companies must listen to their customers. Nowadays, customers want value at low cost with high functionality. In other words, quality must be given. The most successful companies will be those that go beyond today's standard of customer focus, to develop true partnerships with suppliers and customers that transform the arm twisting of the 1990s to sharing of information, joint planning and win/win agreements in the future. The warehouse will be in the middle of the action.

2. Consolidated operations

Operating costs including inventory, space, equipment and labor have to be reduced due to the higher and more reliable levels of customer service from fewer distribution points by an efficient deregulated transportation infrastructure.

3. Continuous flow of material and information

The trend towards more shipments and more receiving put away, picking, and shipping activities will put greater demands on the material handling system used in warehouses. Moreover, on-line and even real-time information systems are replacing batch systems in order to gain quicker response to customers and problem solving.

4. emphasis on value-added services

In the near future, we may find that those products that are now referred to as value-added may be considered standard operating procedure.

5. The application of Information Technology

The barcode system with radio frequency data communication intelligent software, a dictated computer platform and, maybe, even electronic interfaces with host and external computers can create a powerful warehouse system with higher accurate data and faster inputting and retrieving of data.

6. Space compression

In the future, due to the globalization, the market will be extended to the whole world, therefore the products should be packaged for more markets, with more languages, and even for specific customers, and more SKUs. Consequently, the more storage locations and the more space will be required.

7. Time compression

This is truer in the warehouse than anywhere else in industry. Better, cheaper and faster is a battle cry of the future.

Diamond (1997), In his report, the author noticed that trend of production and inventory control packages have been moved to PC based because of many reasons. In the past, MRP and MRP II were associated exclusively with mainframes and minicomputers. Recently, this trend has been changed with the introduction of PC-based manufacturing applications, which can operate on DOS or Windows platform. Today, the PC-based programs are full-fledged, powerful MRP implementations, offering nearly all of the features found on their mainframe counterparts. Furthermore, they deliver solid and dependable methodology to an affordable and flexible platform.

In using PC-based applications, manufacturing cycle times and costs can be reduced, while inventory turns will be increased. Associated with the substantially dropping of the PC's hardware prices, the PC-based production and inventory control systems are very advantageous.

CHAPTER III

DESCRIPTION OF TBK KRUNGTEP CO., LTD

3.1 Company Background

TBK Krungthep Co., Ltd has started since 1991 by a joint venture company between Tokyo Buhin Kogyo Co., Ltd. and C.M. Group. The company is located at Bangpakong Industrial Plant II in Chonburi, Thailand. In the first year, the company supplied aluminium die-cast cooling water pumps and lubrication oil pumps for Isuzu and Nissan pick-up engines, followed in consecutive years by parts for Mitsubishi and Toyota engines.

3.2Company's products

With the experience of Tokyo Buhin Kogyo, leading parts maker in Japan and C.M. Group's expertise in production management, TBK Krungthep is allowed to expand its product range to other engine parts, as shown in figure 3.1.

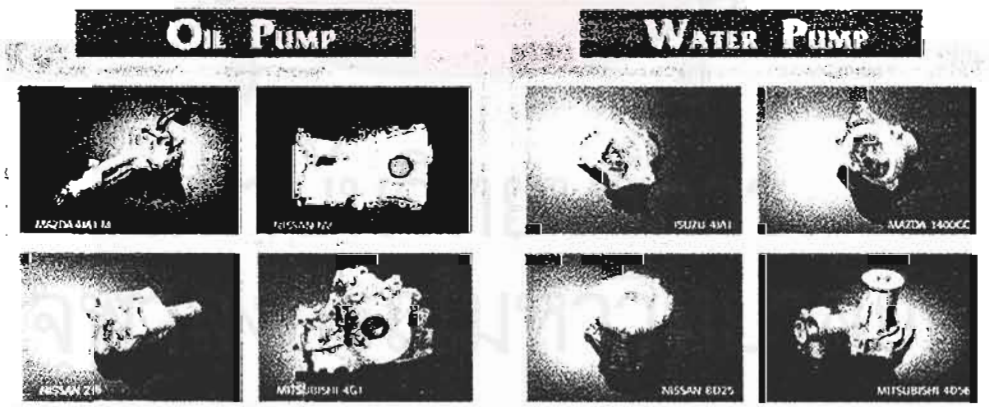


Figure 3.1: TBK Krungthep's automotive parts.

Recently, the company has expanded the range of product to electric appliances such as the body of compressors for refrigerators and air-conditioners. The products can be categorized into 5 main groups as following:

- Oil pumps
- Water pumps
- Cooling fan coupling
- Electrical appliance parts
- Other parts such as drain cocks, release valve

3.3 Certified Standards

Since 1991, the company has received awards from clients in many categories, especially quality, cost, and delivery. Moreover, TBK Krungthep has been awarded ISO9002 and QS9000 quality management system certification from BVQI, and fully complies with American, German, British, and Australian standards. In the future, the company has a plan to achieve ISO14000 in order to ensure that the customers will have only high quality products that are environment friendly.

3.4 Organization Structure

In 1998, the company has been reengineered, so the organization chart was changed in order to improve the efficiency and effectiveness of management. The organization chart of the TBK Krungthep is illustrated in figure 3.2.

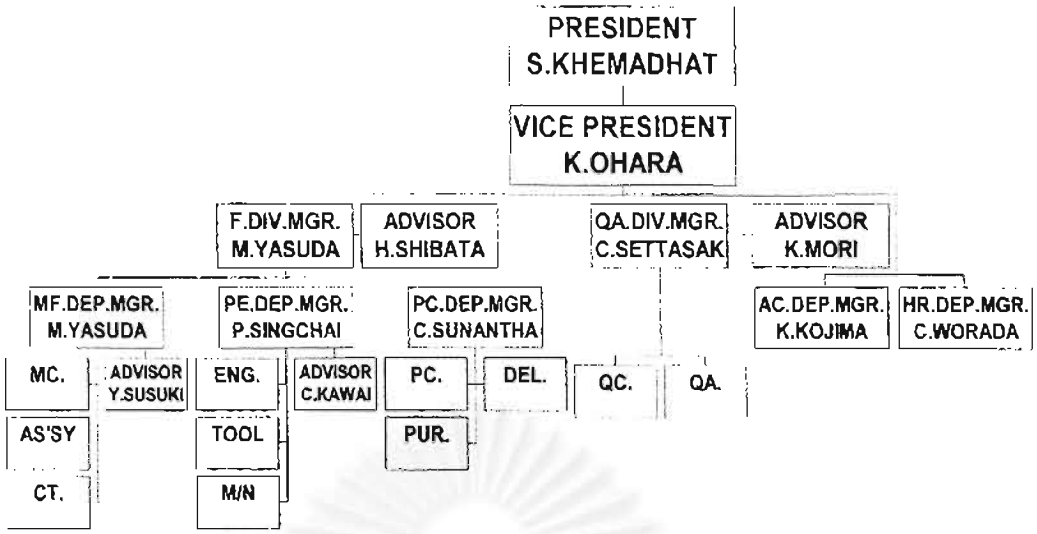


Figure 3.2: The organization chart of TBK Krungthep.

3.5 Manufacturing Processes

In the production processes, the company has been using both on-shore and offshore materials; majority of the materials, such as bearing, and aluminium ingots, has been imported from Japan and Korea. The manufacturing process begins by high-pressure aluminium die casting method. Then, the main parts are moved to machining lines. After that, the main parts and other components are assembled together. The finishing process is necessary after all parts are assembled. Next, QC people will inspect the assemblies, then they will be delivered to the customers. The main manufacturing processes are illustrated in figure 3.3.

The company has been using Local Area Network (LAN) computer system, which allows authorized users to share some of the resources. The operating systems are Microsoft Windows NT and Windows 95. The computers' CPUs range mostly from Intel Pentium 133 to 200 MHz with about 16 to 32 MB RAM.

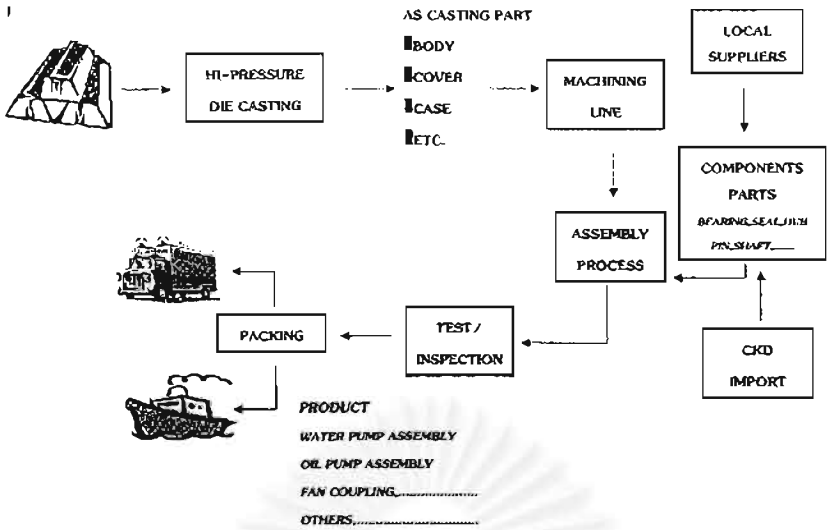


Figure 3.3: Main processes of TBKK.

3.6 Inventory management in TBK Krungthep

In the main warehouse, there is a computer that can connect to the main server in the office via LAN system. The warehouse is an open area near the production lines (machining line). This warehouse is used to store only raw materials, while work in process is stored in the production area and finish goods are stored in assembly zones. . The inventory layout is shown in figure 3.4.

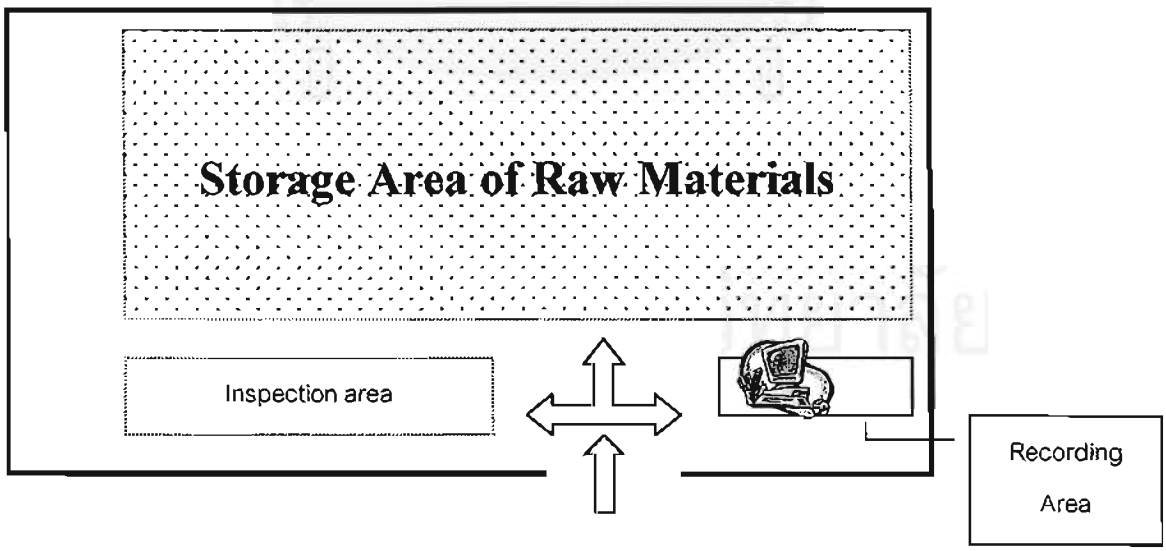


Figure 3.4: TBKK's inventory layout.

There are two inventory workers who control materials in the warehouse. Their main jobs are inspecting materials and recording the data of receiving parts from suppliers and withdrawal from production lines.

Today, the company has more than 500 types of raw materials in the inventory. The production strategy of the company is a combination of made to order and made to stock, so the production department has the responsibility to report the list of raw materials with amount that are needed to be used to the purchasing department based on customers' orders and forecasting. In other words, there is no fixed standard method for the production and purchasing departments in determining the amount of the materials to order. Then, the scheduled receipt of the materials will be passed to the inventory management, and it will be recorded in Microsoft Excel file format.

Due to the fluctuation of the actual demand of the products, mostly, the purchased orders are confirmed about fifteen days before the due date. Nowadays, the inventory department does not involve in planning the receipt and the planned receipt is not to be used in inventory department. In fact, the main job of the inventory department is recording the receipt of materials from suppliers and the withdrawal of parts to the production lines.

CHAPTER IV

EXISTING SYSTEM

4.1 Introduction

The inventory processes can be mapped by simple figures using the Data Flow Diagrams (DFD). DFD is a model that describes the flow of data and the process that change or transform data throughout a system. It is an advanced method in identifying which has helped bring up many improvements. The symbols that are used to form the data flow diagrams are shown in figure 4.1.

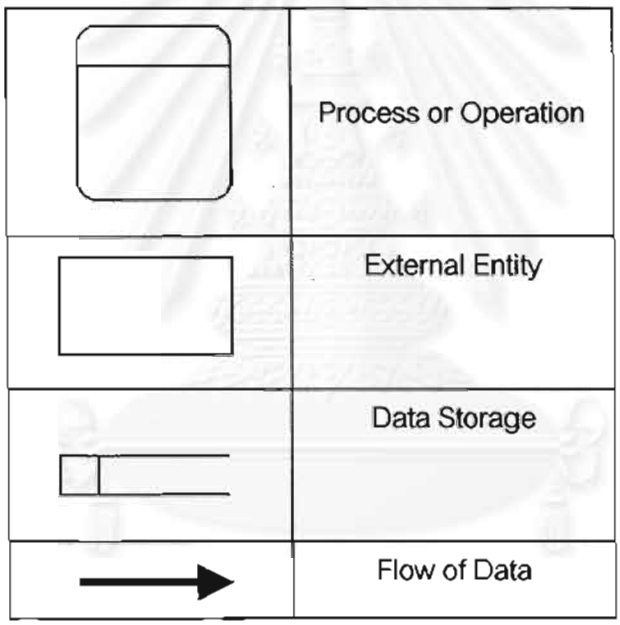


Figure 4.1: Symbols in DFD.

DFD is a very effective tool for system analysis due to the fact that it can identify procedural missing links, duplication and delays of a selected system. DFD provides many benefits as followed:

- Eliminate the duplication
- Identify the missing links

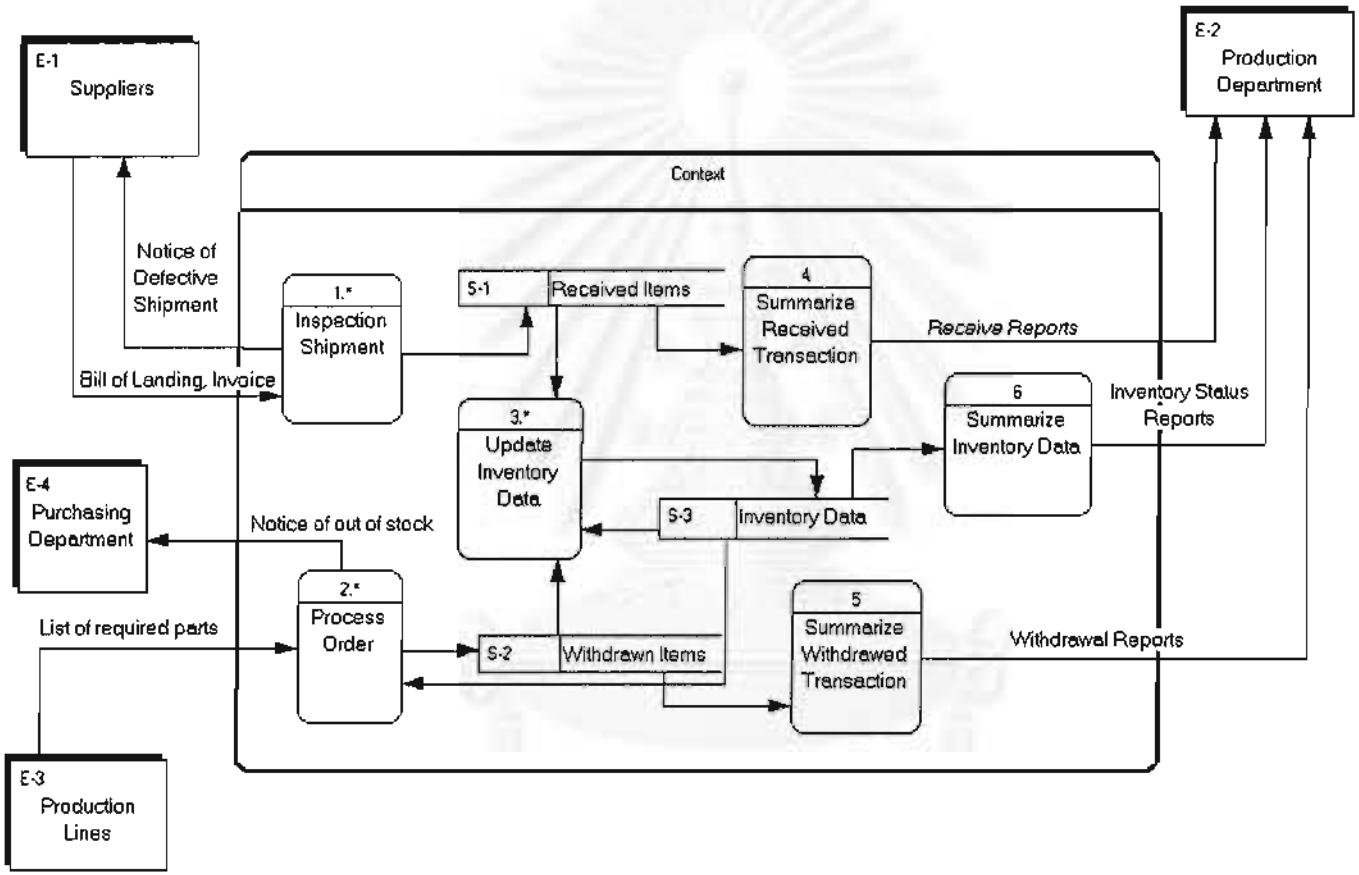
- Identify the delays
- Improve the documentation
- Bring in procedural standardization
- Assist in planning future Information Technology
- Provide basic information for cost reduction

DFD is selected because it can help system engineers to understand, at micro level, the movements of all documents involved in a particular procedure. In addition, when it is exploded from zero level to higher level it provides detailed exposure to each and every activity in a given procedure. DFDs in this report are generated from the SilverRun Business Model software from SilverRun Technology Ltd.

4.2 Inventory procedures

Because of its benefits as mentioned above, DFD is used to map TBKK's inventory procedure. In the DFD, project starts at a context or zero-level DFD in order to get a large view of the system, related elements and flows of information among the elements, as shown in figure 4.2. TBK Krungtep's inventory department process is located at the center. It interacts with four external entities, which are suppliers, production lines, purchasing department, top management and nine major data flows.

In the context diagram the number in the top of each box represents the number of process and the number with asterisk indicates that there is the higher level in that process.


E-1
Suppliers
E-2
Production
Department
Context
Notice of
Defective
Shipment
1.*
Inspection
Shipment
S-1
Received Items
4
Summarize
Received
Transaction
Receive Reports
Bill of Landing, Invoice
6
Summarize
Inventory Data
Inventory Status
Reports
3.*
Update
Inventory
Data
E-4
Purchasing
Department
Notice of out of stock
S-3
Inventory Data
2.*
Process
Order
5
Summarize
Withdrawed
Transaction
List of required parts
S-2
Withdrawn Items
Withdrawal Reports
E-3
Production
Lines

To get into the diagram to the level-1 DFD, let us start at receiving processes because the process of receiving parts from suppliers is the beginning of all inventory jobs. The ordered products, which normally are delivered to the company by trucks, come with bill of landings, or invoices. Then, the inventory personnel will check the invoices or bill of landings and the delivered parts. If they are matched, they will be moved to the inspection area. The specification of the parts will be retrieved from the inspection criteria files. The parts will be divided into two groups; the accepted parts and the defective parts. After that, the defective parts, if any, are rejected to the suppliers with the notice of defective shipment made by the inventory staffs. Then, all information about the shipment is recorded into the computer at the counter in Microsoft Excel file format. Finally, the accepted parts are moved to their prepared racks. The all processes of receiving are shown in the level 1 DFD, as in figure 4.3.

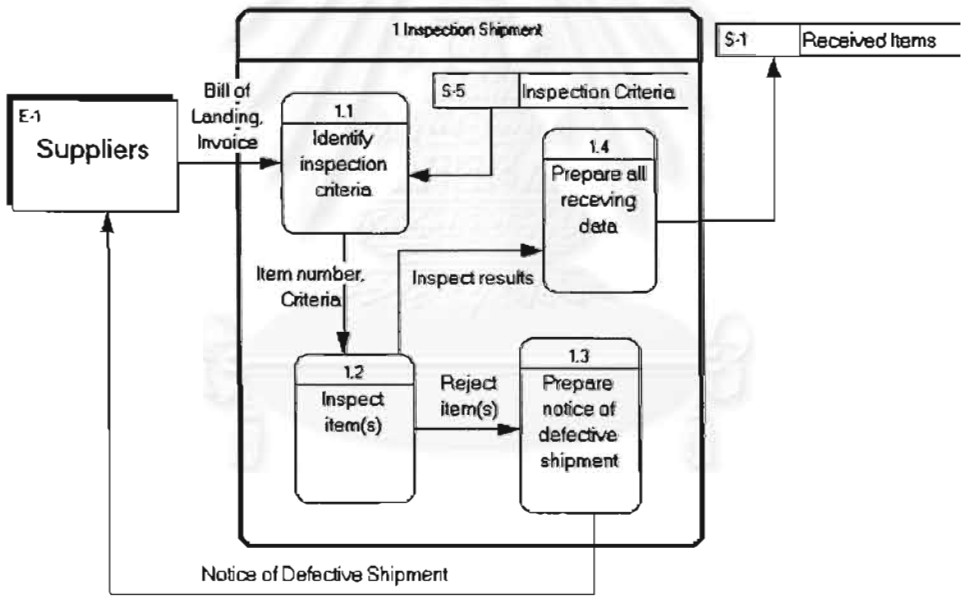
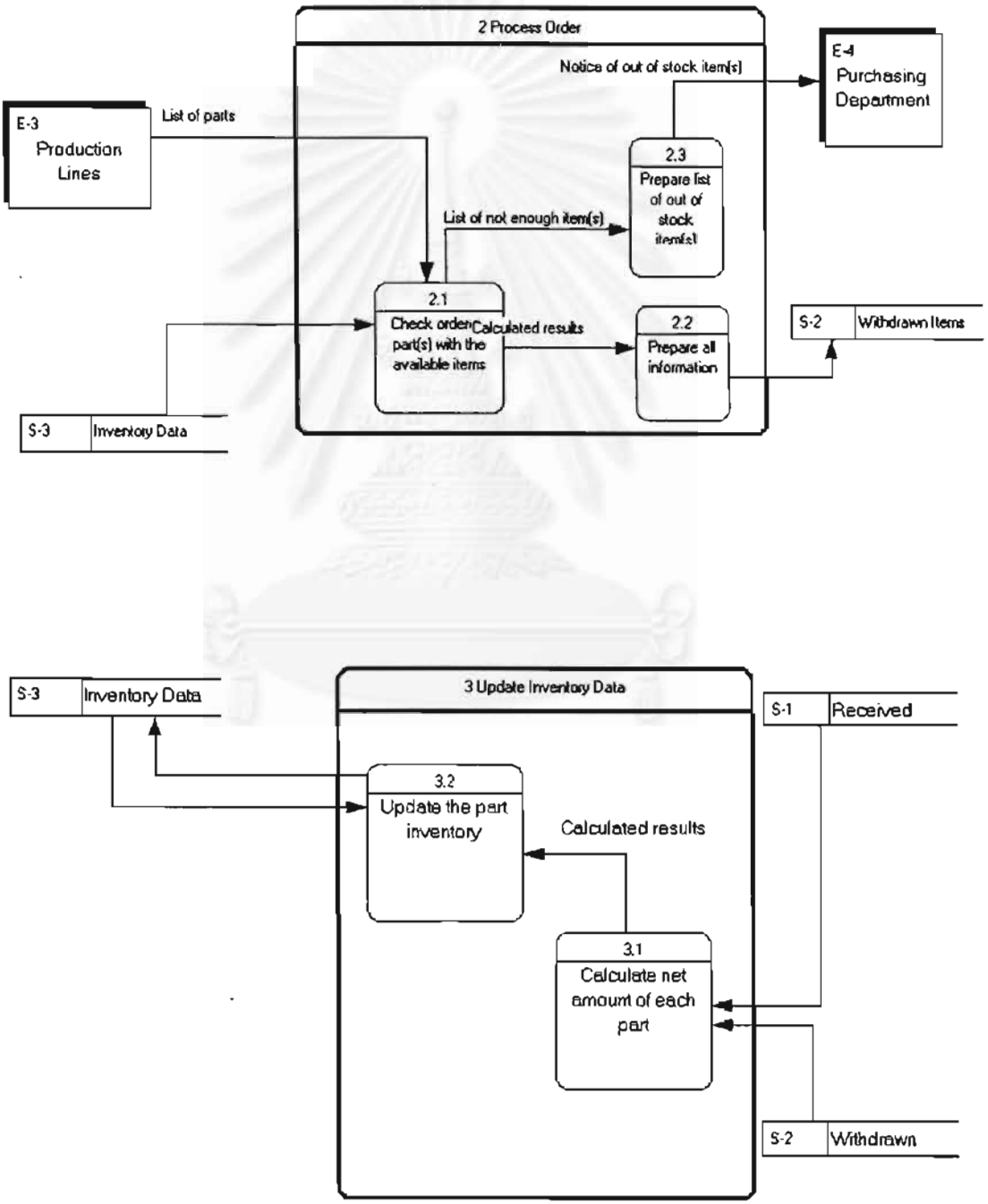


Figure 4.3: Level1 DFD of the receiving processes.

Secondly, the withdrawal of parts to be machined from the production lines is responsibility of the inventory staffs as well. This process begins when the authorized production staffs come to the inventory counter with withdrawal forms. The forms have information about the parts that are required part number, model and amount. After that, each ordered part number and amount in the list will be checked with inventory data file

for the available amount. If there is enough amounts for the order, the parts will be taken from the racks and delivered to the machining lines. The other case, when there are not enough items for the order, all available parts will be withdrawn, then the out of stock item(s) will be reported to the purchasing department. Then, all withdrawal information will be recorded into the computer in the other file. The process order is illustrated in figure 4.4.



The third job in the inventory process is to update the inventory data. When the parts are received and the information of the receiving is recorded, or some parts are withdrawn and the data of the withdrawal is written to the withdrawal file, the updating inventory data process will be activated to calculate the total available amount of the parts in order to be used for the process order. This process can be mapped in a level1 DFD, as shown in figure 4.5.

Finally, in the last day of every month, the inventory department has the responsibility to create the reports of receiving shipments, withdrawal for production lines, and summaries of available amount of that month to the top management in order to be used in future planning. However, it takes quite a long time to gather all data, basically about 3 days. The major problem is the unmatched data between the actual amount in inventory and the recorded amount, therefore the errors will be checked manually with the withdrawal forms and the bill of landings or invoices of that month. The causes of the problem are listed below:

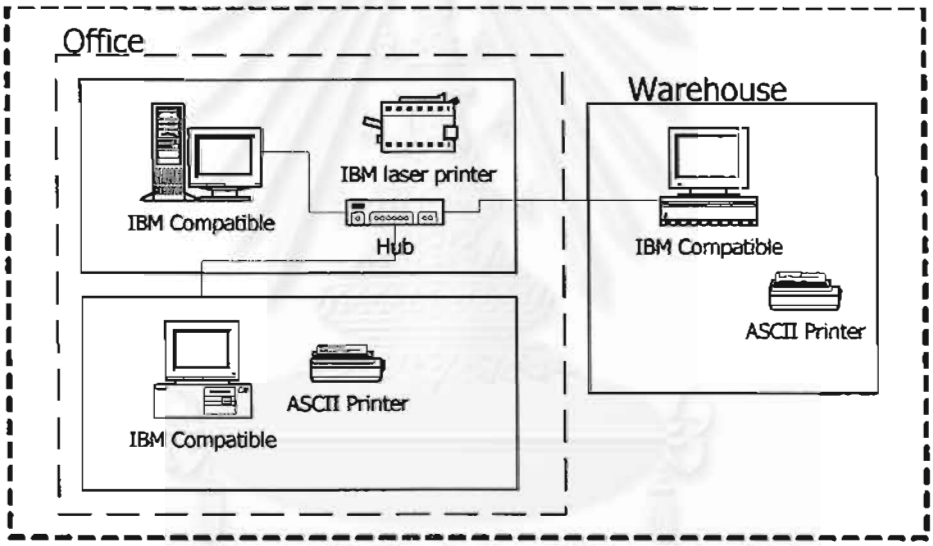
- The receiving data is not recorded immediately after the shipment is completed because of whatever reasons.
- The information of withdrawals is not written in the withdrawn item file instantaneously after the withdrawal process is finished.
- Due to the fact that the provided files are the Microsoft Excel files, which are the spreadsheet format that composes of many cells, the data may be recorded in the wrong cells. To illustrate, product A is received from a supplier but the information is recorded in the product B cell which is located below the product A.

Consequently, the inventory data can not be used as real-time data because of the errors that needs to be fixed every time before summarizing process. For example, if the production planning team wants to know the amounts of part A, B, C, and D for the next three months plan, the inventory personnel might take about three hours to answer the question since there are more than five hundred parts in inventory now. Obviously, the company does not use its information system effectively and efficiently. The revised

inventory control information system, with bar-coding system, is necessary in order to improve the accuracy and timeliness of inventory management.

4.3 Hardware

Today, the computer system of inventory department can be illustrated in figure4.6. There is a main server computer connected with two personal computers, one is in the office, and the other is in the warehouse. In this thesis, the main structure of the hardware will not be changed due to the fact that this system has been set properly, while it has not been used properly.



CHAPTER V

REVISED INVENTORY SYSTEM

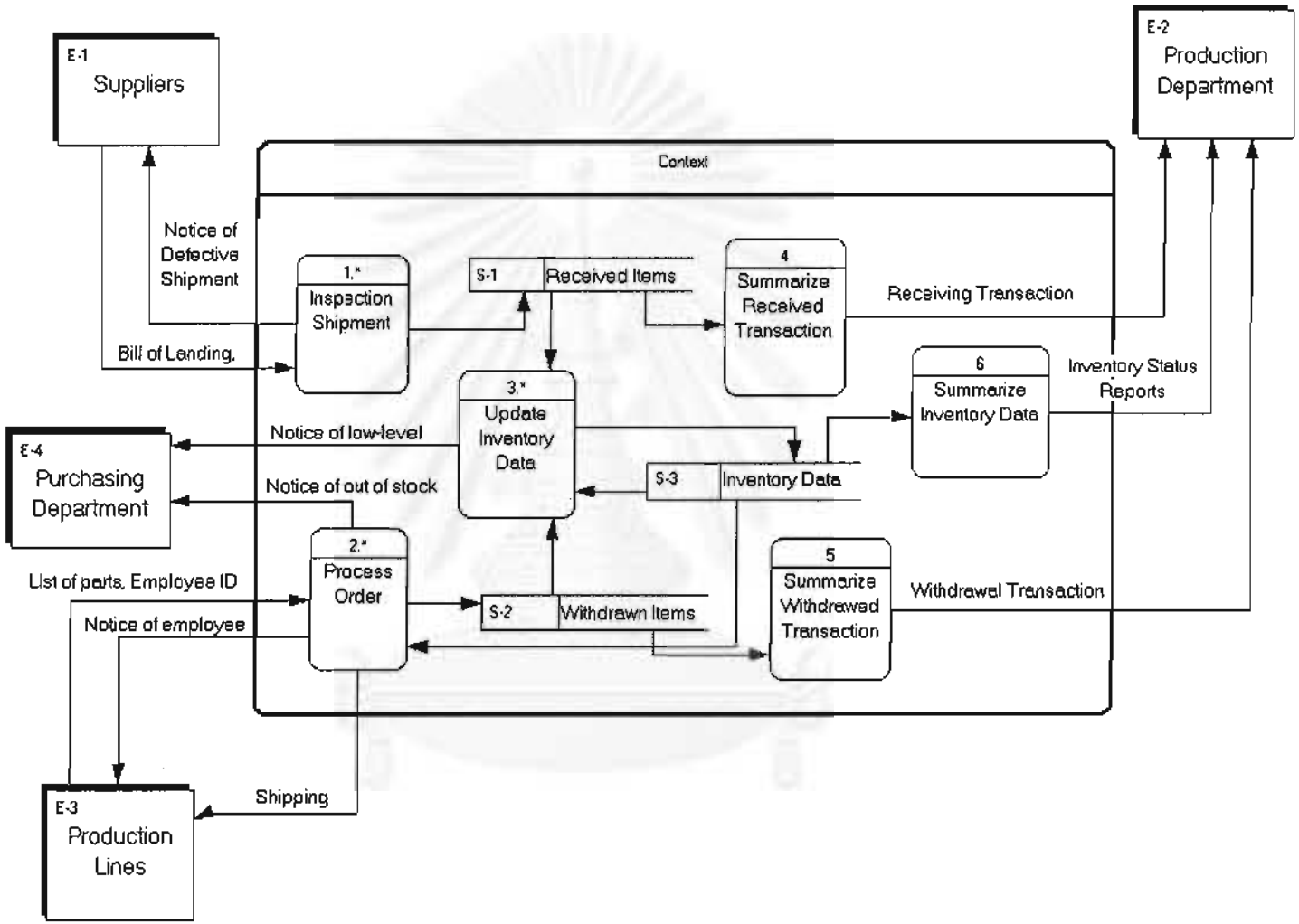
5.1 Introduction

As mentioned in the first chapter, the company has certified the ISO9000 standard, this means that all processes, methods and procedures had been studied and set up by the company's professional team, while the study may not include the management of the flow of information. In this thesis, the information system of inventory department will be redesigned in order to solve the problems of information system. However, this thesis will not try to change the whole inventory processes, on the other hand, it will attempt only to redesign the flow of the inventory data for more effectiveness and efficiency by using a barcode system for data entry. The study starts with the analysis and the redesigning of some processes. Then, database system will be developed in order to support the processes.

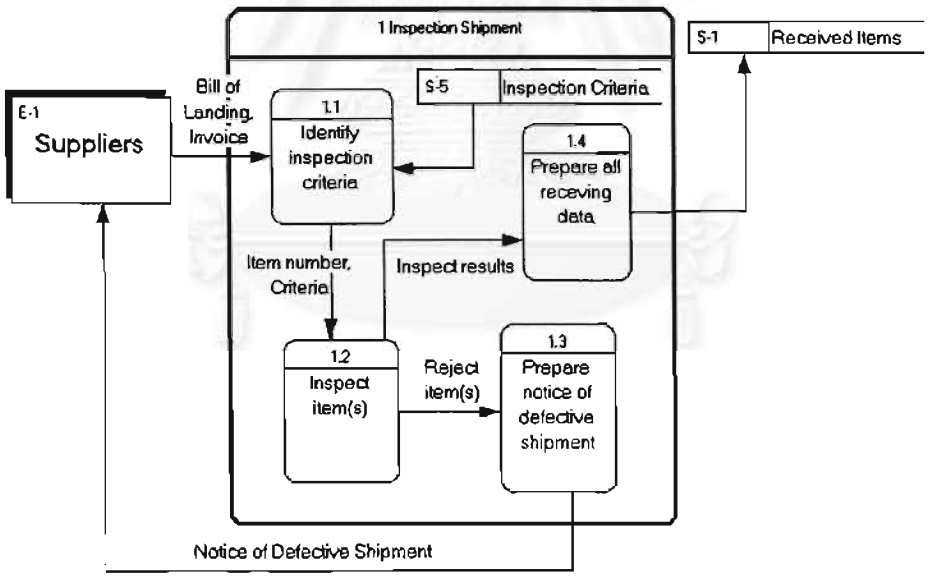
5.2 Process Design

Firstly, from the DFDs of the existing inventory system, there are many points that can be changed by adding some procedures to make the inventory works more effectively. The aim of the new design is to improve and enable the old processes to record and use the stored data more efficiently. The revised inventory system is illustrated in context-level DFD in figure 5.1.

In the revised data flow diagram, there are some changes in the context level those are the interactions of the inventory department to the purchasing department and the production lines. Firstly, not only the list of out of stock parts but also lists of low-level parts can be transferred to the purchasing department. The second point is that the production lines have to give the employee id with barcode to the inventory personnel to identify their authorization and thus be able to execute the withdrawal process. In return, the production lines will receive the list of shipped parts.


E-1
Suppliers
E-2
Production Department
Context
Notice of Defective Shipment
Bill of Lading.
1.*
Inspection Shipment
S-1
Received Items
4
Summarize Received Transaction
Receiving Transaction
6
Summarize Inventory Data
Inventory Status Reports
3.*
Update Inventory Data
Notice of low-level
E-4
Purchasing Department
Notice of out of stock
S-3
Inventory Data
2.*
Process Order
List of parts, Employee ID
Notice of employee
S-2
Withdrawn Items
5
Summarize Withdrawal Transaction
Withdrawal Transaction
E-3
Production Lines
Shipping

In level1 DFD of the inspection shipment, there is no major modification in this process. Nevertheless, the inventory personnel have to change the data entry method, from manual operation to an Excel file, to the automatic entry using a barcode scanner which records data into the provided form on the monitor. The new recorded data will have receiving date and time of the shipment. The date and time will be recorded automatically into the inventory database. In the existing system, the company can not find the date and time of the data that was recorded to the file. Moreover, a great advantage of the new system is its traceability of the recorded data. This is possible due to the fact that inventory workers' id cards have to be scanned before they can input the data, that is the employees' data of those who key in the record are saved with other data. In short, the new information of receiving will compose of received parts, amounts, date and time of recording and employee ID who recorded that transaction. If there is any error, the inventory personnel will be able to trace back to the root causes of error. The level1 DFD of the inspection shipment processes is shown in figure 5.2.



In the order processing, again, there is a major change. That is the information about the authorized employee is added to the withdrawal forms. The forms will come with the employee ID cards that have barcodes instead of the withdrawal forms that contain only the required part numbers and amounts. The additional process is to

check the authorities of the employee IDs. If they do not match with the information on the authority of the employees in the inventory database or the IDs can not be found, those orders will be rejected. In contrast, when the orders are accepted the order will move to the normal process. The last additional process is to prepare shipping lists that contain the data about the delivery parts of the orders. All reports can be printed out by printers or exported in the Microsoft Excel format. The new order processing DFD is shown in figure 5.3.

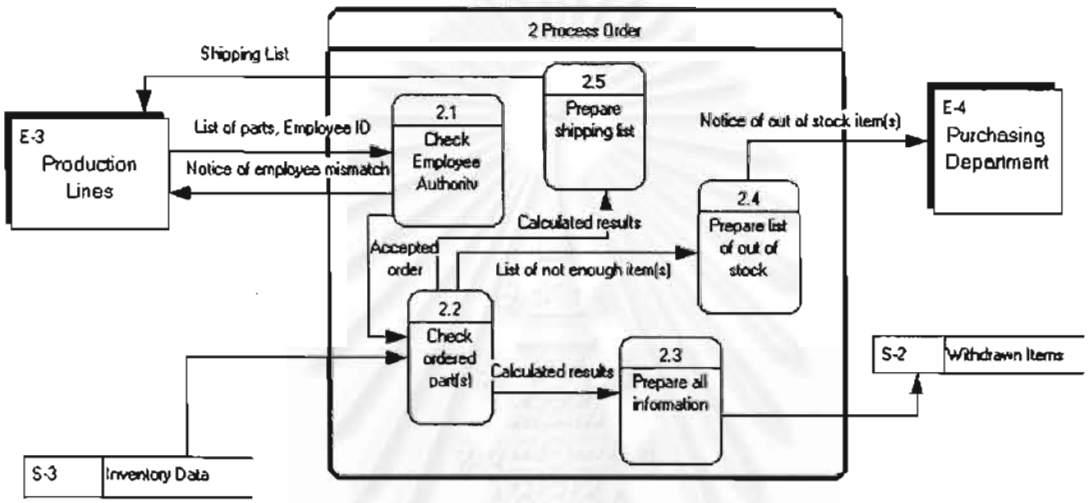


Figure 5.3: Level-1 DFD – Process order.

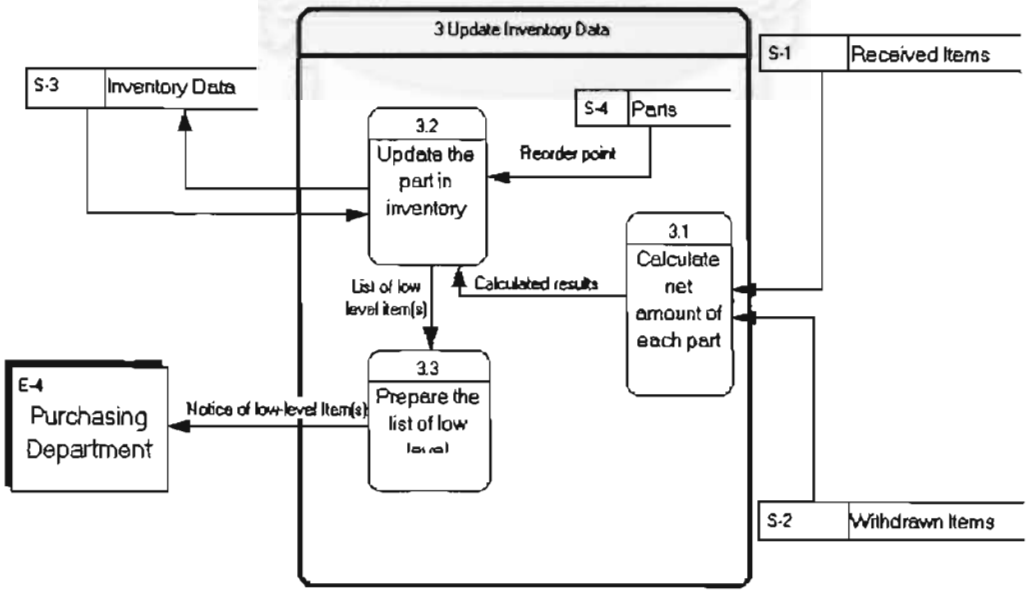


Figure 5.4: Level-1 DFD – Updating inventory data.

The third process, updating inventory data, is a process that performs the checking of the reorder point of the part. So, the parts information is needed. In fact, the inventory personnel are not required to perform this process because the software automatically activates it. In other words, when either received items file or withdrawal items file is already recorded, this process will be activated to update the amounts of parts and check the available amounts to the reorder points of those parts. If the low-level items are found, the list of them will be reported on the screen. The reports can be printed out and sent to the purchasing department or production department. The level1 DFD of the updating inventory data is illustrated in figure 5.4.

5.3 Database Design

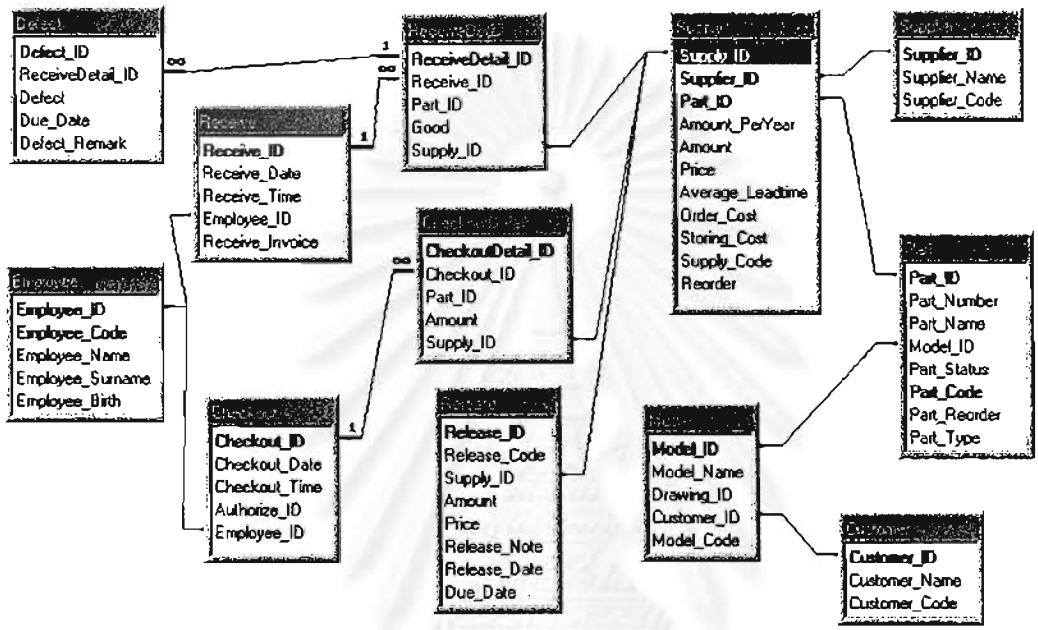
After the flows of the inventory data are revised, the database has to be created to support the inventory processes. Furthermore, the bar-coding system has to be taken into account. In this phase, the relational database is selected due to the fact that it can support all jobs, not only in the inventory but also the whole company, and it is an economical system, today. In this study, the database is designed in Microsoft Access 97, which is a relational database management system. The database composes of tables, queries, relationships, and integrity rules.

Again, DFDs are the very useful maps in the database design phase because they have already included the stored data files, which are the necessary tables that the inventory database should have, in the diagrams. Foremost, an important thing that should be clarify through the design stage is to draw the basic concepts of database design as shown as follows:

- To avoid duplicate data
- To be able to support multi-user
- To minimize invalid data entries using validation rules

In this phase, entity relationship diagrams (ER Diagrams) are the powerful tools for creating the TBKK's inventory database. The ER diagram of the complete inventory database is shown in figure 5.5, using the relationship diagram in Microsoft Access 97.

Each box in the diagram represents a table, and each row in the box is a field or a column. Lines between the boxes represent that there are relationships among the boxes, while the infinity sign means many records are linked and number one means one related record. In addition, each table must have at least one primary key, which is shown by the bold fonts.



The details of fields in all tables such as data types, lengths, validation rules, and related tables are attached in appendix B. The database file (MDB) is attached in the CD ROM.

CHAPTER VI

SOFTWARE DESIGN & IMPLEMENTATION

6.1 Introduction

After the database is designed, the user interfaces that can support the bar-coding system will be developed. According to the TBKK's computer system, the applications will be used in Microsoft Windows 95 and Client/Server environment, so the applications, in this thesis, have to be developed with the development tool that can work on the Microsoft Windows Client/Server environment. The selected tool is the Microsoft Visual Basic Version 5 (VB5) which is a powerful Microsoft application development tool. Nowadays, VB5 is a very popular tool because of the wide ranges of its applications, and its full compatibility with Microsoft Windows 95, 98 and NT. In addition, the programming language that is used in VB5 is based on BASIC language.

Fist of all, again, it is necessary to clarify the goals of developing software in order to define the framework of the applications. The objectives are presented bellowed:

- User friendliness – fast and easy to understand and use.
- Flexibility – files can be exported in many formats such as hard copies, and soft copies.
- Ability to support multi-users over the LAN system, the warehouse workers can work concurrently with the inventory system administrators in the office.
- Accuracy of the data – by providing validation rules in every form such as in the employee ID textbox, the inventory personnel can not enter any alphabet, only numeric data can be input.
- Ability to fully replace to the existing system.
- Ability to support the automatic data collection that is barcode system.

In this chapter, the flow charts are not used because VB5 is an event-driven applications development, not a procedural structure, therefore the flow charts are not suitable for this project.

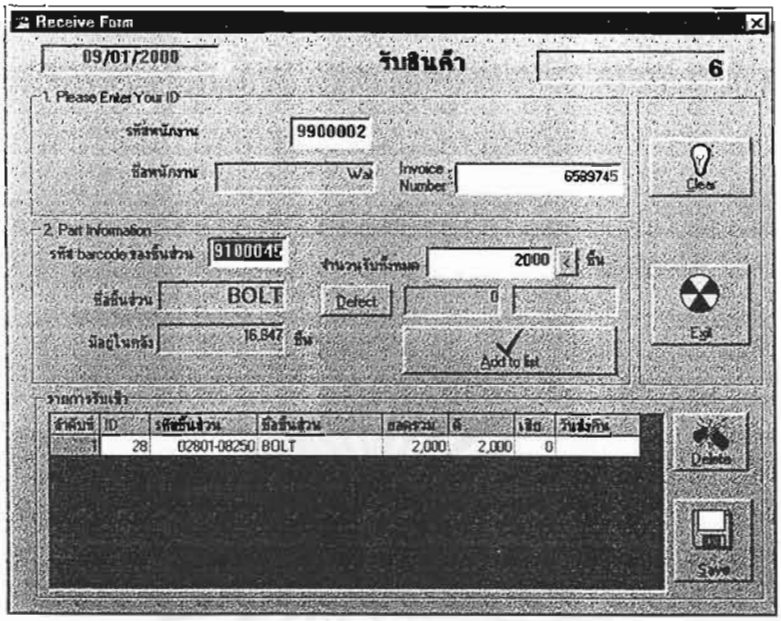
6.2 User interfaces

Designing user interfaces is an important issue in software development because it has direct effects on the easiness when using the program or user friendliness. In fact, if software is designed to be easy to use, users will be able to learn and work faster than a complex one. In the meantime, if the software has provided user-friendly screens, users will be motivated to use it. For example, the popularity of Microsoft Office series results from its ease of use relative to other similar applications such as Lotus Smart Suite. However, more important than the form layouts of an application, its structure inside the application has direct effects on the efficiency of the application and the errors in the application. In the development phase, both issues discussed above are always kept in mind.

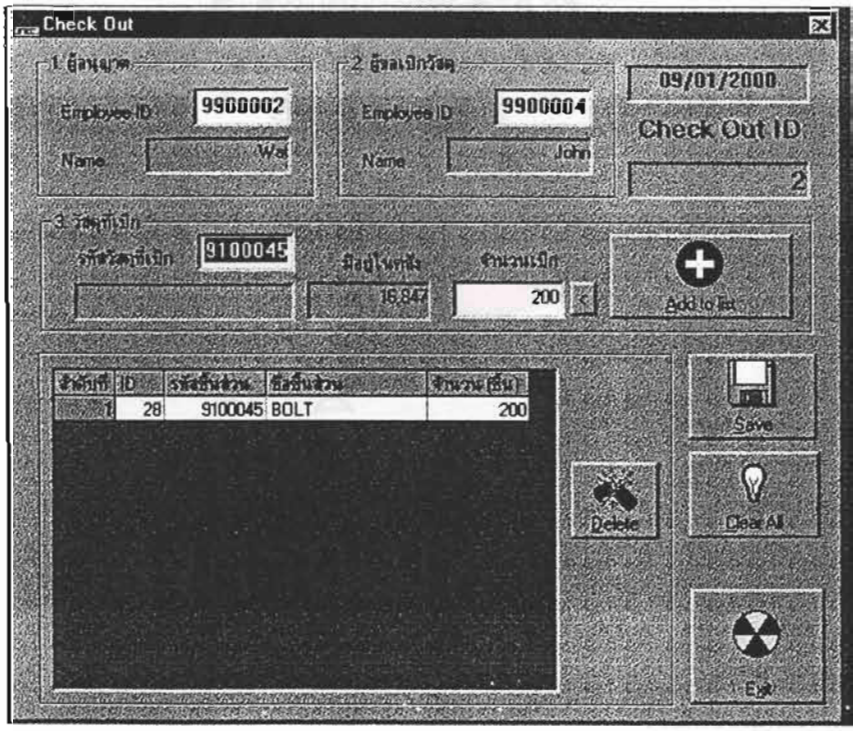
In this project, the application is divided into two main parts which are the operators section that performs the receiving and withdrawing processes, and generating some reports, and administration section that performs all jobs of the operators section does with the ability to manipulate the inventory database added.

In the operators' section, four forms are generated in order to support the new inventory processes and the ability to well-connect to the database. The list of necessary forms is shown below.

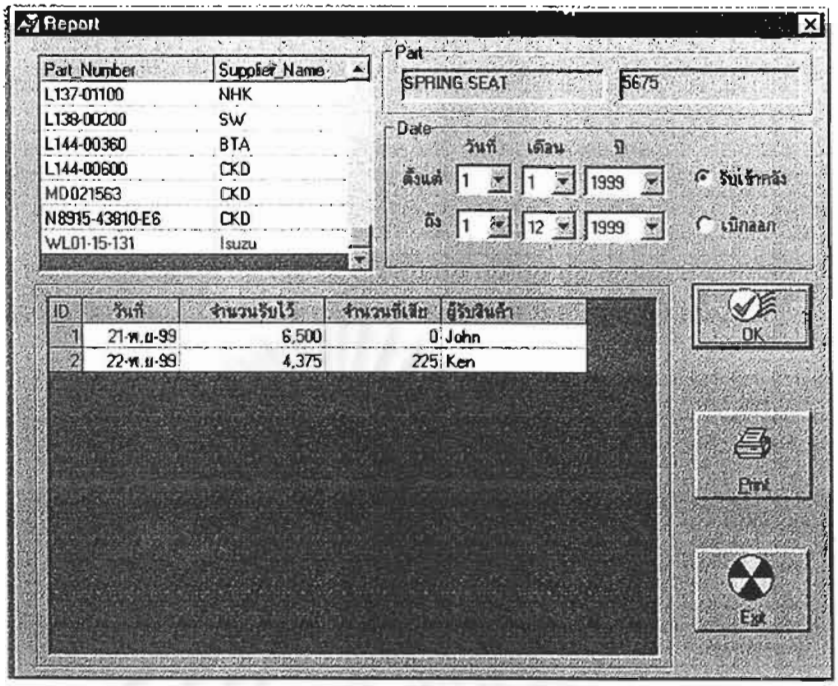
1. Parts Receiving form



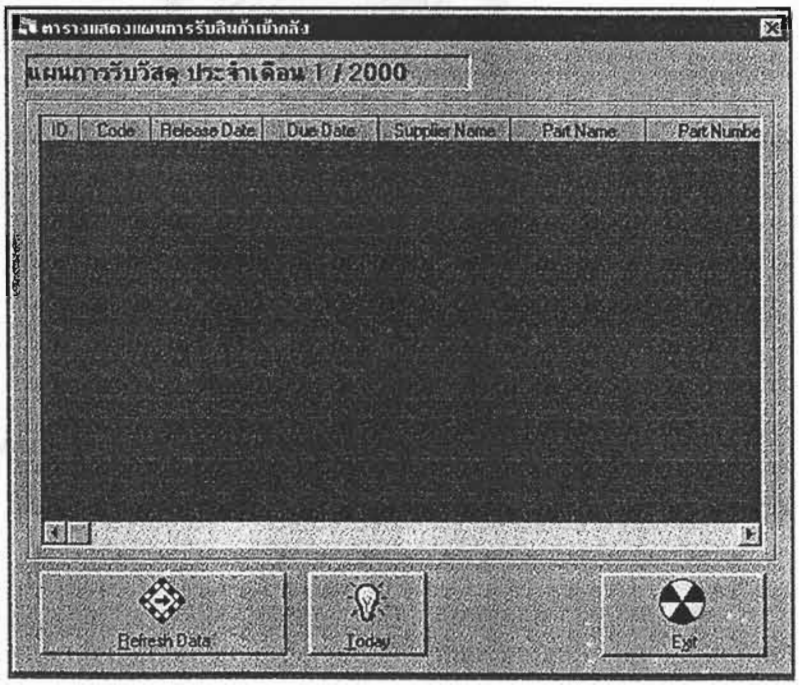
2. Parts Requisition form



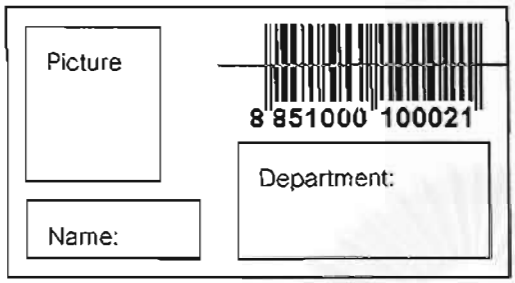
3. Report generator form

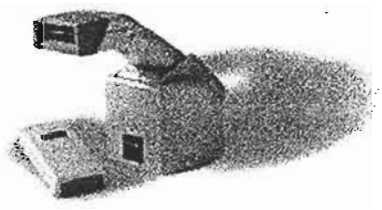


4. Scheduled receipt form



The scheduled receipt is provided for future use, when the company fully implements the barcode system. Basically, to use the receiving and withdrawal forms, the inventory personnel have to scan their employee ID cards first. The employee ID card is illustrated in figure 6.1.





Then, the subsequent inputs will be permitted, otherwise the form will send an error message to the user and the other parts of the form are not activated. The basic sequential procedures of the receiving and withdrawal processes are summarized below:

1. Input employee ID thru barcode scanners or keyboard
2. Input part ID thru barcode scanners or keyboard
3. Input amount
4. Confirm order
5. Save transaction

In contrast, for the administration section, apart from the functions performed in the operators' section, the administrator can also change the name, number of parts, models, customers, and suppliers. In other words, the administrator has full authority in inserting (adding new records), deleting, and updating the inventory database. Moreover, the necessary features, such as barcode labels for employees, parts, and shipping can be generated. In addition, more reports including economic order quantity (EOQ) of parts, ABC analysis reports, and transaction reports can be printed out. Furthermore, when a part amount is lower than its reorder point, which is set by supervisors, the low-level form will appear automatically when the program is opened or when the user click on the low-level button. In short, this enables the users to manage

and control all procedures in the inventory. The summary of the additional forms is shown below.

1. Parts information form – parts, models, supplier, customers data
2. Employees information form
3. Receiving transactions reports form
4. Withdrawal transactions reports form
5. Reports form – EOQ, ABC analysis, and Transaction reports
6. Scheduled receipt plan form
7. Barcode generator form
8. Low-level report form

The user-interfaces of the program are attached in appendix A.

6.3 Barcode system

The selected barcode system in this project is UCC/EAN 128 due to the fact that it can be used throughout the supply chain, not only within a company. In this project, two main groups of codes, which are internal code and shipping code, are defined. The internal codes, such as part codes (begin with 91) and employee codes (begin with 99), are the codes that are used within the company. Some examples of codes are shown in figure 6.2.

Figure 6.2: Example of employee code and part code

In contrast, the shipping codes should be international codes, which are the serial shipping container codes (SSCC). The SSCC has to begin with 00 following by 17 digits and 1 check-digit. An example of SSCC label from the application is illustrated in figure 6.3.

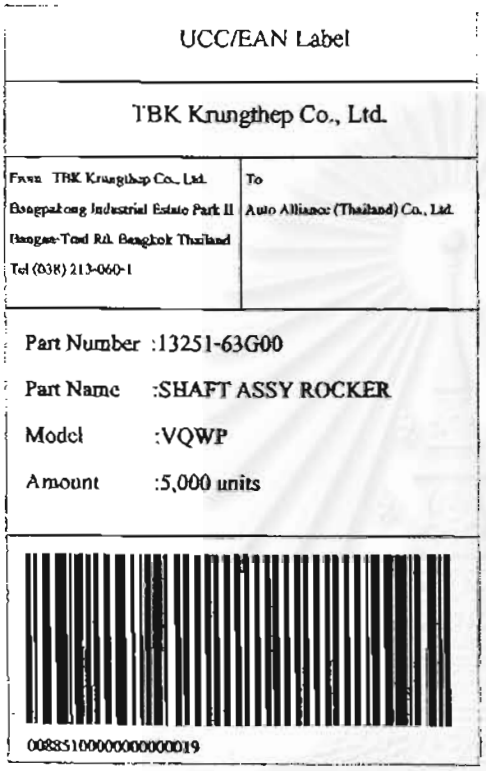


Figure 6.3: SSCC Label.

6.4 Hardware

In this topic, major changes are not made due to the limitation of the investment and time. The added devices are two barcode scanners and two printers for uses in the warehouse. The barcode scanners can be either CCD, laser or RF scanners. A recommended system is the laser scanner because its prices are reasonable and its flexibility in long distance use (depending on the wire). However, the RF scanner or wireless scanner is the most suitable for the warehouse jobs, but its price is very high compared with other systems. The price of a RF scanner is more than 70,000 baht.

There is no change in the inventory computer and network system. The new computer system layout is illustrated in figure 6.4. Nevertheless, in the inspection area, there should be one computer that can connect to the main server in order to enable the inventory personnel to key in the defective parts to the database immediately, instead of waiting until he or she completes the whole processes.

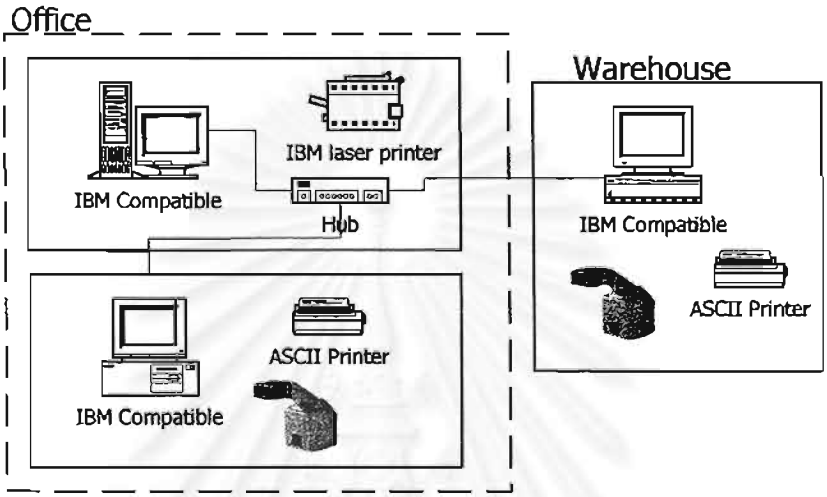


Figure 6.4: new computer hardware layout in the TBKK's inventory

CHAPTER VII

EVALUATION

7.1 Introduction

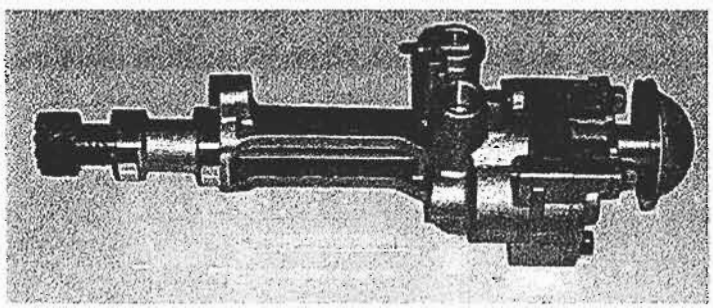
In this project, the new TBKK inventory software was first installed in the warehouse computers on 20th October 1999. The application on the operators' section was installed in the computer at the warehouse, while the administrators' section was installed in a computer in the office. In the warehouse, two inventory operators use the software to input the data of receiving and withdrawing transactions. At the office, the software has been used by an inventory supervisor, Mr. Prasop Kanakasai.

This software will be evaluated by comparing the accuracy of the data and the time consumed in recording transactions and summarizing data with those of the existing system. In the accuracy issue, the amounts of the parts in the database, the amounts that were stored in the old system and the actual amounts in the inventory were compared. For the timeliness, the time used in inputting the data using the new system was compared with the time the present one takes.

Due to the fact that all receiving and withdrawal procedures of all shipments and orders are the same and the limited time warehouse personnel can give, all parts can not be selected to evaluate the software. Therefore, the comparison in this thesis is made with three parts of an oil pump of Isuzu engine, which have highest number of transactions, about 30 transactions per month. The selected items are:

1. Pinion gear
2. Spring
3. Spring seat

The pictures of the Isuzu oil pump and the three parts are illustrated in figure 7.1.



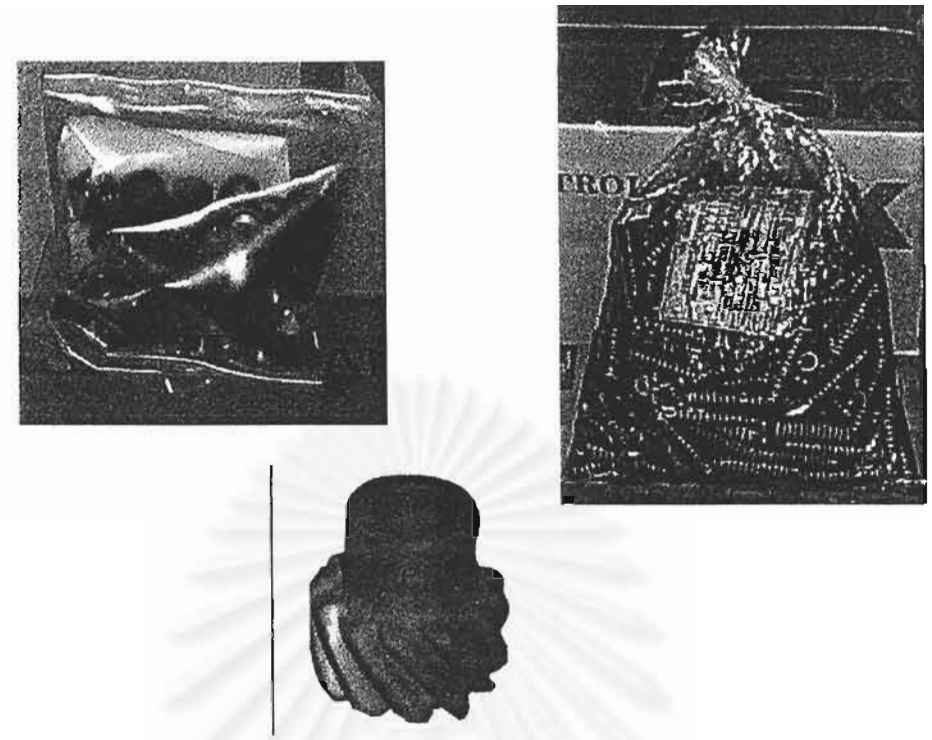


Figure 7.1: Oil pump, pinion gear, spring seats, and springs

The new system was run during November 1999 in parallel with the old processes. The testing started in 1st November 1999; the beginning amounts were recorded. Then, in the 30th November 1999, the remaining amounts of the three parts that had been stored in the new system and the old system, and the actual amounts in the inventory were counted and compared. Moreover, the test was done with one employee using the old system and another employee using the new system with a barcode scanner.

In this evaluation, the input device is a CCD barcode scanner, which is the simplest type of scanners. CCD scanner has to be used in a limited distance from the barcode label (less than 2 cm), thus, it is not actually suitable for using in warehouses in the real situation. Instead, the scanner should be the laser or the RF (wireless) system.

For the other issue, the new system was tested its ease of use comparing with the old system. The comparison was done by having an employee input 20 transactions of one or two parts in the old system and the new system, then, had the two sets of data compared.

7.2 Results

7.2.1 Accuracy

During November, there were 12 receiving and 15 requisition orders transactions for pinion gears, 2 receiving and 15 requisition orders transactions for spring, 2 receiving and 15 requisition orders transactions for spring seat. The remaining amounts and errors of the three parts as of 30th of November 1999 are shown in table 7.1.

Table 7.1: Remaining amounts at November 30th 1999 (units)

		Actual Amounts	New System	Old System	Errors (Units)	% Errors
L125-00410	PINION GEAR	540	540	520	-20	-4%
L137-01100	SPRING	2200	2200	2200	0	0%
L138-00200	SPRING SEAT	2700	2700	2400	-300	-11%
				Average	-107	-5%

Notice that, there were some errors (5 percent) occurred in the old system in November. In the old system, there are several causes of the errors including the fact that receiving or withdrawal transaction was not recorded to the computer or recorded in an incorrect cell in the worksheet. In contrast, there was no error in the new system. This means that the new system has been proven that it is better system than the existing one on the accuracy issue.

7.2.2 Timeliness

In the ease of use topic, the results of the time each system took (in seconds) in the test are illustrated in table 7.2. Hypothesis testing of two means with variances unknown has been used in this evaluation. The assumptions are the distribution of time used in the new and existing systems is normal distribution, and their variances are equal. The one-sided null and alternative hypothesis are shown below:

$$H_0: \quad \mu_1 = \mu_2$$

$$H_1: \quad \mu_1 < \mu_2$$

Where μ_1 = mean of time consumed by the new system

μ_2 = mean of time consumed by the existing system

Using $\alpha = 0.05$, the H_0 will be rejected if the test statistic $t_0 < -t_{0.05,28}$. All results of simulation are shown in table 7.2

Table 7.2: Average inputting time (seconds) from the testing

	New System	Existing System
	24	46
	27	48
	22	52
	25	49
	25	53
	24	51
	28	47
	24	47
	26	46
	28	50
	27	57
	27	48
	29	49
	25	49
	28	51
	28	47
	30	50
	24	48
	21	49
	25	56
Mean	25.85	49.65
Variance	5.78	9.95
Standard Deviation	2.40	3.15

Table 7.3: the calculated t_0.

S_p^2	t_0	$t_{0.05,28}$
37.75	-1.7266	-1.701

From the results in table 7.3, we can conclude that: Since t_0 = -1.726 < -1.701, H_0: $\mu_1=\mu_2$ is rejected and conclude at the 0.05 level of significance that the time consumed by the new system in doing transactions was less than that of the existing system. This means that the new system has an advantage over the old system in the working time to record a transaction, that is if the company uses the new system the employee will have more time to do other jobs. However, this issue is less important for the inventory than the first one.

7.2.3 Overstocking

In this topic, the application is evaluated indirectly by considering on the average on-hands amount per day when the company uses the new system comparing with the existing one. As mentioned above, the new system provides the EOQ model reports, and the ABC analysis report that classifies parts into three main groups: Type A inventory, Type B inventory, and Type C inventory. Notice that, Type C items are the most suitable to use the EOQ model or two bins system for ordering due to the fact that their estimated total value per year is about 5 percents of the total inventory values.

When the transactions of the three parts, which are pinion gear, spring, and spring seat, have been recorded during November 1999, the ABC analysis report function is activated and it shows that spring and spring seat are categorized into type C items. This means that the EOQ model should be used to make the ordering of the spring and spring seat by using their average prices, estimated storing costs per year (10% of the prices), estimated order costs (3 baht), and average lead-times. Therefore, the EOQ model has been applied to the spring and spring seat in November and December 1999, in order to compare the on-hand amounts when using EOQ model, as shown in table 7.4, with the existing system. The results of the on-hand amount of November 1999, and December 1999 are illustrated in table 7.5, 7.6, 7.7, and 7.8.

Table 7.4: EOQ model for the spring and spring seat.

	EOQ (units)	Periods (Days)
Spring	1,297.04	4.28
Spring Seat	2,235.80	7.80

Table 7.5: Inventory status of Spring and Spring seat (November 1999) by using existing inventory control system.

Spring	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
In			2,000						800		3,400				400																6,600
Out		400	600			400				200	200	400			200	400	400	400	400			200		600	200				600		5,600
Available	1,200	800	2,200	2,200	2,200	1,800	1,800	1,800	2,600	2,400	5,600	5,200	5,200	5,200	5,400	5,000	4,600	4,200	3,800	3,800	3,800	3,600	3,600	3,000	2,800	2,800	2,800	2,800	2,200	2,200	96,600
Spring Seat																															
In									6,700																						6,700
Out		300	300			300				300	200	500			300	400	500	100	400			400		600	100				600		5,300
Available	1,300	1,000	700	700	700	400	400	400	7,100	6,800	6,600	6,100	6,100	6,100	5,800	5,400	4,900	4,800	4,400	4,400	4,400	4,000	4,000	3,400	3,300	3,300	3,300	3,300	2,700	2,700	108,500

Table 7.6: Inventory status of Spring and Spring seat (November 1999) when using the EOQ model in the table 7.4.

Spring	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
In(EOQ)					1,300					1,300					1,300					1,300					1,300					1,300	7,800
Out		400	600			400				200	200	400			200	400	400	400	400			200		600	200				600		5,600
Available	1,200	800	200	200	1,500	1,100	1,100	1,100	1,100	2,200	2,000	1,600	1,600	1,600	1,900	1,500	1,100	700	300	1,600	1,600	1,400	1,400	800	1,900	1,900	1,900	1,900	1,300	2,600	41,100
Spring Seat																															
In(EOQ)								2,200								2,200								2,200							6,600
Out		300	300			300				300	200	500			300	400	500	100	400			400		600	100				600		5,300
Available	1,300	1,000	700	700	700	400	400	2,600	2,600	2,300	2,100	1,600	1,600	1,600	1,300	3,100	2,600	2,500	2,100	2,100	2,100	1,700	1,700	3,300	3,200	3,200	3,200	3,200	2,600	2,600	60,100

Table 7.7: Inventory status of Spring and Spring seat (December 1999) by using existing inventory control system.

Spring	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
In	4,800																															4,800
Out	400		400	400			200			400	200		200	400	400	200				400	200	200	400	200			200					4,800
Available	2,200	6,600	6,600	6,200	5,800	5,800	5,800	5,600	5,600	5,600	5,200	5,000	5,000	4,800	4,400	4,000	3,800	3,800	3,800	3,800	3,400	3,200	3,000	2,600	2,400	2,400	2,400	2,200	2,200	2,200	2,200	127,600
Spring Seat																																
In							4,800								5,200																	10,000
Out	400		400	400		200				200			200	300	500	400	200			200		200	400	200			600					4,800
Available	2,700	2,300	2,300	1,900	1,500	1,500	1,300	6,100	6,100	6,100	5,900	5,900	5,900	5,700	5,400	10,100	9,700	9,500	9,500	9,500	9,300	9,300	9,100	8,700	8,500	8,500	8,500	7,900	7,900	7,900	7,900	202,400

Table 7.8: Inventory status of Spring and Spring seat (December 1999) when using the EOQ model in the table 7.4.

Spring	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
In(EOQ)					1,300					1,300					1,300					1,300					1,300					1,300		7,800
Out	400		400	400			200			400	200		200	400	400	200				400	200	200	400	200			200					4,800
Available	2,200	1,800	1,800	1,400	1,000	2,300	2,300	2,100	2,100	2,100	3,000	2,800	2,800	2,600	2,200	3,100	2,900	2,900	2,900	2,900	3,800	3,600	3,400	3,000	2,800	4,100	4,100	3,900	3,900	3,900	5,200	88,900
Spring Seat																																
In(EOQ)		2,200								2,200								2,200								2,200						8,800
Out	400		400	400		200				200			200	300	500	400	200			200		200	400	200			600					4,800
Available	2,700	2,300	4,500	4,100	3,700	3,700	3,500	3,500	3,500	3,500	5,500	5,500	5,500	5,300	5,000	4,500	4,100	3,900	6,100	6,100	5,900	5,900	5,700	5,300	5,100	5,100	7,300	6,700	6,700	6,700	6,700	153,600

Table 7.9: Results of average on-hand amounts per day of spring and spring seat in November 1999.

	Average on-hand amounts per day		
	Existing System (units)	New System (units)	% reduced
Spring	3,187	1,370	57%
Spring Seat	3,587	2,033	45%

Table 7.10: Results of average on-hand amounts per day of spring and spring seat in December 1999.

	Average on-hand amounts per day		
	Existing System (units)	New System (units)	% reduced
Spring	4,116	2,868	30%
Spring Seat	6,529	4,955	24%

When the EOQ model is applied to the two parts, the average amounts on-hand have substantially reduced for about 50% when it was applied in November 1999, and around 25% in December 1999. This means that if the new system is fully implemented, the company will be able to reduce the Type C parts in the inventory. Meanwhile, the possibilities of overstocking and out of stock are reduced because the company has a better system to manage the parts by using a proper set of order quantities. However, the EOQ model and the ABC analysis need real data of the estimated ordering costs, storing costs, averages usage per year, averages lead-time, and prices in calculation.

In fact, to directly evaluate the overstocking levels of parts when the company applies the new software, it should take at least three months to illustrate that the new system will reduce the overstocking situations in the company. Remark that, due to the noticeable improvement in the accuracy and timeliness of the warehouse that enable the supervisors and managers to manage their inventory data more efficiently, there is a strong possibility that the overstocking levels will be reduced in the long run.

7.3 Summary

To conclude, there are evidences that the new system has performed better than the existing system in the three major topics, which are the accuracy of data, the time consumed in entering data, and the overstocking. In the overstocking issue, the possibility of overstocking is reduced due to the average on-hand amounts of parts is decreased.

CHAPTER VIII

CONCLUSIONS & RECOMMENDATIONS

The thesis has been conducted to investigate the information flow problems of present inventory management of TBK Krungtep Co., Ltd. and to develop a computer based inventory system with barcode application in perspective of information systems. The thesis begins by the analysis of existing inventory system to identify the areas that can be improved. Then, the new computer based inventory system is designed and implemented. Finally, summaries of the thesis conclusions and recommendations are drawn as follows:

8.1 Conclusions

1. In order to cope with the present inventory problems, the whole existing information system of TBKK's inventory has been revised. Beginning with the data flow in the system, it was refined by using the Data Flow Diagram (DFD). Then, the inventory database has been developed using relational database software (Microsoft Access) with user-interfaces that cooperate between the users and the database.
2. All company's raw materials and finished goods information with their barcode numbers have been recorded in the new inventory database. Furthermore, they are linked to their finished goods' models, suppliers and customers.
3. The inventory database has been developed with the security system that protects the database from the attempts of unauthorized users to add, delete, or change the data or the structure in the database. Consequently, the new database has a higher security level relative to the existing system, which can be opened by anyone who can access to the company hard drive.
4. The new receiving and requisition procedures, and other inventory jobs have not been changed in this thesis due to the fact that the all procedures have to be done under procedure manuals of the company that had been developed

since the company has started practicing the ISO9000 and QS9000. Therefore, the user-interfaces of the software have been designed with concerns on the existing procedures and the linkage to the new database.

5. The user-interfaces have been designed in two parts, which are the operating part and the administration part. The operating part is able to do the general inventory jobs those are receiving, picking and producing some reports. This part will be installed in the company's warehouse. The administration part has been developed for doing a wide variety of inventory works such as handling the information of raw materials, suppliers, and customers, employees and barcodes. Moreover, the reports of transactions, low-level items, EOQ (Economic Order Quantity) and ABC Analysis are provided. The barcode labels for employee and the parts can be generated by the administration part.
6. The user-interfaces have been created to work with a keyboard and all types of barcode scanner except Radio Frequency (RF) with internal memory barcode scanner.
7. The selected barcode system in this thesis is the UCC/EAN 128, which provides ease of use and flexibility for the future use. However, due to the company's limited power of negotiation to its suppliers in forcing them to print the barcode labels on their products when they dispatch their products to the company, the internal code is inevitable. In the future, when the company need to have a full barcode system, the database has been provided to cope with the change in code numbers.
8. The codes have been generated by the company due to the fact that the suppliers can not support on this issue. In this thesis, part codes begin by the number 91 and follow by 5 digits.
9. The three parts that have the highest transactions per month were selected to conduct the evaluation and comparison between the new and the existing systems. The new system were used concurrently with the existing system during November 1999 to compare the accuracy between them, and the EOQ model has been applied during November 1999 and December 1999.

10. The accuracy and time-consumption in summarizing the inventory data of the existing inventory control system (using Excel files) can be improved considerably through the new computer based inventory control system (using a relational database) that uses the bar-coding system.
11. The developed inventory software has a number of important characteristics that lead to improved performance in inventory management including:
    - The ability to work with bar-coding system and print the barcodes by the software itself.
    - Necessary reports are provided.
    - The database can be shared in multi-users environment.
12. The new inventory system has been designed to be able to immediately replace the existing system. However, the new system still has some limitations same as those of the existing system such as tracking of raw materials and the compliance issue of the operator in the warehouse in inputting the inventory data instantaneously, which can not be enforced directly.
13. The warehouse personnel have more explicit sequential procedures in inputting inventory data due to the restrictions of the user interfaces. In addition, they can not access the main database to do unauthorized jobs; therefore the database is protected, only administrators are able to access or change the values or structures in the database.
14. The barcode system allows the users to work faster than in the past and reduces human errors in the key-in process.
15. In the new system, the production planning and purchasing departments are able to access the inventory database to retrieve the summary of the most updated inventory status at anytime.

8.2 Recommendations

Due to the lack of investments for the hardware, it was felt that the application of immediate nature be developed to solve the problems of immediate needs. So, this

thesis only concentrated on the controlling of raw materials by using internal code system in inventory division, which is considered as being of intensive need. In the future, further needs of information system applications can be explored to cope with other remaining problems.

1. The information in inventory department has to be linked with that of the production department's in order to improve the effectiveness and efficiency of the company's information system. For example, the remaining amounts of parts data can be accessed by production planning team, and the scheduled receipts will be input directly by the production or purchasing department.
2. Location codes should be developed in order to gain the advantages of the ability to track materials in the warehouse. Moreover, containers and pallets should be labeled with the barcodes too. However, this system needs modification of the general processes in the warehouse, and especially a large investment in hardware including barcode printers, RF barcode scanners, and training.
3. The prices of parts should be recorded from the very beginning process, scheduled receipts, and receiving in order to help the company to estimate the cost of parts when they are picked to the production lines under whether FIFO or LIFO system. However, it is necessary to modify some procedures in inventory procedure manuals. Moreover, the cooperation among the inventory, purchasing, production and accounting departments is needed as well.
4. The information from the suppliers, such as the lot numbers, invoice numbers, and prices, should be able to be linked with the company. Furthermore, the barcode labels should be printed from the suppliers to make sure that the codes are correct because the codes are generated from the source of origins, which are the vendors.
5. Electronic Data Interchange (EDI) is needed in the future. The bar-coding system is just a requirement of implementing the EDI system. In practice, the EDI invoice will be transferred with the barcodes of products. Therefore, the

company should study further on important issues of EDI with the company's suppliers and customers.

6. The study of utilizing the barcodes in production department should be started because the codes at the parts can be used in the manufacturing system as well. To illustrate, in the assembly lines, when a part is picked, the part code should be scanned in order to update the status of that part from warehouse to the production line. This means that, the company is able to use the codes for the shop floor controls projects as well.
7. In order to implement the UCC/EAN 128 bar-coding system project, the cooperation among suppliers, customers and the company itself is very essential. Therefore, the co-study of using UCC/EAN 128 bar-coding system between the company and customers such as Isuzu, Mitsubishi, and Toyota should be initiated in order to identify the customer needs of data that should be added in the barcode labels.
8. The company should have some training programs about basic idea of the ADC system in order to prompt the employees for the new system. Even though the ADC system seems to be easy to use, if a company lets the operators to use an ADC system like robots without understanding how the ADC system works, it will be quite difficult to find the root causes and solutions when the problems occur. For example, will the operator knows, when a barcode of a product is scanned and the name of that product appears on the screen, whether that data is saved to the database? and if the operator cancels that transaction, whether that transaction is deleted from the company's database?

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Appendices

Appendix A

Current UCC/EAN Application Identifiers

Appendix A: Current UCC/EAN Application Identifiers

The three AIs in italics are not part of the American National Standard ANSI/UCC41995: UCC/EAN-128 Application Identifier Standard, June 1995 because these AIs had not been approved by the UCC at the time this standard was submitted to ANSI. This information will be incorporated in the ANS in future revisions of the standard.

AI	Content	Format
00	SSCC-18	n2+n18
01	SCC-14	n2+n14
02	Item Number of Goods Contained Within Another Unit (Must Use with AI 37)	n14
10	Batch or Lot Number	n2+an..20
11 (*)	Production Date (YYMMDD)	n2+n6
13 (*)	Packaging Date (YYMMDD)	n2+n6
15 (*)	Sell By Date (Quality) (YYMMDD)	n2+n6
17 (*)	Expiration Date (Safety) (YYMMDD)	n2+n6
20	Product Variant	n2+n2
21	Serial Number	n2+an..20
22	HIBCC - Quantity, Date, Batch and Link	n2+an..29
23 (**)	Lot Number (Transitional Use)	n3+n..19
240	Additional Product Identification assigned by the Manufacturer	n3+an..30
250	Secondary Serial Number	n3+an..30
30	Quantity	n2+n..8
310 (***)	Net Weight, Kilograms	n4+n6
311 (***)	Length or 1st Dimension, Meters	n4+n6
312 (***)	Width, Diameter or 2nd Dimension, Meters	n4+n6
313 (***)	Depth, Thickness, Height or 3rd Dimension, Meters	n4+n6
314 (***)	Area, Square Meters	n4+n6
315 (***)	Volume, Liters	n4+n6
316 (***)	Volume, Cubic Meters	n4+n6

320 (***)	Net Weight, Pounds	n4+n6
321 (***)	Length or 1st Dimension, Inches	n4+n6
322 (***)	Length or 1st Dimension, Feet	n4+n6
323 (***)	Length or 1st Dimension, Yards	n4+n6
324 (***)	Width, Diameter, or 2nd Dimension, Inches	n4+n6
325 (***)	Width, Diameter, or 2nd Dimension, Feet	n4+n6
326 (***)	Width, Diameter, or 2nd Dimension, Yards	n4+n6
327 (***)	Depth, Thickness, Height or 3rd Dimension, Inches	n4+n6
328 (***)	Depth, Thickness, Height or 3rd Dimension, Feet	n4+n6
329 (***)	Depth, Thickness, Height or 3rd Dimension, Yards	n4+n6
330 (***)	Gross Weight, Kilograms	n4+n6
331 (***)	Length or 1st Dimension, Meters, Logistics	n4+n6
332 (***)	Width, Diameter or 2nd Dimension, Meters, Logistics	n4+n6
333 (***)	Depth, Thickness, Height or 3rd Dimension, Meters, Logistics	n4+n6
334 (***)	Area, Square Meters, Logistics	n4+n6
335 (***)	Gross Volume, Liters	n4+n6
336 (***)	Gross Volume, Cubic Meters	n4+n6
340 (***)	Gross Weight, Pounds	n4+n6
341 (***)	Length or 1st Dimension, Inches, Logistics	n4+n6
342 (***)	Length or 1st Dimension, Feet, Logistics	n4+n6
343 (***)	Length or 1st Dimension, Yards, Logistics	n4+n6
344 (***)	Width, Diameter or 2nd Dimension, Inches, Logistics	n4+n6
345 (***)	Width, Diameter or 2nd Dimension, Feet, Logistics	n4+n6
346 (***)	Width, Diameter or 2nd Dimension, Yards, Logistics	n4+n6

347 (***)	Depth, Thickness, Height or 3rd Dimension, Inches, Logistics	n4+n6
348 (***)	Depth, Thickness, Height or 3rd Dimension, Feet, Logistics	n4+n6
349 (***)	Depth, Thickness, Height or 3rd Dimension, Yards, Logistics	n4+n6
350 (***)	Area, Square Inches	n4+n6
351 (***)	Area, Square Feet	n4+n6
352 (***)	Area, Square Yards	n4+n6
353 (***)	Area, Square Inches, Logistics	n4+n6
354 (***)	Area, Square Feet, Logistics	n4+n6
355 (***)	Area, Square Yards, Logistics	n4+n6
356 (***)	Net Weight, Troy Ounce	n4+n6
360 (***)	Volume, Quarts	n4+n6
361 (***)	Volume, Gallons	n4+n6
362 (***)	Gross Volume, Quarts	n4+n6
363 (***)	Gross Volume, Gallons	n4+n6
364 (***)	Volume, Cubic Inches	n4+n6
365 (***)	Volume, Cubic Feet	n4+n6
366 (***)	Volume, Cubic Yards	n4+ n6
367 (***)	Gross Volume, Cubic Inches	n4+ n6
368 (***)	Gross Volume, Cubic Feet	n4+ n6
369 (***)	Gross Volume, Cubic Yards	n4+ n6
37	Quantity of Units Contained (For Use With AI 02 Only)	n..8
400	Customer's Purchase Order Number	n3+an..30
410	Ship To (Deliver To) Location Code Using EAN-13	n3+n13
411	Bill To (Invoice To) Location Code Using EAN-13	n3+n13
412	Purchase From (Location Code of Party from Whom Goods are Purchased)	n3+n13

414	EAN Location Code for Physical Identification	n3+n13
420	Ship To (Deliver To) Postal Code Within a Single Postal Authority	n3+an..9
421	Ship To (Deliver To) Postal Code With 3-Digit ISO Country Code Prefix	n3+n3+an..9
8001	Roll products - Width, Length, Core Diameter, Direction and Splices	n4+n14
8002	Electronic Serial Number for Cellular Mobile Telephones	n4+an..20
8003	UPC/EAN Number and Serial Number of Returnable Asset	n4+n14+an..16
8004	UCC/EAN Serial Identification	an..30
8005	Identifies the Price Per Unit of Measure	n6
8100	Coupon Extended Code - Number System Character and Offer	n4+n1+n5
8101	Coupon Extended Code - Number System Character, Offer, and End of Offer	n4+n1+n5+n4
8102	Coupon Extended Code - Number System Character preceded by zero	n4+n1+n1
90	Mutually Agreed, Between Trading Partners or FACT DIs	n2+an..30
91	Intra-Company (Internal)	n2+an..30
92	Intra-Company (Internal)	n2+an..30
93	Intra-Company (Internal)	n2+an..30
94	Intra-Company (Internal)	n2+an..30
95	Internal-Carriers	n2+an..30
96	Internal-Carriers	n2+an..30
97	Intra-Company (Internal)	n2+an..30
98	Intra-Company (Internal)	n2+an..30
99	Internal	n2+an..30

(*) :	To indicate only year and month, DD must be filled with "00"
(**) :	Plus one digit for length indication
(***) :	Plus one digit for decimal point indication

Data Value Representation:			
a	alphabetic characters	an3	3 alphanumeric characters, fixed length
n	numeric characters	a..3	up to 3 alphabetic characters
an	alphanumeric characters	n..3	up to 3 numeric characters
a3	3 alphabetic characters, fixed length	an..3	up to 3 alphanumeric
n3	3 numeric characters, fixed length		

Appendix B

Details of the TBKK's Inventory Database

Properties

Date Created:	8/25/99 9:44:34 PM	Def. Updatable:	True
Last Updated:	2/9/00 10:59:24 PM	OrderByOn:	False
RecordCount:	15		

Columns

Name	Type	Size
Checkout_ID	Number (Long)	4
Checkout_Date	Date/Time	8
Checkout_Time	Date/Time	8
Authorize_ID	Number (Long)	4
Employee_ID	Number (Long)	4

Properties

Date Created:	8/25/99 9:46:38 PM	Def. Updatable:	True
Last Updated:	2/9/00 10:59:24 PM	OrderByOn:	False
RecordCount:	45		

Columns

Name	Type	Size
CheckoutDetail_ID	Number (Long)	4
Checkout_ID	Number (Long)	4
Part_ID	Number (Integer)	2
Amount	Number (Long)	4
Supply_ID	Number (Long)	4

Properties

Date Created:	2/11/99 12:02:47 AM	Def. Updatable:	True
Last Updated:	2/9/00 10:59:25 PM	OrderByOn:	False
RecordCount:	5		

Columns

Name	Type	Size
Customer_ID	Number (Integer)	2
Customer_Name	Text	50
Customer_Code	Text	50

Properties

Date Created:	8/11/99 9:04:03 PM	Def. Updatable:	True
Last Updated:	2/9/00 10:59:25 PM	OrderByOn:	False
RecordCount:	0		

Columns

Name	Type	Size
Defect_ID	Number (Long)	4
ReceiveDetail_ID	Number (Long)	4
Defect	Number (Long)	4
Due_Date	Date/Time	8
Defect_Remark	Memo	-

Properties

Date Created:	8/11/99 9:56:08 PM	Def. Updatable:	True
Last Updated:	2/9/00 10:59:25 PM	OrderByOn:	False
RecordCount:	6		

Columns

Name	Type	Size
Employee_ID	Number (Long)	4
Employee_Code	Text	5
Employee_Name	Text	50
Employee_Surname	Text	50
Employee_Birth	Date/Time	8

Properties

Date Created:	2/11/99 12:02:04 AM	Def. Updatable:	True
Last Updated:	2/9/00 10:59:25 PM	OrderByOn:	False
RecordCount:	4		

Columns

Name	Type	Size
Model_ID	Number (Long)	4
Model_Name	Text	50
Drawing_ID	Number (Integer)	2
Customer_ID	Number (Integer)	2
Model_Code	Text	20

Properties

Date Created:	9/27/99 2:46:17 PM	Def. Updatable:	True
Last Updated:	2/9/00 10:59:25 PM	OrderByOn:	False
RecordCount:	497		

Columns

Name	Type	Size
Part_ID	Number (Long)	4
Part_Number	Text	20
Part_Name	Text	30
Model_ID	Number (Integer)	2
Part_Status	Text	10
Part_Code	Text	5
Part_Reorder	Number (Long)	4
Part_Type	Text	10

Properties

Date Created:	8/11/99 11:21:29 AM	Def. Updatable:	True
Last Updated:	2/9/00 10:59:25 PM	OrderByOn:	False
RecordCount:	14		

Columns

Name	Type	Size
Receive_ID	Number (Long)	4
Receive_Date	Date/Time	8
Receive_Time	Date/Time	8
Employee_ID	Number (Long)	4
Receive_Invoice	Text	50

Properties

Date Created:	9/28/99 8:55:04 AM	Def. Updatable:	True
Last Updated:	2/9/00 10:59:25 PM	OrderByOn:	False
RecordCount:	16		

Columns

Name	Type	Size
ReceiveDetail_ID	Number (Long)	4
Receive_ID	Number (Long)	4
Part_ID	Number (Long)	4
Good	Number (Long)	4
Supply_ID	Number (Long)	4

Properties

Date Created:	10/25/99 11:03:45 AM	Def. Updatable:	True
Last Updated:	2/9/00 10:59:25 PM	OrderByOn:	False
RecordCount:	16		

Columns

Name	Type	Size
Release_ID	Number (Long)	4
Release_Code	Text	5
Supply_ID	Number (Long)	4
Amount	Number (Long)	4
Price	Number (Single)	4
Release_Note	Text	200
Release_Date	Date/Time	8
Due_Date	Date/Time	8
Status	Yes/No	1

Properties

Date Created:	2/10/99 11:52:02 PM	Def. Updatable:	True
Last Updated:	2/9/00 10:59:25 PM	OrderByOn:	False
RecordCount:	16		

Columns

Name	Type	Size
Supplier_ID	Number (Long)	4
Supplier_Name	Text	50
Supplier_Code	Text	50

Properties

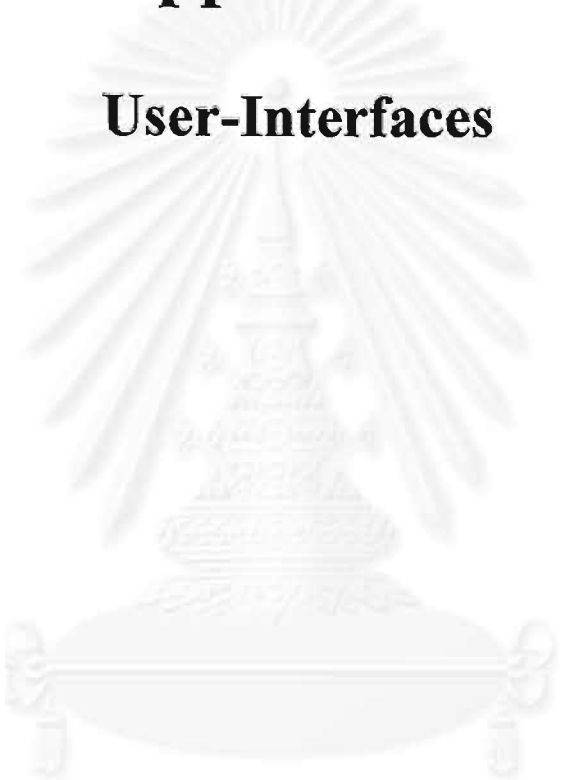
Date Created:	2/10/99 11:53:11 PM	Def. Updatable:	True
Last Updated:	2/13/00 10:20:31 AM	OrderBy:	Supply.Storing_Cost DESC
OrderByOn:	True	RecordCount:	501

Columns

Name	Type	Size
Supply_ID	Number (Long)	4
Supplier_ID	Number (Integer)	2
Part_ID	Number (Integer)	2
Amount_PerYear	Number (Long)	4
Amount	Number (Long)	4
Price	Number (Single)	4
Average_Leadtime	Number (Single)	4
Order_Cost	Number (Single)	4
Storing_Cost	Number (Single)	4
Supply_Code	Text	5
Reorder	Number (Single)	4

Appendix C

User-Interfaces



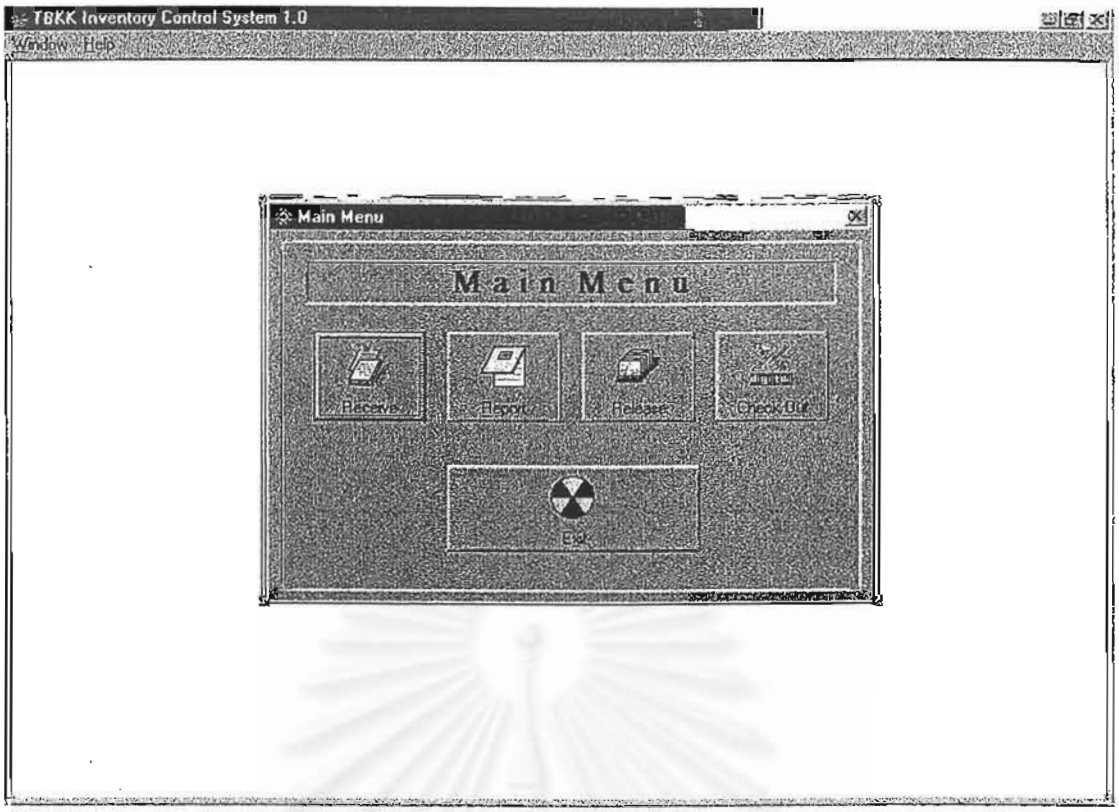


Figure C1: Operational Interface.

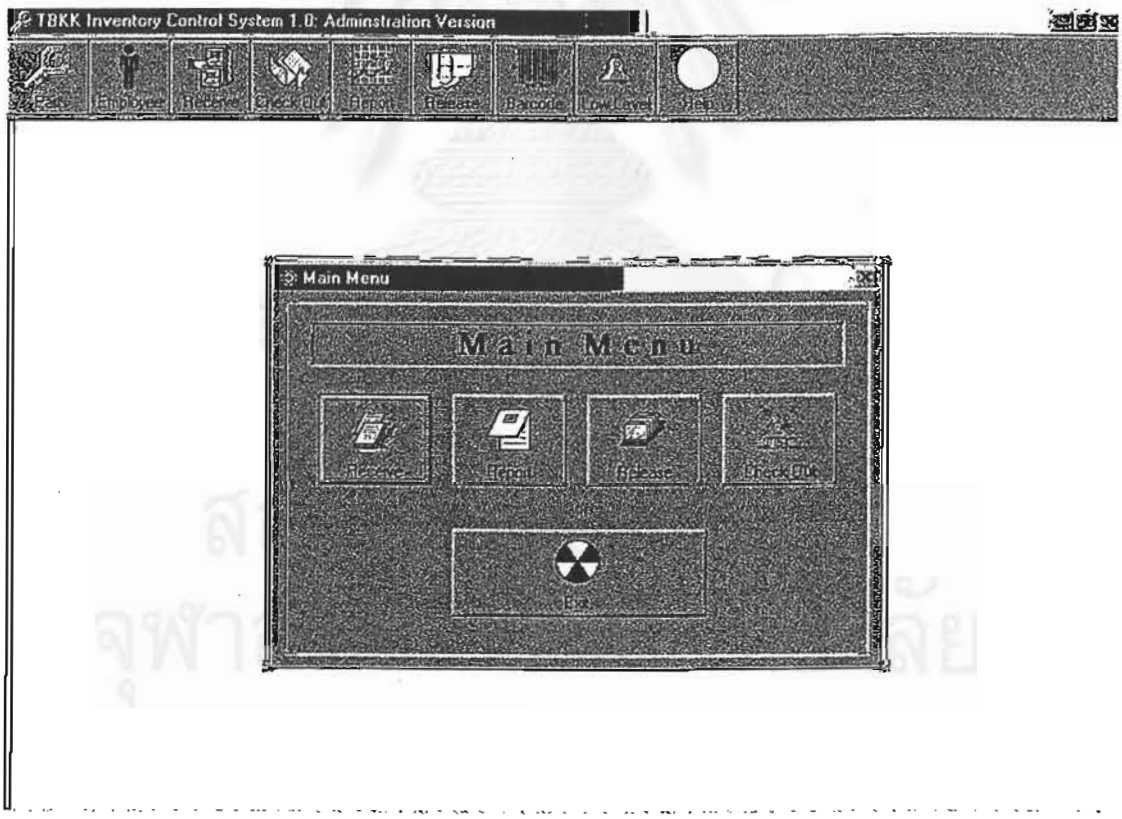


Figure C2: Administration interface.

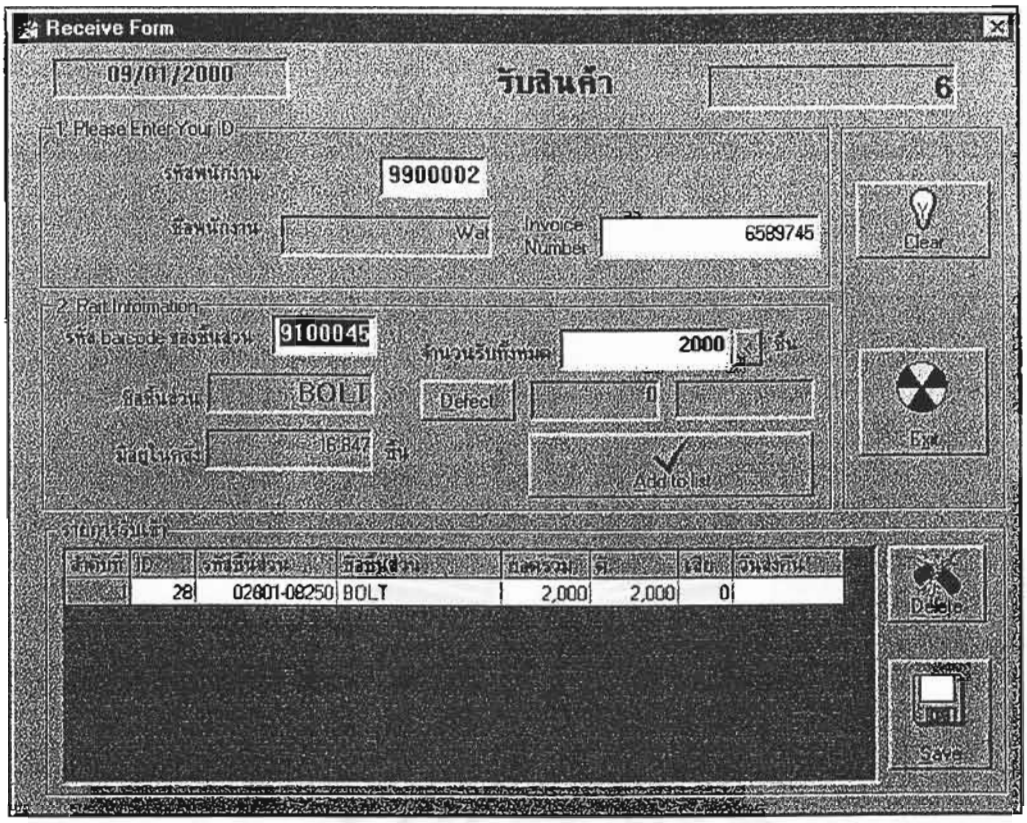


Figure C 3: Receiving form.

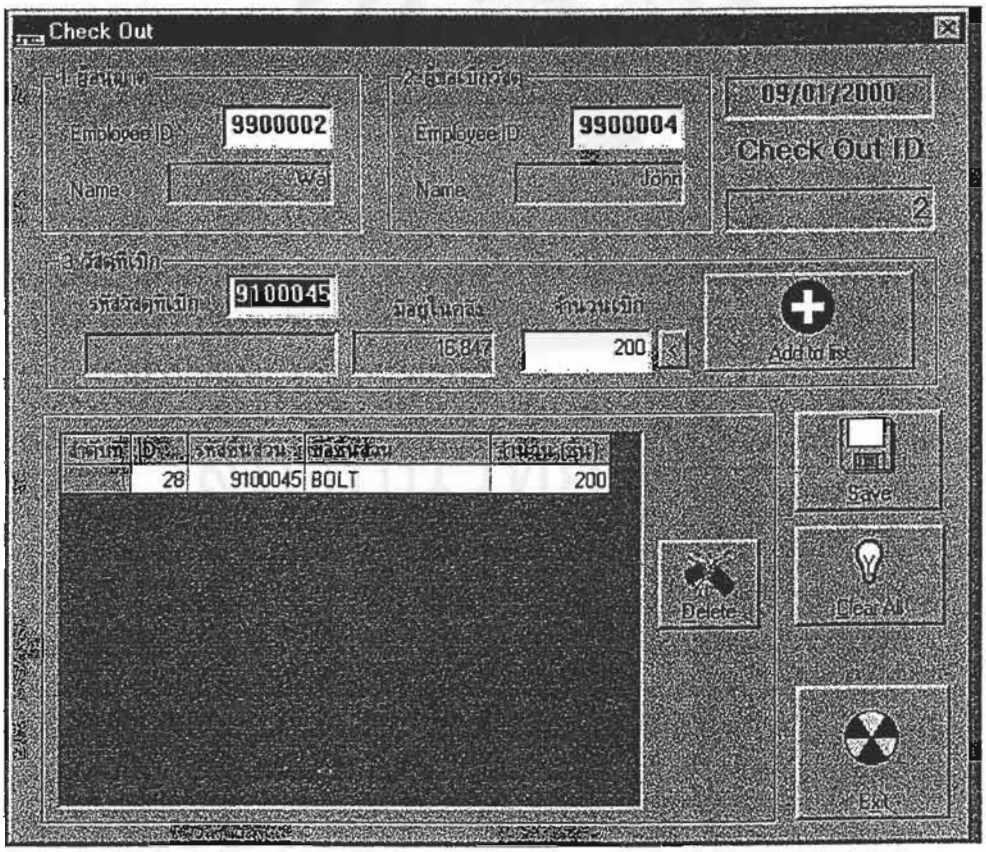


Figure C4: Picking form.

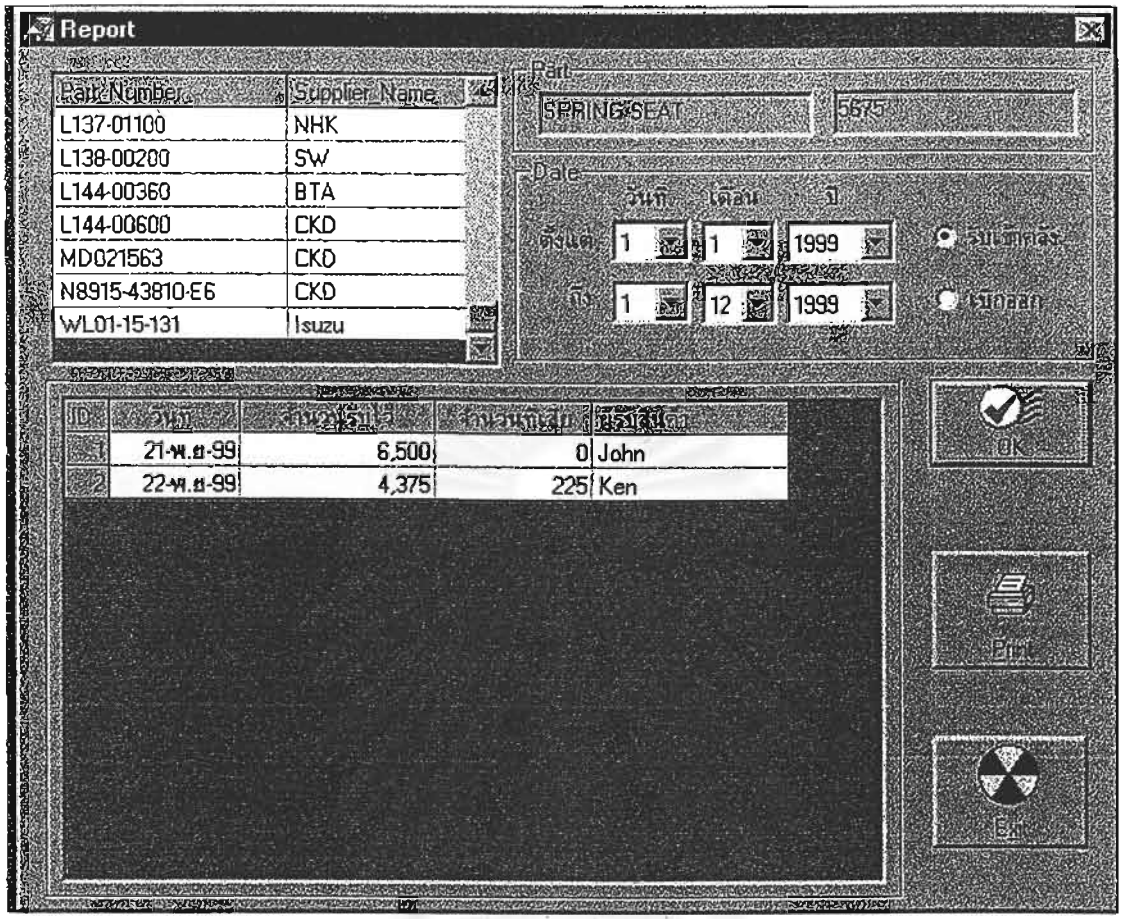


Figure C 5: Report.

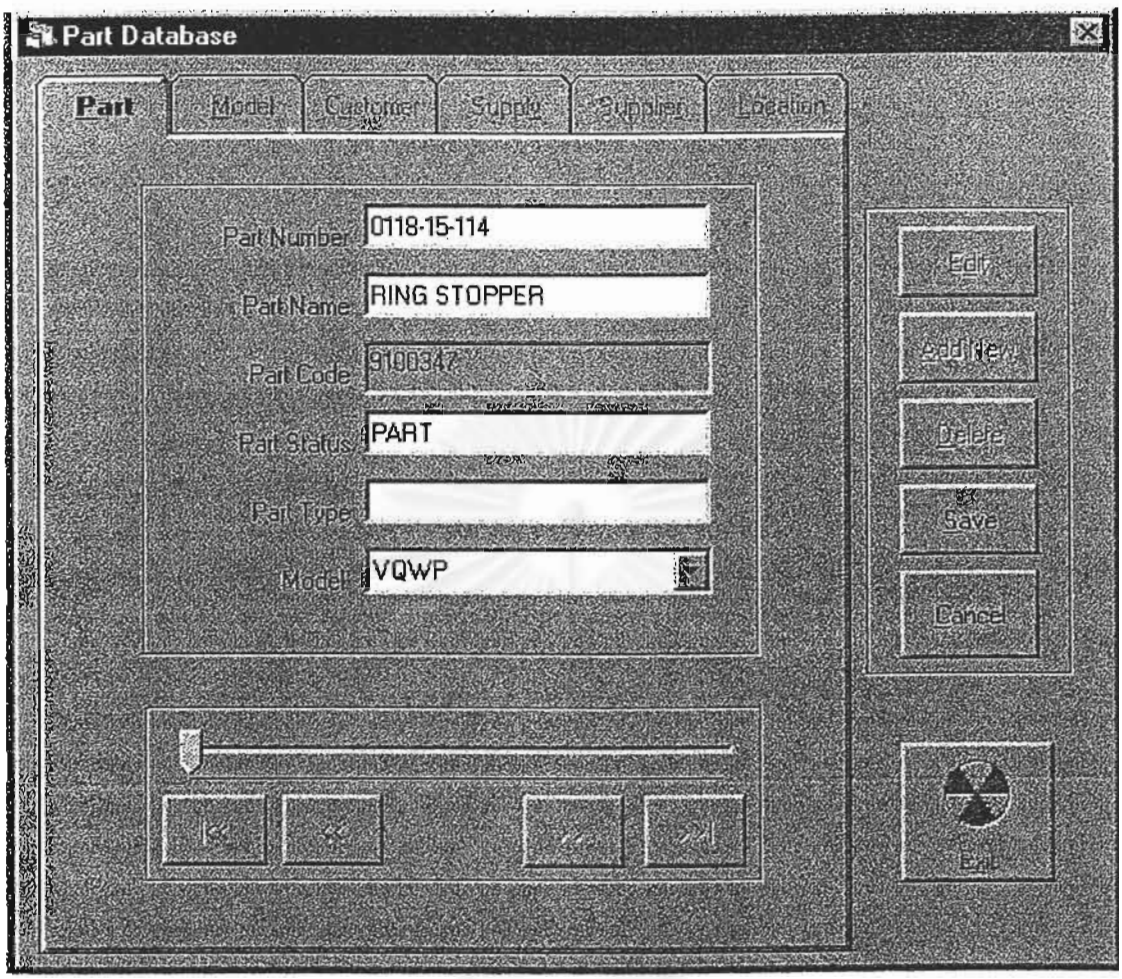


Figure C6: Information of parts, models, customers, Suppliers.

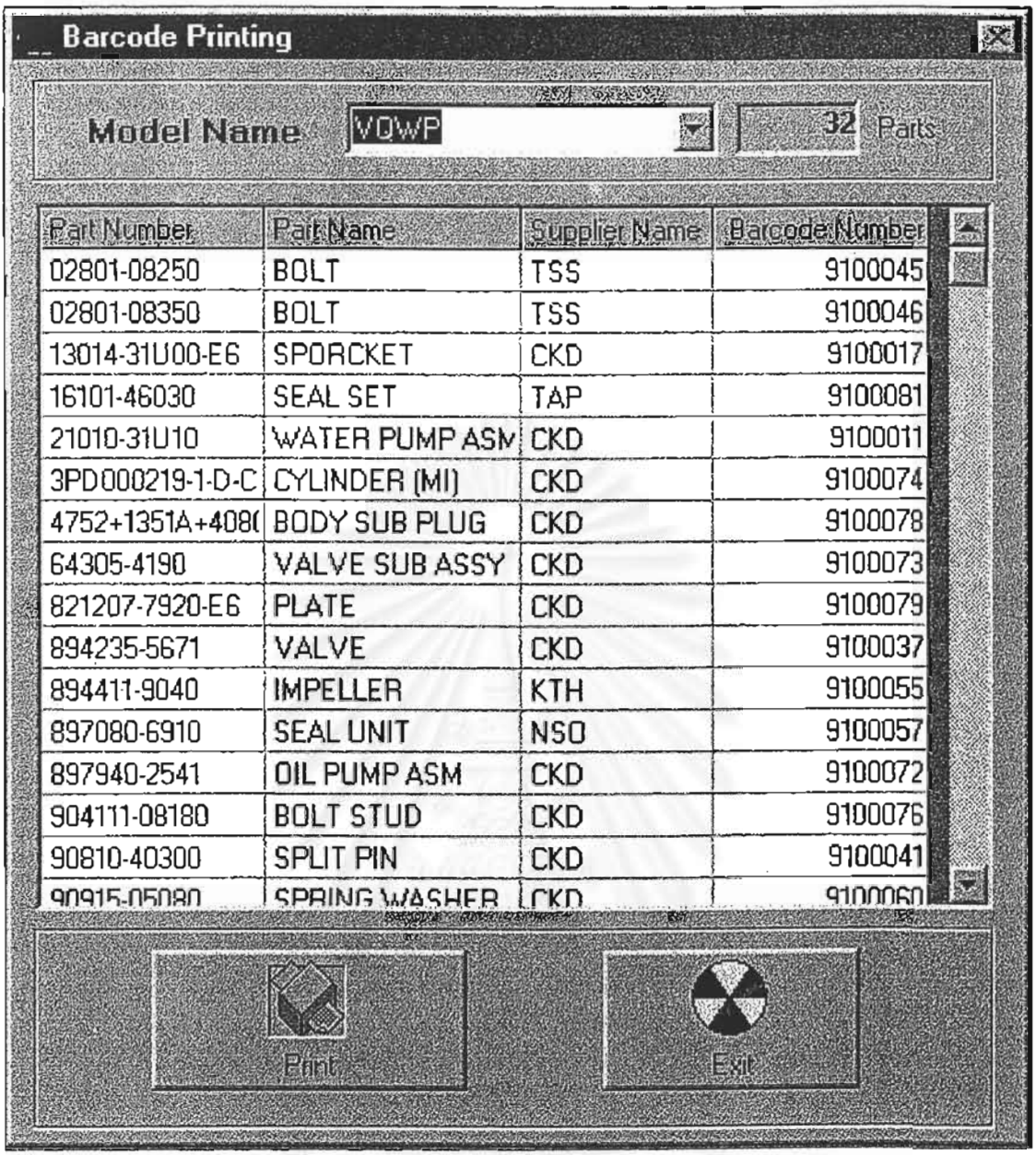


Figure C7: Barcode printing form.

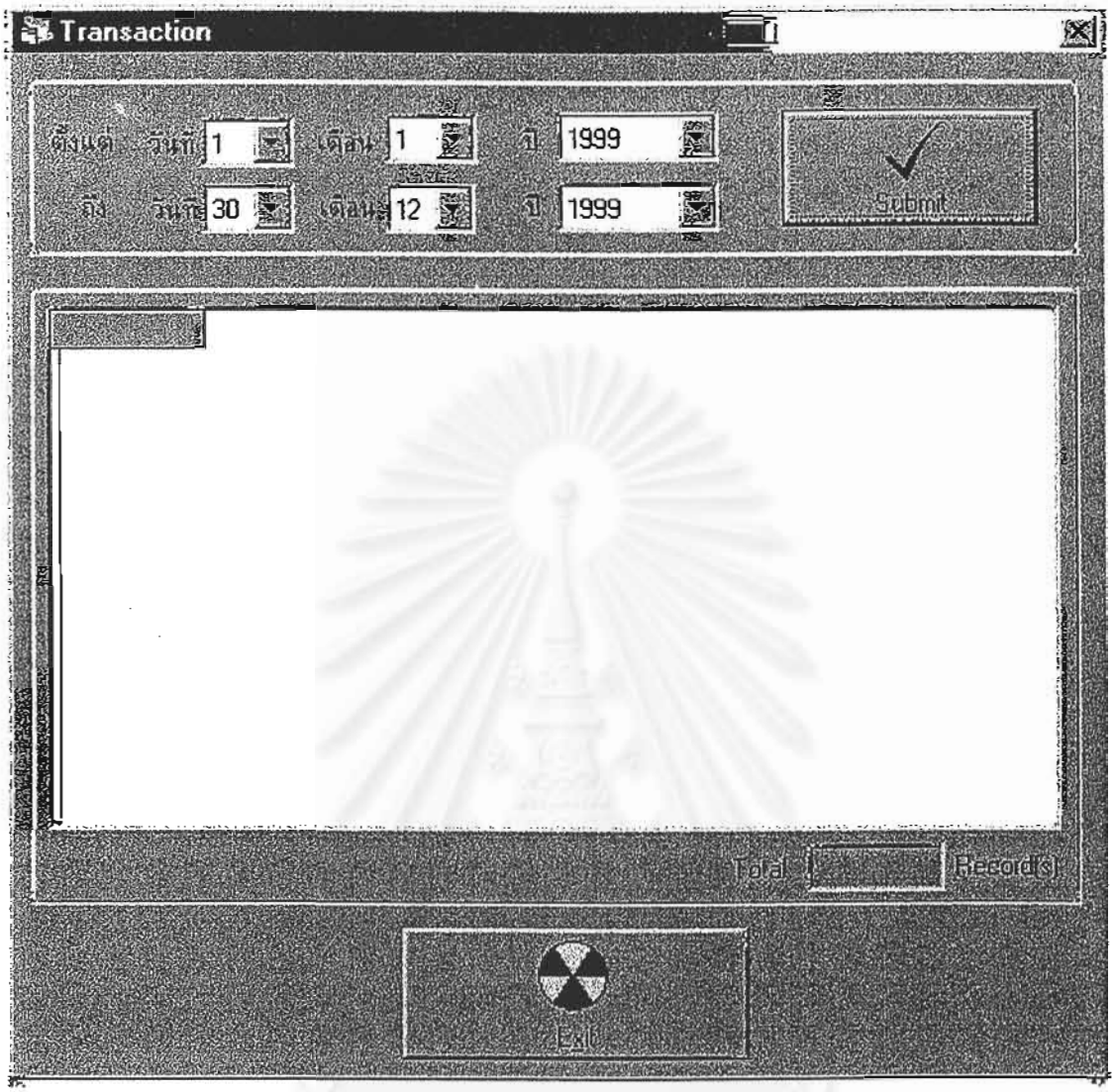


Figure C 8: Report of all transactions in a specified range of days.

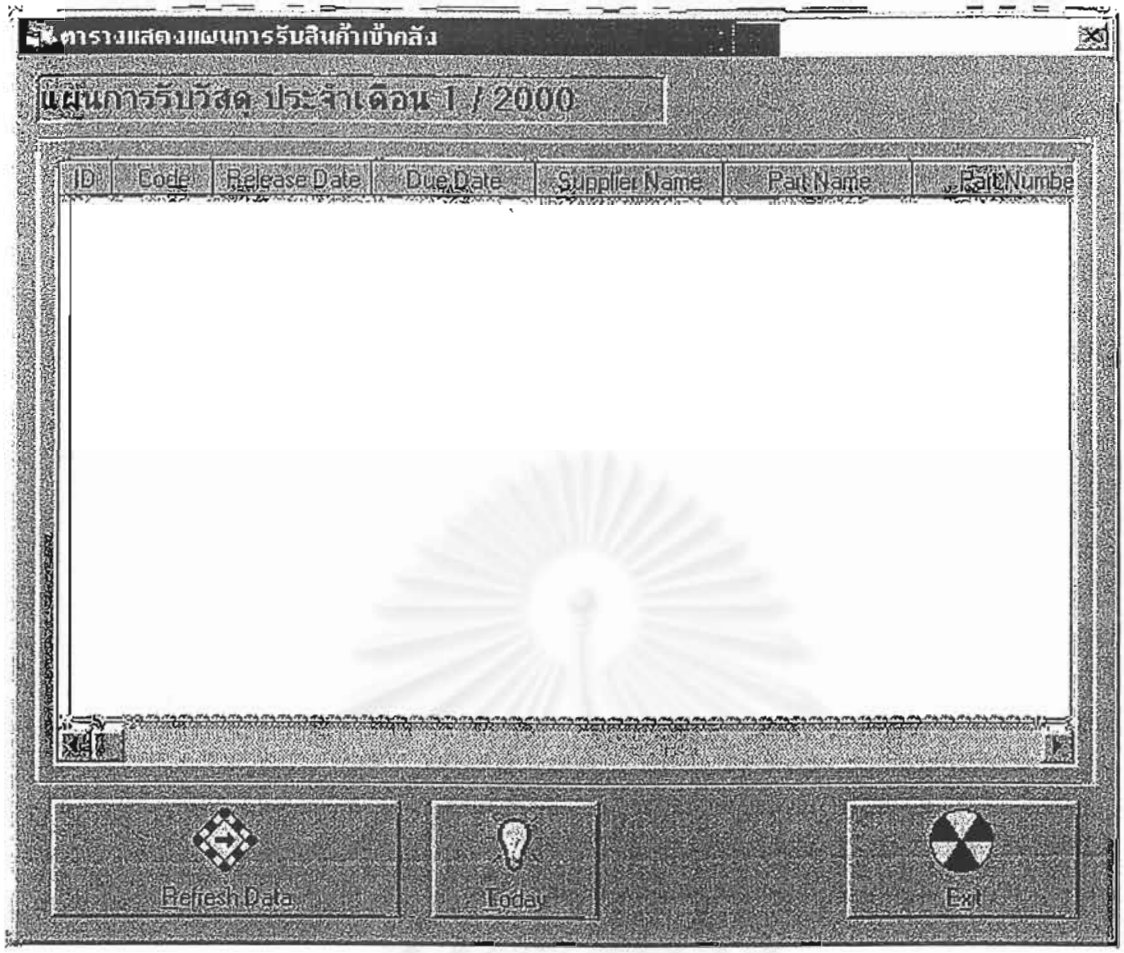
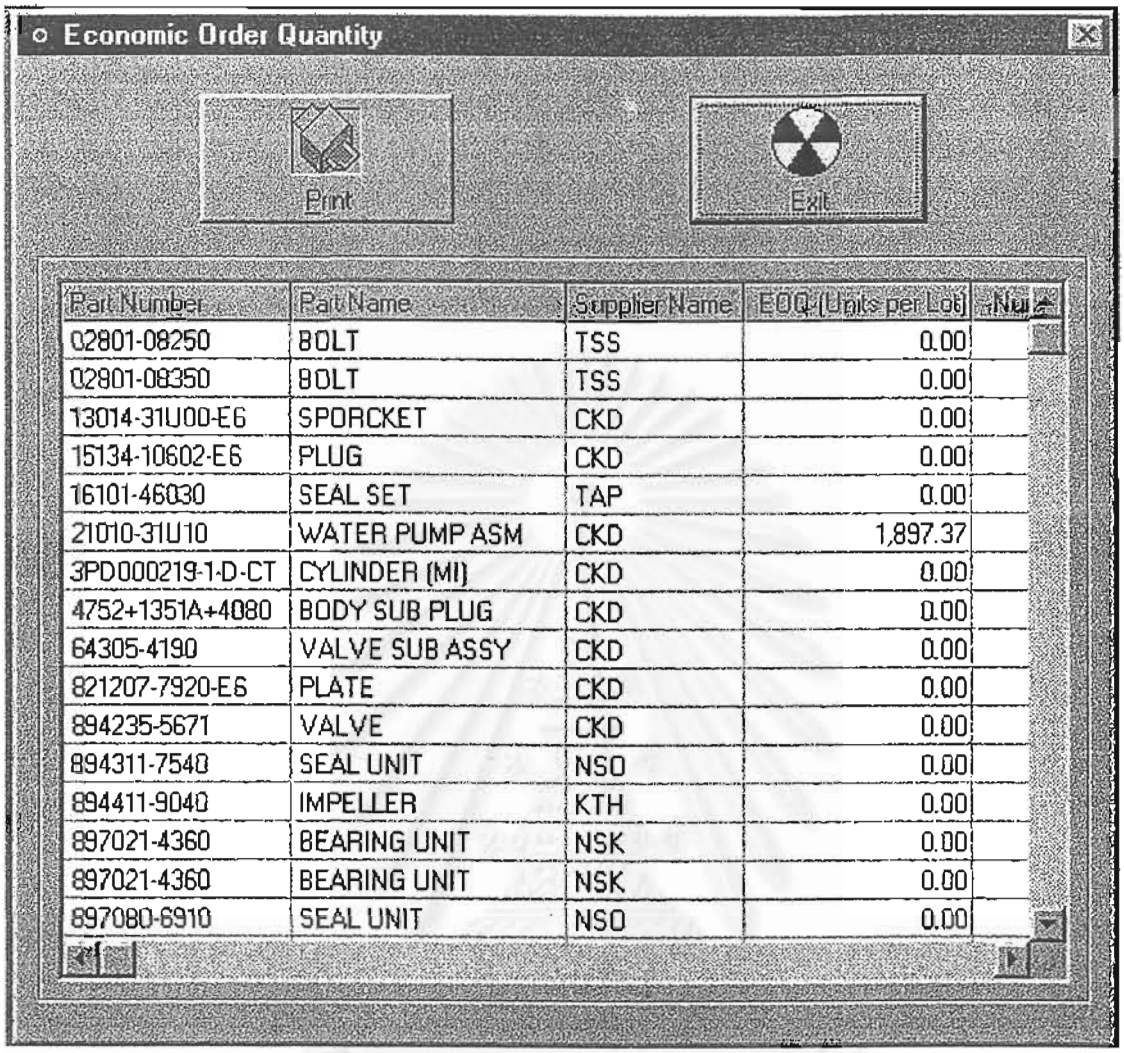
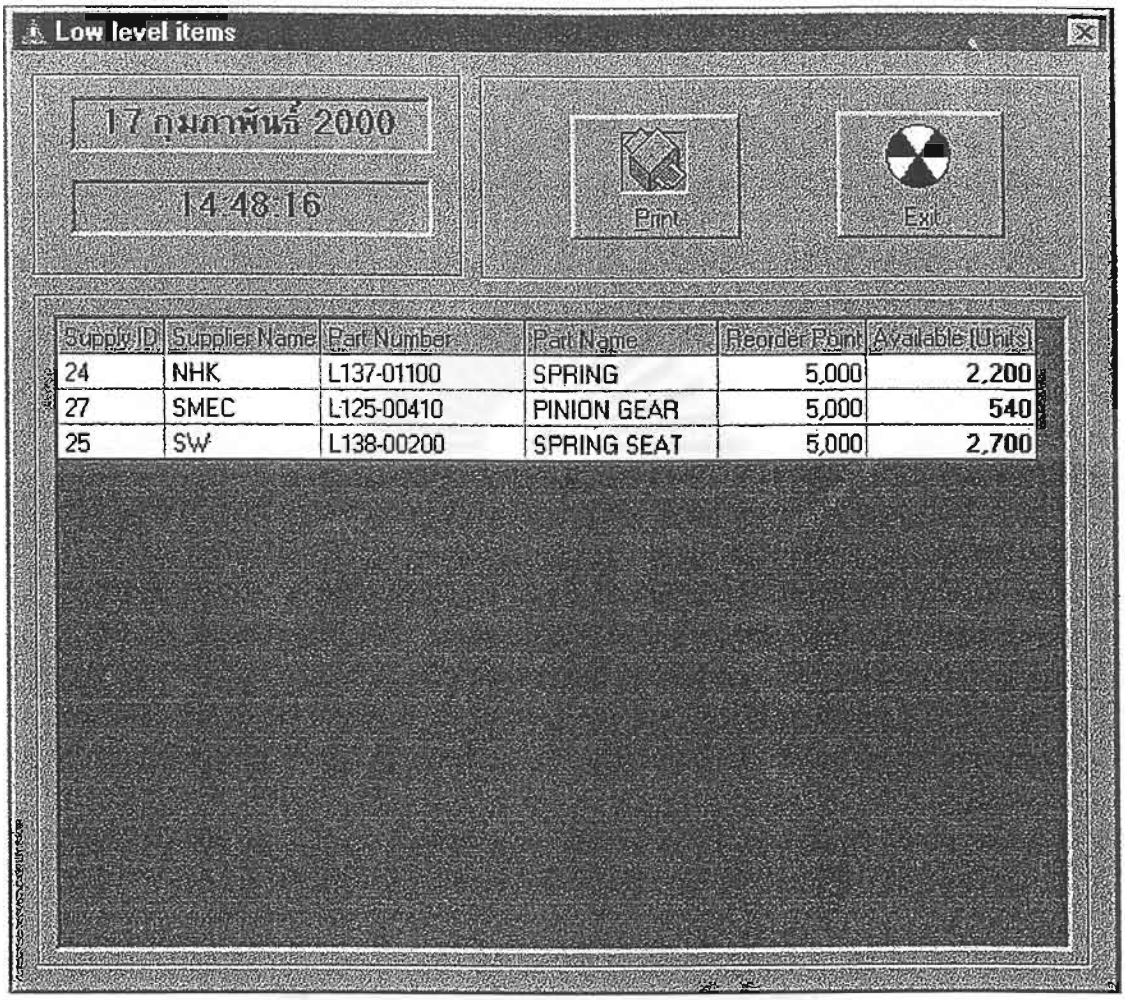


Figure C9: Scheduled receipts.



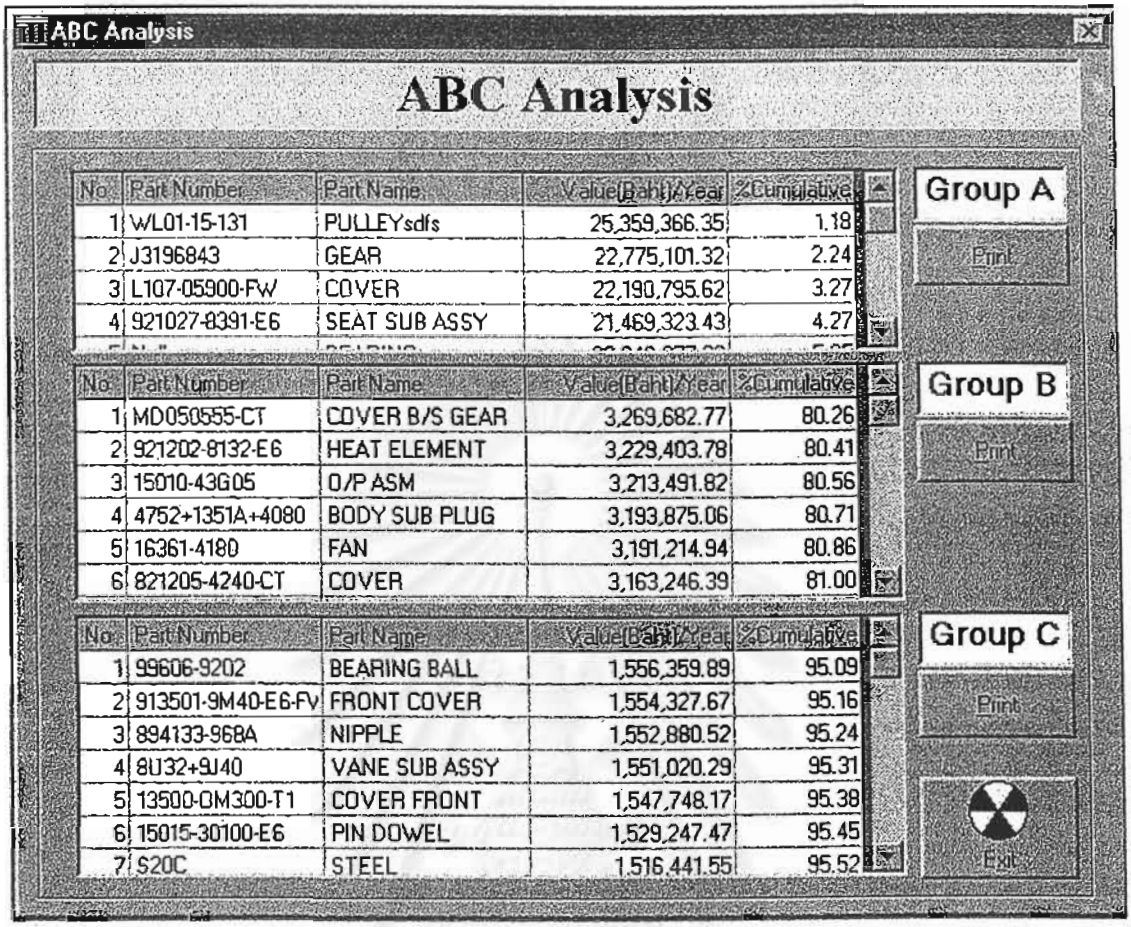
Part Number	Part Name	Supplier Name	EOQ (Units per Lot)	Nu
02801-08250	BOLT	TSS	0.00	
02801-08350	BOLT	TSS	0.00	
13014-31U00-E6	SPORCKET	CKD	0.00	
15134-10602-E6	PLUG	CKD	0.00	
16101-46030	SEAL SET	TAP	0.00	
21010-31U10	WATER PUMP ASM	CKD	1,897.37	
3PD000219-1-D-CT	CYLINDER (MI)	CKD	0.00	
4752+1351A+4080	BODY SUB PLUG	CKD	0.00	
64305-4190	VALVE SUB ASSY	CKD	0.00	
821207-7920-E6	PLATE	CKD	0.00	
894235-5671	VALVE	CKD	0.00	
894311-7540	SEAL UNIT	NSO	0.00	
894411-9040	IMPELLER	KTH	0.00	
897021-4360	BEARING UNIT	NSK	0.00	
897021-4360	BEARING UNIT	NSK	0.00	
897080-6910	SEAL UNIT	NSO	0.00	

Figure C10: Report of EOQ.



Supply ID	Supplier Name	Part Number	Part Name	Reorder Point	Available [Units]
24	NHK	L137-01100	SPRING	5,000	2,200
27	SMEC	L125-00410	PINION GEAR	5,000	540
25	SW	L138-00200	SPRING SEAT	5,000	2,700

Figure C 11: Low-level items report.



No.	Part Number	Part Name	Value(Baht)/Year	%Cumulative
1	WL01-15-131	PULLEYsdfs	25,359,366.35	1.18
2	J3196843	GEAR	22,775,101.32	2.24
3	L107-05900-FW	COVER	22,190,795.62	3.27
4	921027-8391-E6	SEAT SUB ASSY	21,469,323.43	4.27

No.	Part Number	Part Name	Value(Baht)/Year	%Cumulative
1	MD050555-CT	COVER B/S GEAR	3,269,682.77	80.26
2	921202-8132-E6	HEAT ELEMENT	3,229,403.78	80.41
3	15010-43G05	O/P ASM	3,213,491.82	80.56
4	4752+1351A+4080	BODY SUB PLUG	3,193,875.06	80.71
5	16361-4180	FAN	3,191,214.94	80.86
6	821205-4240-CT	COVER	3,163,246.39	81.00

No.	Part Number	Part Name	Value(Baht)/Year	%Cumulative
1	99606-9202	BEARING BALL	1,556,359.89	95.09
2	913501-9M40-E6-FV	FRONT COVER	1,554,327.67	95.16
3	894133-968A	NIPPLE	1,552,880.52	95.24
4	8U32+9J40	VANE SUB ASSY	1,551,020.29	95.31
5	13500-0M300-T1	COVER FRONT	1,547,748.17	95.38
6	15015-30100-E6	PIN DOWEL	1,529,247.47	95.45
7	S20C	STEEL	1,516,441.55	95.52

Figure C 12: ABC Analysis report.

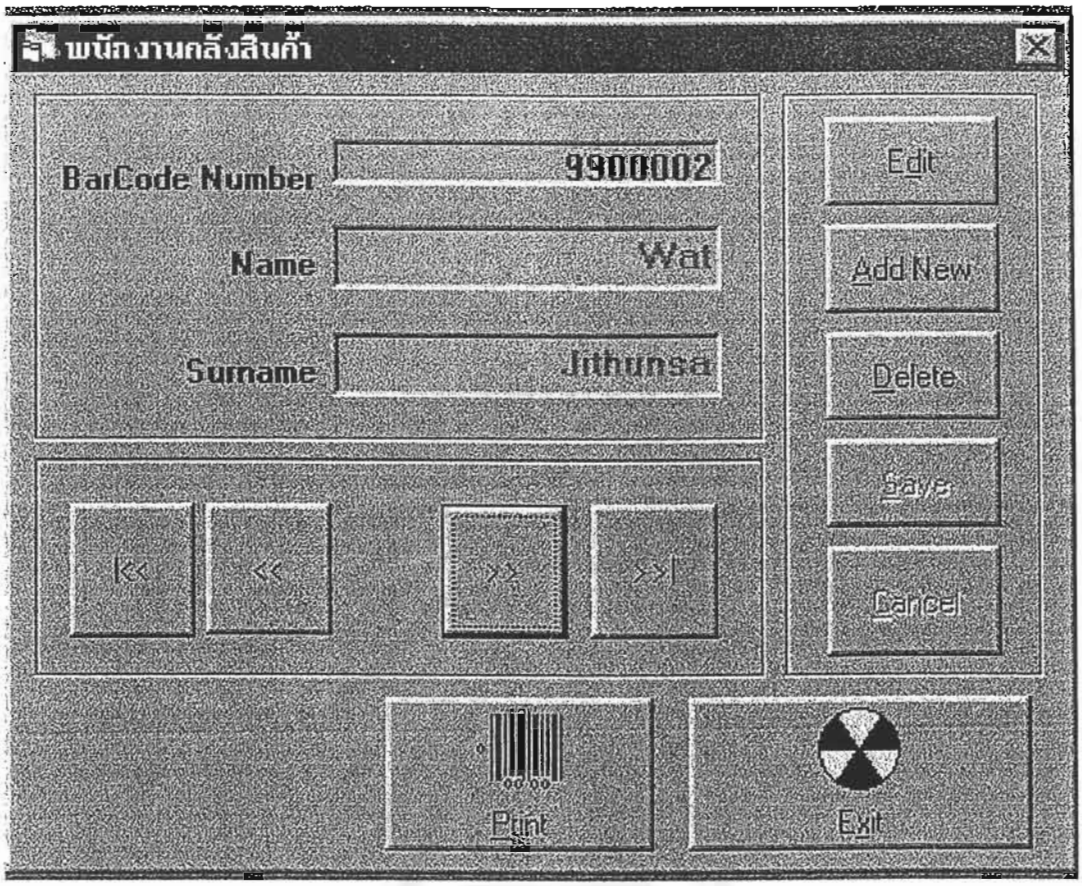


Figure C 13: Information of employees.

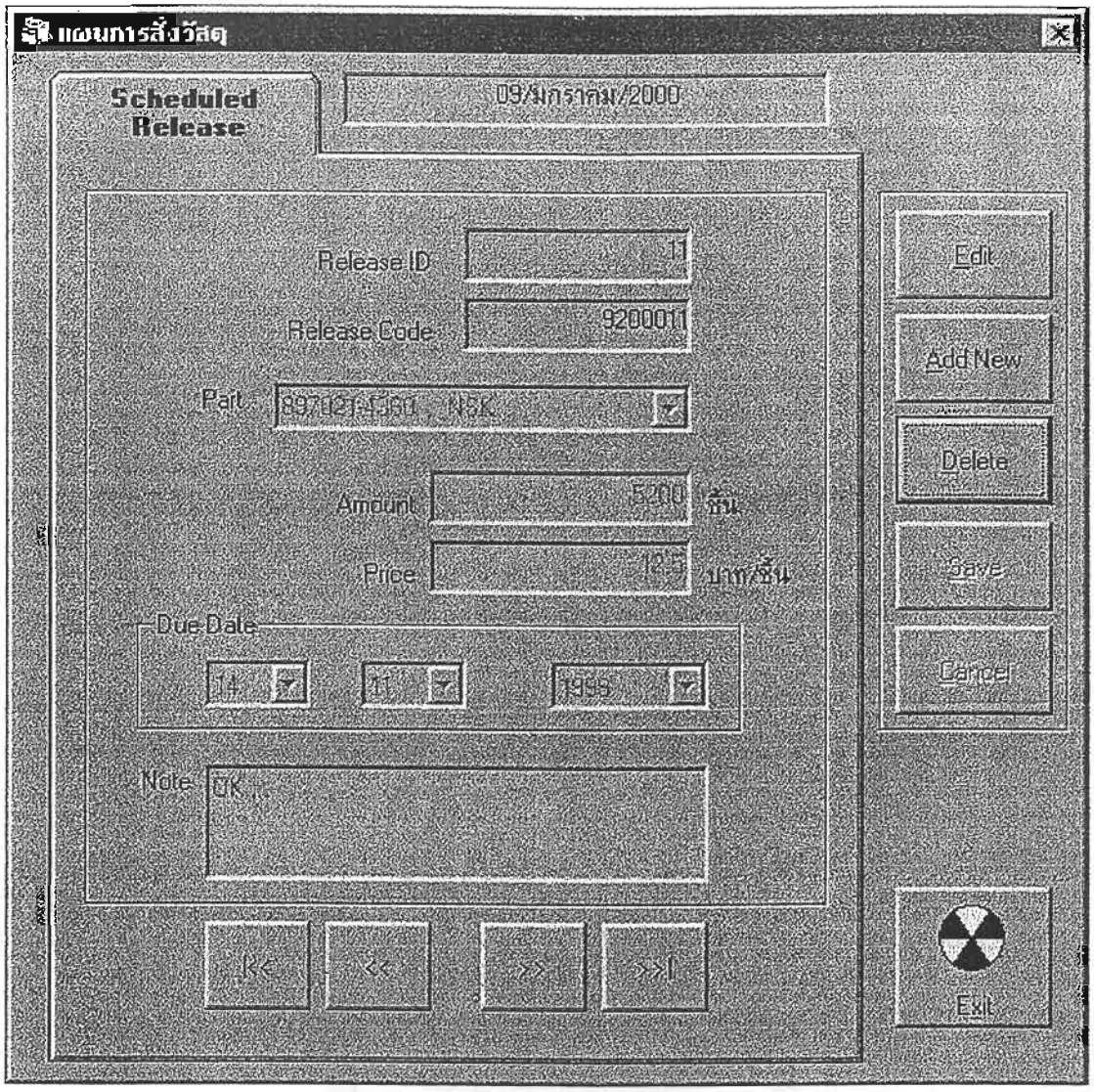


Figure C 14: Scheduled receipt planning form.

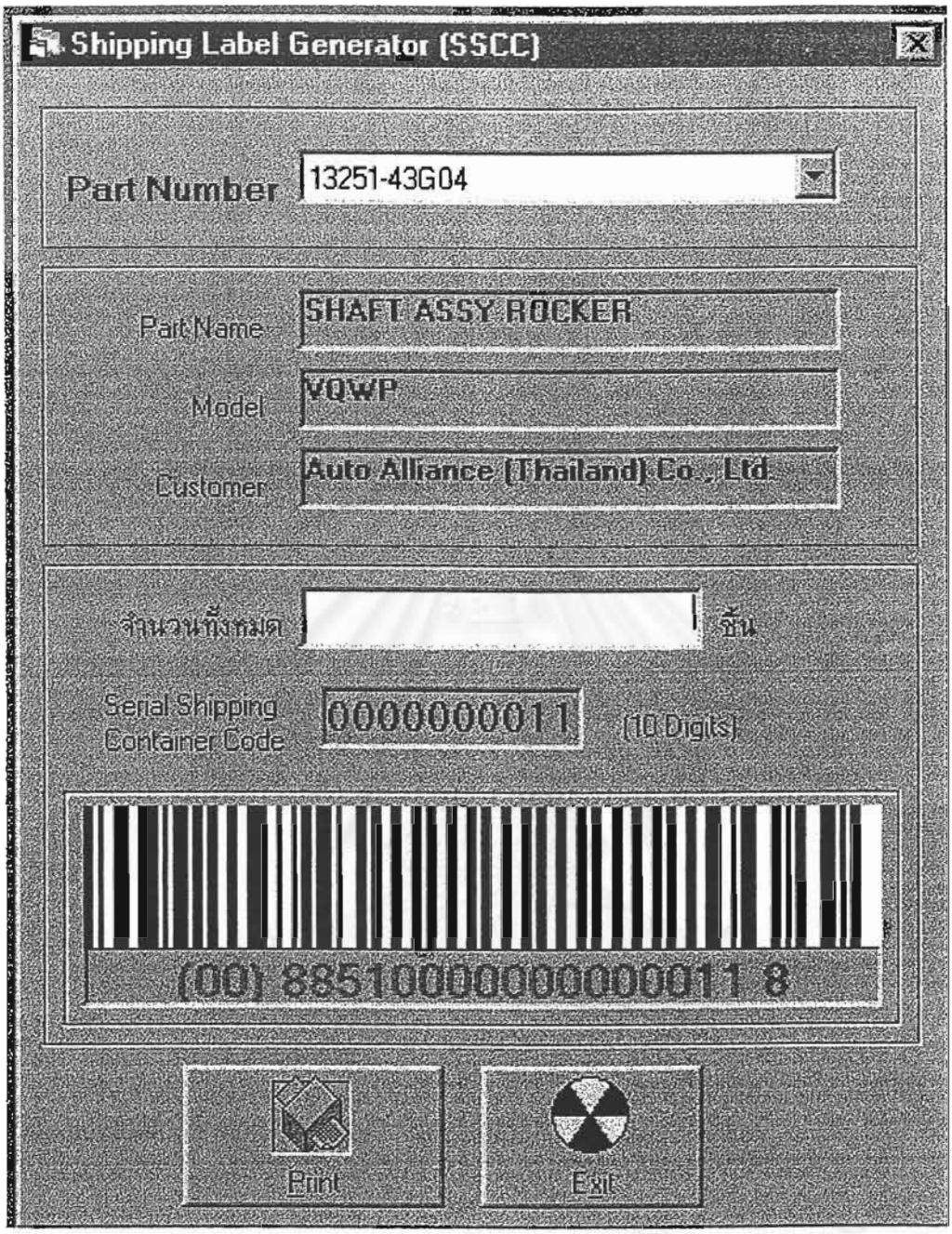


Figure C15: Shipping form.

Appendix D

Installation Manual

Installation Manual (for Windows)

To install TBKK's Inventory Management Software (TIMs), you will require at least the following equipments:

- A personal computer with upto 200 MHz Pentium Processor
- 16 MB RAM (Memory)
- A CD-ROM Drive
- Hard disk drive (with 20 MB free space)
- Microsoft Windows 95/98 with 32-bit ODBC (Open Database Connectivity)
- SVGA resolution monitor (800x600 or above)
- Keyboard and mouse

It is assumed that you already now how to use either Microsoft Windows 95 or 98. If you are unfamiliar with using Windows, please refer to the documentation that came with your computer.

Steps to install the TIMs (Administration Part)

1. Insert TIMs CD into a CD-ROM Drive.
2. Chose run command from Start menu.
3. Click Browse button.
4. Select the CD-ROM Drive that has the TIMs CD.
5. Chose TIM_Ad directory.
6. Select the Setup.exe file.
7. Click Open.
8. Click OK.
9. The TIMs Administration Version installation screen will be displayed, click Next.
10. Select your Destination Directory to install the TIMs' program files, then click Next.

11. Select your Program Folder, then click Next.
12. Confirm your installation details, then click Next.
13. The TIMs Administration Version are now being installed in your computer.
14. Restart your computer to enable the new settings.

Steps to install the TIMs (Operating Part)

1. Insert TIMs CD into a CD-ROM Drive.
2. Chose run command from Start menu.
3. Click Browse button.
4. Select the CD-ROM Drive that has the TIMs CD.
5. Chose TIM directory.
6. Follow step 6-14 of installation above.

Steps to build an ODBC Definition

In order to make a connection to the inventory database on the client-server environment, the Open Database Connectivity (ODBC) is a driver that has to be configured before using the TIMs.

1. Choose Start | Settings | Control Panel from the main Windows 95/98 menu. The Control Panel appears, as shown in figure M.1. Double-click the 32-bit ODBC icon to open the ODBC Administrator.

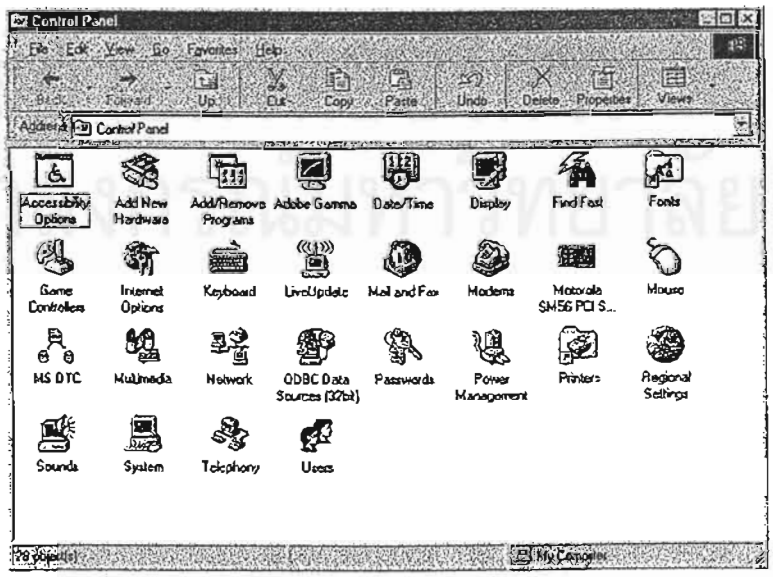


Figure M.1: Accessing the 32-bit ODBC Administrator from the Control Panel.

2. After the ODBC Data Source Administrator dialog box appears, select the System DSN tab and click Add. The Create New Data Source dialog box appears, as shown in figure M.2.

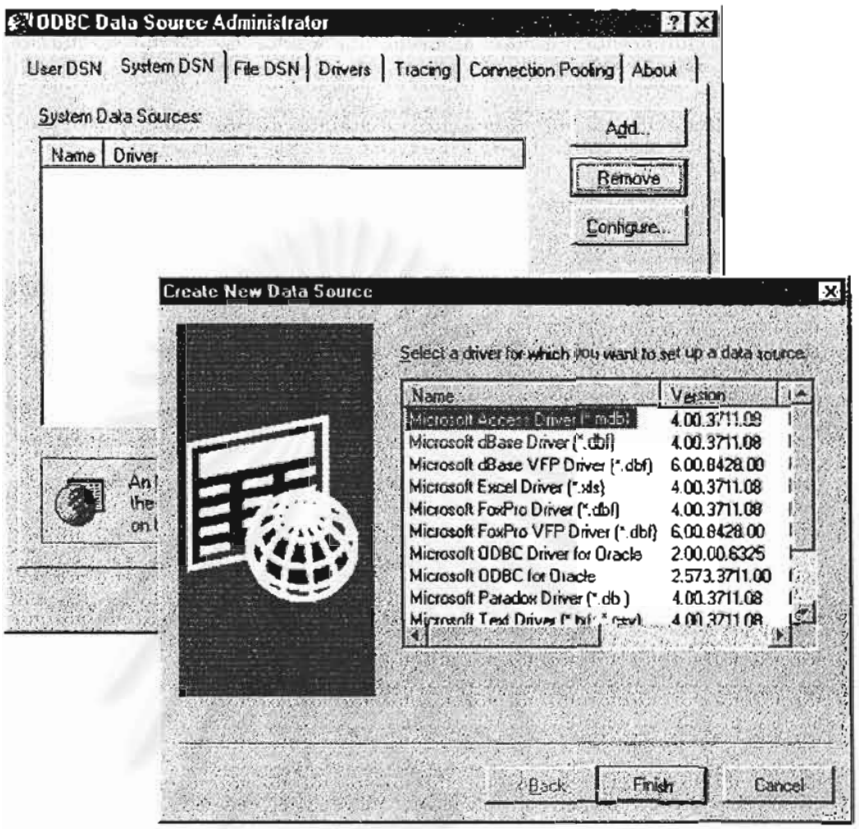


Figure M.2: Adding a new System DSN.

3. Double-click the Microsoft Access 7.0 Database driver. The ODBC Microsoft Access 97 Setup dialog box appears. In the Data Source Name field, enter TBKK. In the Description field, enter Remote Data Connection to Inventory.mdb. In the Database section, specify the your selected path, then select the file Inventory.mdb. In the clicking select and navigating to it in the Select Database dialog box. Figure M.3 shows what the dialog box should look like at this point.

4. Click OK to save the definition and then exit the ODBC Administrator applet.

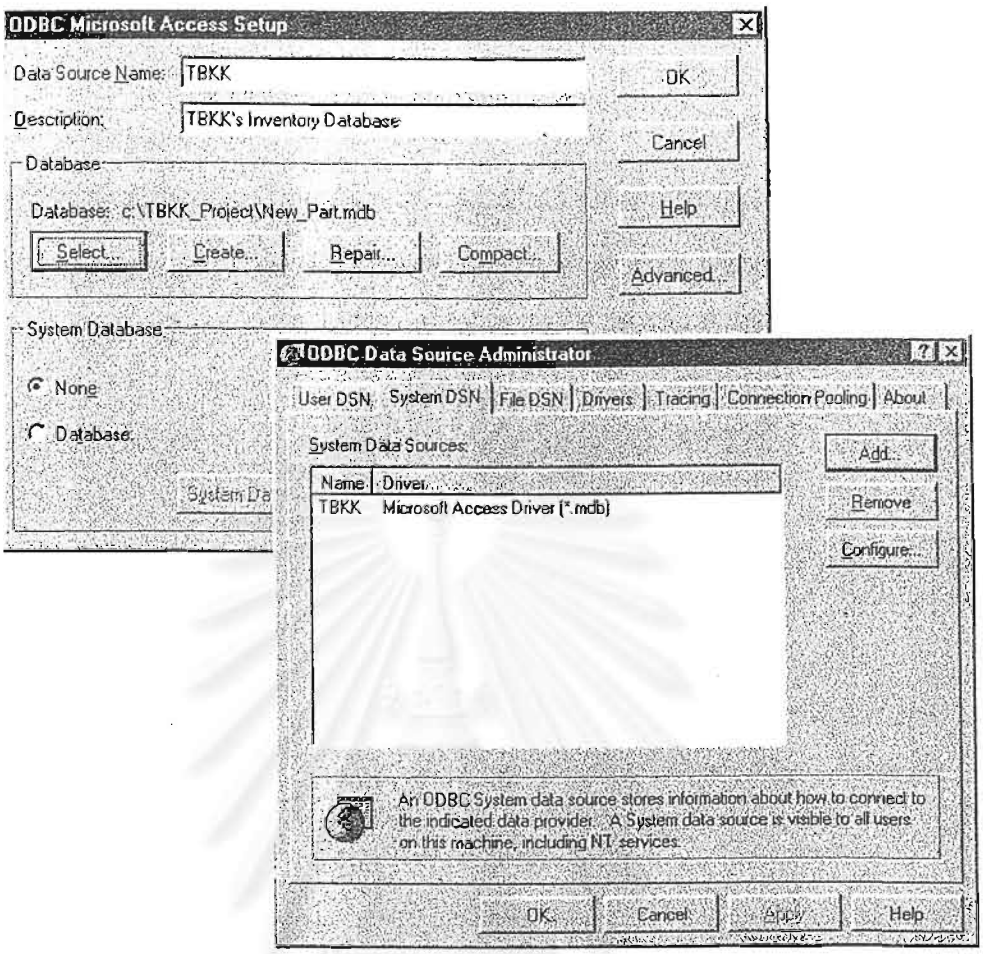


Figure M.3: Filling in the Microsoft Access DSN properties.

Biography

Name: Mr. Siriwat Jithunsa

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Education: 1994 - 1997 Bachelor of Engineering, Industrial Engineering.