Smart Card Packaging Process Control System

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Smart Card Packaging Process Control System

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Abstract

The project focuses on the packaging process of the smart card manufacturing industry. The idea of the project concerns how to increase production packaging efficiency by introducing a control system. After taking an in-depth look at the current production environment, the following system goals were defined: packaging time reduction, cost reduction, decrease in human errors, and reducing the number of customer complaints. To achieve these goals, the thesis project was divided into the following tasks: discovering a feasible solution, actual system development, testing, and evaluation. The proposed system is based on hardware (i.e. barcode scanner, and barcode printer) integrated with customized control software. The barcode scanner acts as a bridge between the system and the production process by scanning a barcode printed on each product. The system prints the required information label for the product's package according to the scanned product. This label is pasted on the product's box and is used as a tracking tool during further production steps. The system is very flexible and suits any packaging model. Other functional properties maintained in the system include data security, product traceability, and real time production monitoring. Testing of the system was done in an actual production environment at an Oberthur Technologies manufacturing site. Two production lines were selected to test the system's functionality, specifically the SIM card production packaging line and the Scratch card/ Bank Card production packaging line. The results obtained during the evaluation phase of the proposed system show that the proposed solution decreased the packaging processing time by (27.3%) over the previous values. Moreover, the resulting human error rate is close to (zero%).

Sammanfattning

Projektet fokuserar på förpackningen processen smartkortet tillverkningsindustrin. Tanken med projektet handlar om hur att öka effektiviteten produktionen förpackningar genom att införa ett styrsystem. Efter att ha tagit en fördjupad titt på den nuvarande produktionsmiljö, var följande systemkrav mål definieras: nedsättning förpackning tid, minskade kostnader, minskad mänskliga fel och minska antalet kundklagomål. För att uppnå dessa mål var examensarbetet indelad i följande uppgifter: att upptäcka en genomförbar lösning, faktisk systemutveckling, testning och utvärdering. Det föreslagna systemet bygger på hårdvara (dvs streckkodsläsare och streckkod skrivare) integreras med skräddarsydd styrprogram. Den streckkodsläsare fungerar som en bro mellan systemet och produktionsprocessen genom att läsa en streckkod tryckt på varje produkt. Systemet skriver den erforderliga informationen etiketten för produktens förpackning enligt den scannade produkten. Denna etikett klistras in på produktens ask och används som ett verktyg för spårning under ytterligare produktionssteg. Systemet är mycket flexibelt och passar varje förpackning modell. Andra funktionella egenskaper bibehålls i systemet inkluderar datasäkerhet, spårbarhet och i realtid övervakning av produktionen. Testning av systemet gjordes i en verklig produktionsmiljö i ett Oberthur Technologies tillverkningsanläggning. Två produktionslinjer valdes för att testa systemets funktionalitet, särskilt i SIM-kortet produktionen förpackning linje och skrapkort / Bank kortproduktion förpackningslinje. De resultat som erhållits under utvärderingsfasen av det föreslagna systemet visar att den föreslagna lösningen minskade tiden förpackningen behandling av (27,3 %) jämfört med föregående värden. Dessutom är den resulterande mänskliga fel som ligger nära (noll %).

Acknowledgements

First of all I am very thankful to Al-mighty Allah who although not physically but spiritually has been the greatest source of guidance and who gave me the sense of responsibility and utmost driving force to acquire and complete this feat.

I owe my deepest gratitude to my industrial supervisor Muzaffar Khokhar at Oberthur Technologies, who accept this project as a master thesis and provide me a support at each phase of the project until the implementation, especially to arranged a free time slot for the implementation and testing of this project in an actual packaging production environment.

I am deeply indebted to my supervisor Prof. Gerald Q from the KTH Royal Institute of Technology School of Information and Communication Technology, who guide me a lot in writing the thesis project report. His valuable reviews and suggestions helps to provide me a great support to improve the thesis work.

Finally, I would like to dedicate this thesis to my parents.

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List of Acronyms and Abbreviations

1D	One-Dimensional
2D	Two-Dimensional
3D	Three-Dimensional
3-DES	Triple Data Encryption Standard
ABS	Acrylonitrile Butadiene Styrene
APO	Advanced Planner and Optimizer
ASCII	American Standard Code for Information Interchange
ATM	Automatic Teller Machine
ATR	Accept to Request
CCD	Charge Couple Device
CD	Compact Disk
CLK	Clock
CPU	Central Processing Unit
DES	Data Encryption Standard
DFPkg	Design For Manual Packaging
DSA	Digital Signature Algorithm
ECB	Electronic Codebook Mode
EEPROM	Electrically Erasable Programmable Read-Only Memory
ERP	Enterprise Resource Planning
FEAL	Fast Encryption algorithm
GND	Ground
GSM	Global System for Mobile Communications
I/O	Input/Output
IC	Integrated Circuit
ICA	Inköpscentralernas aktiebolag
ID	Identification
IDEA	International Data Encryption Algorithm
ISO	International Organization for Standardization
IEC	International Electrotechnical Commission
IP	Internet Protocol address
IT	Information Technology
LED	Light Emitting Diode
min	Minute
OCR	Optical Character Recognition
PDF-417	Portable Data File
PETG	Polyethylene terephthalate
UML	unified modeling language

PIN	Personal Information
PVC	Poly Vinyl Chloride
QRCode	Quick Response Code
RAM	Random Access Memory
RFID	Radio Frequency for Identification
ROM	Read Only Memory
RSA	Ron Rivest, Adi Shamir and Leonard Adleman
SAP	Systems, Applications, and Products in Data Processing
SIM	Subscriber Identity Module
SOP	Standard Operating Procedure
SP	Standard Packaging
UICC	Universal Integrated Circuit Card
UMTS	Universal Mobile Telecommunications System
UPC	Universal Product Code
USB	Universal Serial Bus
VAP	Value Added Packaging
VPN	Virtual Private Network
XOR	Exclusive OR

Chapter 1

Introduction

This chapter gives the motivation for carrying out this thesis project. It also explains the problem area, and summarizes the contributions of this thesis. Furthermore, it explains the organization of the thesis and also gives an outline of the structure of the rest of the thesis.

1.1 Background

The era we live in is known to be a golden age of science and technology. The invention of the internet reduced the communication gap leading to a global village. There is a great influence of Information Technology (IT) in our life, devices are shrinking and processes are increasingly automated, both in our daily life and in our scientific research and industrial processes.

The word "automation" was first introduced commercially by Fairchild Semiconductor and Texas Instruments, in 1961, in the form of a small electronic circuit, i.e. a microprocessor [28]. After this invention, a lot of work has been done and even now researchers continue to find more innovations in the design, implementation, and exploitation of microprocessors. Due to this effort, production of goods has reached new productivity levels with microprocessors being embedded into many devices, and in our life there is hardly anything which is not touched or managed, by automation [28].

Production automation is the automation of individual steps or the whole chain of steps necessary to produce some product [28]. When we talk about product automation, we refer to the automation of devices that fulfill various tasks in industry, not necessarily limited to the tasks in the production process [28]. The word automation includes using hardware (such as microprocessors or microcontrollers), but automation may also involve using software. For example, SAP [33] - APO [34] is considered to be one of the leading systems for providing global automation in logistics. The planning tasks of procurement, production distribution, and sales can be organized under different planning scopes and hierarchies [3].

This thesis project has been carried out at Oberthur Technologies, one of the leading smart card manufacturing organizations. Oberthur Technologies is a world leader in the field of secure technologies with a turnover around 979 million Euros in 2010 [26].

The thesis project concerns utilizing production automation in the packaging industry, specifically focusing on packing smart cards in different hierarchical packagings. Both software and hardware are used to automate the manual packaging process.

1.2 Research Goal

The product manufacturing life cycle varies between products and their production environments. This project focuses on the smart card manufacturing industry, specifically the packaging process of finished smart cards. Figure 1.1 depicts an overview of the production process. The production or manufacturing cycle consists of different processes which include customer order processing, manufacturing and packaging of the chips into card bodies, quality assurance, and logistics (warehouse movement and dispatch to customer), as shown in figure 1.1.

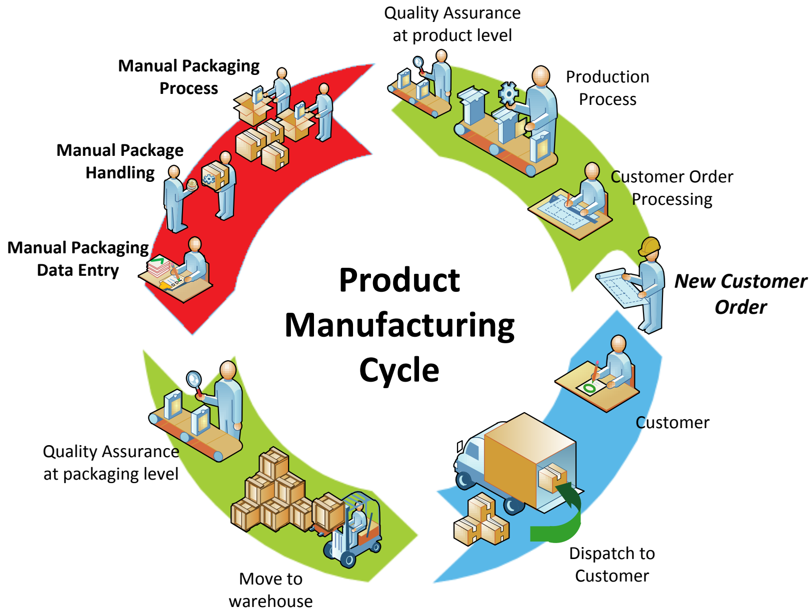

Figure 1.1: Product Manufacturing Cycle: The red area shows the manual packaging process.

The smart card manufacturing process is very complicated and involves many steps. Figure 1.2 shows the complete manufacturing process of the smart card from card body printing to the packaging. Although there are many processes involved in the smart card manufacturing process, this thesis project focuses on the manual packaging process (highlighted in figure 1.2). The aim of the thesis project is to automate the packaging process by introducing a controlled process which eliminates part of the manual packaging process. Different system parameters have to be taken into account, for example: data security, over all production cost reduction, reduced human intervention, and decrease in customer complaints regarding packaging.

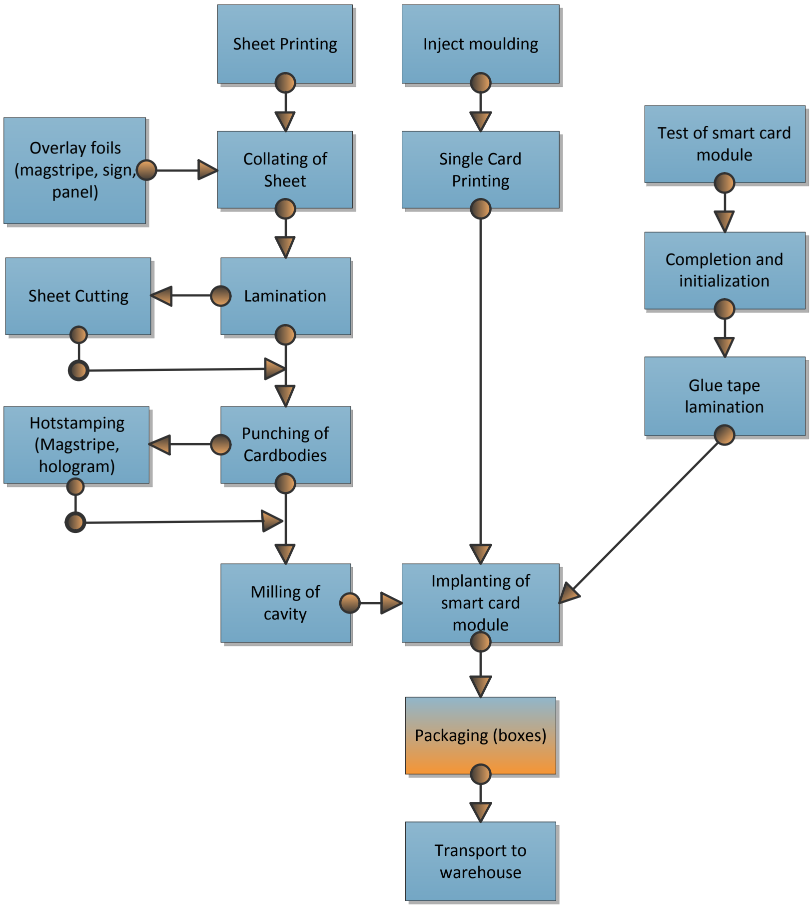

Figure 1.2: Card body Manufacturing Flow Chart [9]

1.3 Research Approach

The scientific research methodology considered in this thesis is quantitative in nature. This project will be carried out in three phases:

- Theoretical evaluation,
- Practical evaluation in an actual environment, and
- Comparative study.

1.3.1 Theoretical evaluation

In the theoretical evaluation phase, we will study different methods of automating packaging, and propose a solution, which can solve our problem; while considering all the parameters stated in the previous section.

1.3.2 Practical evaluation in an actual environment

In this phase, we can evaluate our solution by implementing the required hardware and software and test this implementation in an actual production environment to collect data about the performance of the system. This data will be evaluated both itself and in conjunction with the subsequent comparative study.

1.3.3 Comparative Study

Finally, we setup the system in two testing scenarios on the same packaging production line and compare their results to evaluate our concept.

1.4 Anticipated Obstacles

During the project development cycle, there were a few minor obstacles at each step from gathering project requirements to the project deployment phase, but these are worth highlighted here. The main anticipated obstacle was that due to the high volume of card production, it would not be easy to find a free slot to test a system in the actual production environment because of pressure from customers to dispatch products in a timely manner. My thesis supervisor was talked to the production manager and arranged a free time slot to overcome this obstacle.

1.5 Audience

This thesis project concerns automation in industrial processes. Therefore, the audience is all the packaging industry, either related to card processing or manufacturing based organizations. The thesis might also be interesting for another production related industry or business-process automation organizations.

1.6 Thesis Organization

The rest of the thesis is organized in the following chapters. Chapter 2 is based upon the literature study done for this thesis. The background chapter explains the relevant terminologies, specifically: the smart card manufacturing process, and different packaging techniques including bar-coding, scanning process, fulfillment process, etc. Chapter 3 and chapter 4 explain the detailed elements of the performance of the system design and how it will be implemented. Chapter 5 explains the results and our comparison of the system in different production scenarios. Finally, chapter 6 summarizes the overall contributions and the results; along with offering suggestions for future work or development that should follow this project.

Chapter 2

Background

This chapter gives a detailed and extensive background regarding smart card technology, identification systems, data security, and a discussion of related work. The first section gives an overview of smart cards with their architecture. This is followed by a description of the relevant International Organization for Standardization (ISO) standards used in the smart card manufacturing industry. A description of real world applications and the associated types of the smart card technology used by these applications is given. In the second section, smart card manufacturing process steps are explained in detail, including the terminology used in the manufacturing process. This section describes the packaging process in detail because the thesis project will focus upon this; therefore, an understanding of the details of the packaging process is necessary. The third section gives an overview of identification systems such as optical character recognition (OCR), barcode technologies, etc. In-depth knowledge of bar-coding technology was necessary to carry out this project. This knowledge is also important for the reader in order to understand this project. Therefore, in the fourth section bar-coding technology is discussed in detail. Finally, the last section gives a broad overview of related prior work.

2.1 Smart Cards

The simplest definition of a smart card (for a layman) is adding storage and processing to a dumb plastic or poly vinyl chloride (PVC) card. The history of the smart card began around 40 years old. Today smart-cards remain popular and are used in the banking and telecommunication sectors. The first proposal for a smart card was presented by two German inventors, Jurgen Dethloff and Helmut Grötrupp in 1968 [36]. In 1984, a French bank was the first to introduce this then bleeding-edge technology in the banking industry [29]. After the initial invention, a lot of research work has been done to further evolve this technology, such as introducing keypads and displays to make smart cards even more innovative and powerful. Smart card technology is also widely used in remote authentication [1] [7].

[1]Remote authentication is a process in which a remote user authenticates their identity over an insecure communication link.

2.1.1 Smart Card Architecture

A smart card is composed of a variety of electronic modules and components such as a read-only memory (ROM), central processing unit (CPU), electronically erasable programmable ROM (EEPROM), random access memory (RAM), and input and output (I/O) components as shown in figure 2.1. The ROM is used to store permanent information (i.e. the basic smart card software and one or more keys that can be used to control and program the EEPROM), while the EEPROM is used to store application data (which can be written or re-written electronically) [36]. The RAM is used as a volatile memory that only stores temporary data. The processing module of the smart card is faster than a 1980 personal computer (PC), and today this processing may be realized by an embedded silicon based 8-bit, 16-bit, or 32-bit processor [36]. The bidirectional I/O port is used to transfer data (by either a wired or wireless link) between a connected device and the smart card.

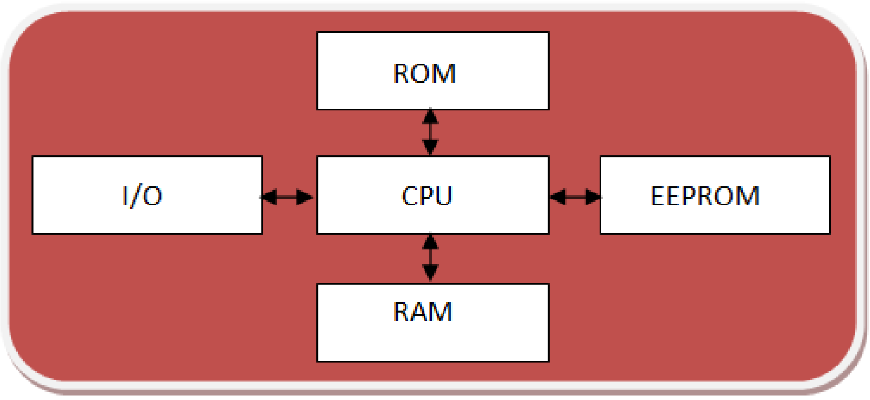

Figure 2.1: Smart card Architecture [36]

2.1.2 Smart Card ISO Standards

Various International Organization for Standardization (ISO) standards concern smart cards. ISO standards 7810, 7811, 7812, and 7813 specify the properties of an identification card in ID-1 format [2]. On the basis of the smart card application, physical characteristics, and communication protocol, ISO defines specifications for the smart card manufacturing industry [36]. A few of these standards are summarized in Table [36].

Table 2.1: ISO Standards [36]

ISO Standard	Specification
ISO/IEC 7810	Identification cards - Physical characteristics
ISO/IEC 781 1-11213141516	Identification cards - Recording technique
ISO/IEC 781 1-1	Embossing
	continued on next page

[2] An ID-1 format smart card has the dimensions: length 85.6 (+/-0.12) mm, width (53.98(+/-0.06)mm), and thickness (0.76(+/- 0.08)mm) [45].

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ISO Standard	Specification
ISO/IEC 781 1-2	Magnetic stripe
ISO/IEC 78 1 1-3	Location of embossed characters on ID-l cards
ISO/IEC 78 1 1-4	Location of read-only magnetic tracks - Tracks 1 and 2
ISO/IEC 78 11-5	Location of read-write magnetic track - Track 3
ISO/IEC 78 1 1-6	Magnetic stripe - High coercivity
ISO/IEC 7812-112	Identification of issuers
ISO/IEC 78 12- 1	Numbering system
ISO/IEC 78 12-2	Application and registration procedures
ISO/IEC 78 13	Identification cards - Financial transactions cards
IS0 7816-1/2/314/5/617/819/10	Identification cards - Integrated circuit cards with contacts
IS0 7816-1	Physical characteristics
IS0 7816-2	Dimensions and location of the contacts
IS0 78 16-3	Electronic signals and transmission protocols
IS0 78 16-4	Inter-industry commands for interchange
IS0 7816-5	Numbering system and registration procedure for application identifiers
IS0 7816-6	Inter-industry data elements
IS0 78 16-7	Inter-industry commands for Structured Card, Query Language (SCQL)
IS0 78 16-8	Security-related inter-industry commands
IS0 7816-9	Additional inter-industry commands and security attributes
IS0 7816-10	Electronic signals and answer to reset for synchronous cards
ISO/IEC 10373-11215	Synchronous cards Identification cards - Test methods
ISO/IEC 10373-1	General characteristics tests
ISO/IEC 10373-2	Cards with magnetic stripes
ISO/IEC 10373-5	Optical memory cards
ISO/EC 10536-11213	Identification cards - Contactless integrated circuit cards - Close-coupled cards
ISO/IEC 10536-1	Physical characteristics
ISO/IEC 10536-2	Dimensions and location of coupling areas

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ISO Standard	Specification
IS/IEC 10536-3	Electronic signals and reset procedures
ISO/IEC 14443	Identification cards - Contactless integrated circuit cards - Proximity cards
ISO/IEC 14443-1	Physical Characteristics
ISO/IEC 15693-1/2	Identification cards - Contactless integrated circuit cards - Vicinity cards
ISO/IEC 15693-1	Physical characteristics
ISO/IEC 15693-2	Air interface and initialization

2.1.3 Smart card Applications

We cannot deny the influence of smart cards in our daily life, due to their wide technological scope and wide usage in various applications smart cards have become more popular than an ordinary plastic magnetic stripe cards. Smart cards are used by a vast variety of commercial, as well as industrial, sectors leading to a wide range of applications in areas such as telecommunication, health, banking, insurance, etc. The details of each application is strongly dependant on the smart card's processing speed and storage capacity as shown in figure 2.2.

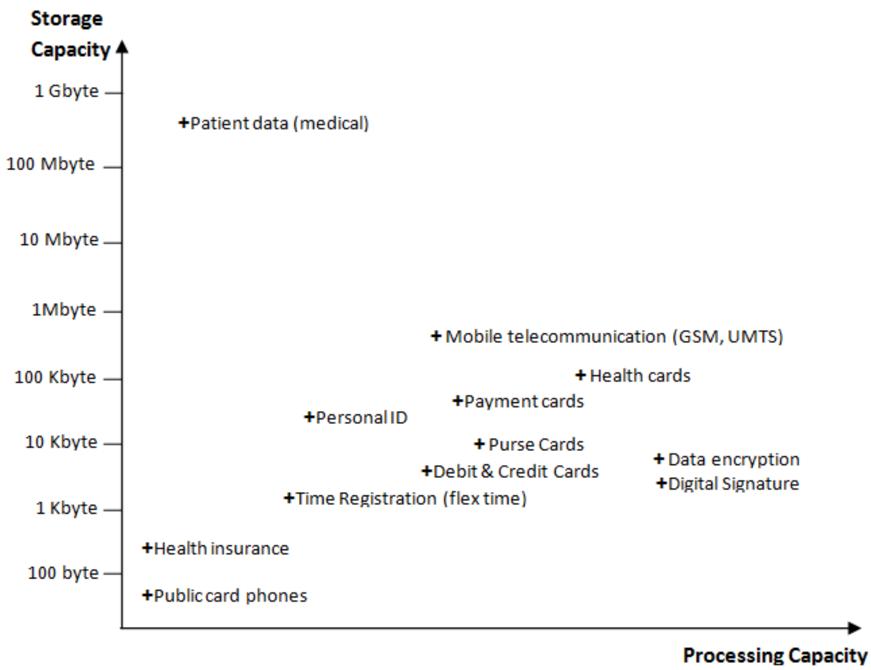

Figure 2.2: Processing speed and the storage capacity required for smart card different application areas [29].

2.1.4 Types of Smart Card

Smart cards can be broadly divided into two types: memory cards and microprocessor cards. Due to their lower consumer demand, memory cards have not gained the same market share as microprocessor cards, as is clearly shown in the smart card production graph shown in Figure 2.3. During the last decade, the demand for microprocessor cards has exponentially increased.

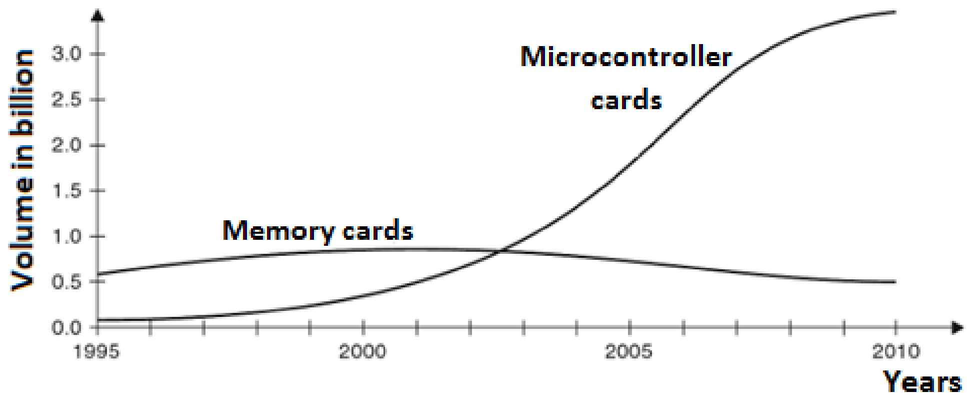

Figure 2.3: Graph: Microprocessor versus Memory Card [29]

2.1.4.1 Memory cards

Memory cards are considered to be the simplest form of smart cards. The main feature of these cards is an embedded ROM memory. This category of the smart cards stores data permanently due to the non-volatile nature of ROM. These memory cards are primarily used as prepaid cards or telephone cards. Due to their uni-directional dataflow and offline usage, they are sometimes referred as "asynchronous cards" [36]. These types of smart cards have an advantage over traditional magnetic strip based cards in terms of their larger storage capacity [36].

2.1.4.2 Microprocessor cards

The name "microprocessor card" reflects the emphasis on the *microprocessor* component of this type of smart card. This type of smart card enables a new way of using such cards in our daily life. The literature refers this type of smart card as a "true" smart card based on semiconductor technology [36]. A microprocessor cards' chip(s) contain three electronic modules: ROM, RAM, and microprocessor. The architectural view of a microprocessor card is shown in figure 2.4. The existence of both a microprocessor and memory enables this type of smart card to work as a multi-application card. A combination of the functionalities of a credit card, debit card, stored value card, and loyalty card in one package clearly shows the multi-application capability of this type of smart card [36].

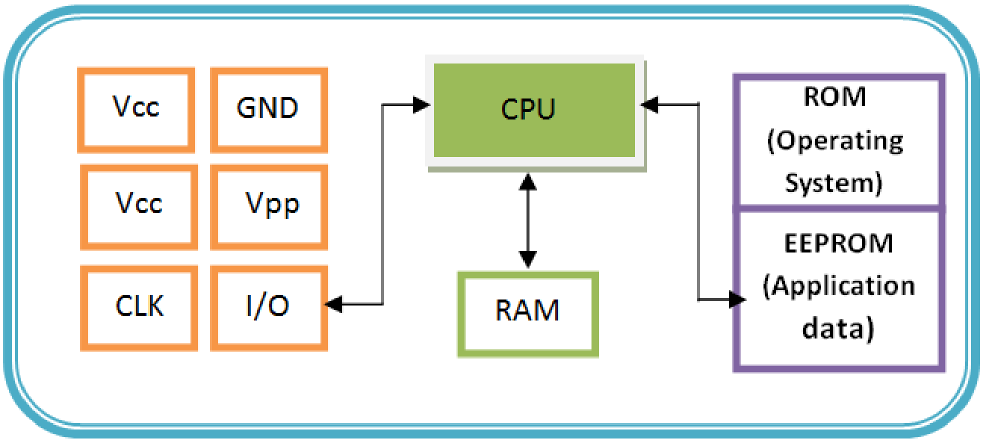

Figure 2.4: Architectural view of a microprocessor card [11]

2.2 Smart Card Manufacturing Process

The smart card production process involves a number of activities that are done with the help of state-of-the-art manufacturing technologies. Broadly speaking, the production process is divided into three steps (shown in figure 2.5):

- Card Body Manufacturing Process,
- Card Personalization Process, and
- Card Packaging Process.

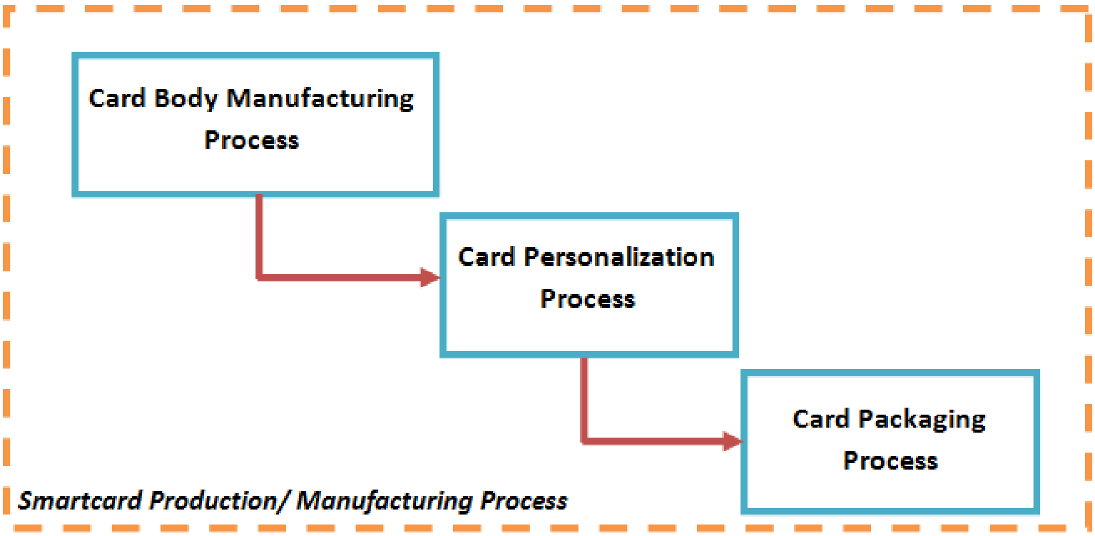

Figure 2.5: Smart Card Manufacturing Process

The card body manufacturing process begins with printing, laminating, or injection moulding of the card body in the first phase and is followed by card personalization, fulfillment, packaging, and logistics [9]. We will give an overview of each production step to provide some basic knowledge about the smart card manufacturing process.

2.2.1 Card Body Manufacturing

A sequence of production processes are involved in the manufacturing of the card body. An overview of this process flow is shown in figure 2.6.

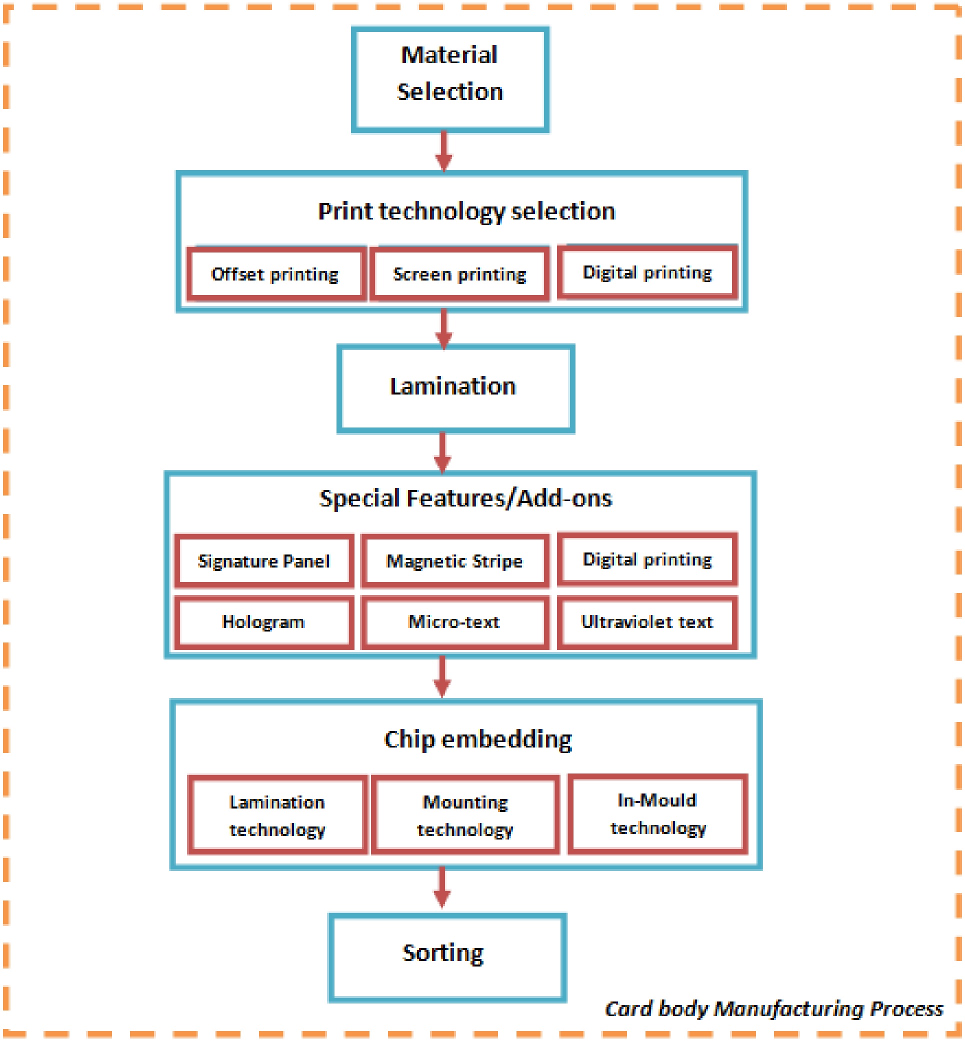

Figure 2.6: Card Body Manufacturing Process

2.2.1.1 Material Selection

There are two possible ways to distinguish card types: one way is based upon the application or type of issuer and the other way is the card's physical characteristics [9]. The ID-1 format is used as a standard in debit and credit cards in the banking sector. Different card types are list in the Table 2.2.

Different types of card materials are used in the manufacturing process. The choice of materials depends upon the customer's requirements. PVC cards are used

Table 2.2: Card Body Types [9]

Card Type	Application
Visa Mini	Credit Card/Debit Card
Plug- In	GSM (3FF)
Mini-UICC	GSM (3FF)
ID-1	Usual smart card

if the client needs a low cost recyclable material. Additionally, a PVC card body is used if the customer requires high temperature stability and high mechanical strength. Acrylonitrile butadiene styrene (ABS) material is used when temperature stability and recycling are the customer's primary requirements, along with an injection moulding process. Polyethylene terephthalate (PETG) is the best choice if the customer requires the most environment-friendly material, but this material comes with a middle range price.

2.2.1.2 Printing Technologies

After material selection, we have to select the printing technology. Due to advances in science and technology, the printing industry has evolved. There exist various types of printing technologies: offset printing, screen printing, digital printing, etc. Offset printing is the most commonly used printing technique in which we use four-colour or five-colour printing plates. These plates are mounted on the printing cylinder of the machine, which continuously rotates against a dampening (with water) roller and ink rollers as shown in figure 2.7. Screen printing is an older technology and is not frequently used in production due to its slower production rate. Digital printing is rarely used in bulk production due to its higher production cost. However, digital printing has the advantage that each card can be uniquely printed.

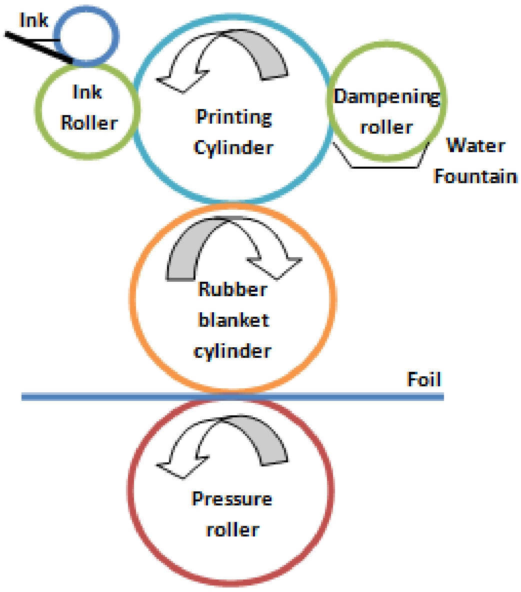

Figure 2.7: Offset Printing[13]

2.2.1.3 Lamination

Lamination consists of pressing two or more thermoplastic material foils together under high temperature. Nowadays, for ID and smart cards, four or five layers (and sometimes even nine layers) of foil are used to laminate the card body.

2.2.1.4 Special Features / Add-ons

There are different types of add-ons which are used when making the card body; again depending upon the customer's needs. Mainly there are five types of additional cards elements: signature panel, magnetic stripe, hologram, microtext, and ultraviolet text.

A signature panel is used in all banking cards, as the user has to sign his/her card before using it. The magnetic stripe is considered to be the main element in traditional payment cards [9]. A hologram is used as a security element. Today a hologram is used in all credit or debit cards. Microtext and ultraviolet text are security features which are provided by the manufacturers as an add-on upon a customer's request. Microtext cannot be read by the naked eyes. It looks like a simple line, therefore one needs a magnifying glass to read it [29]. In order to read the ultraviolet text, we need an ultraviolet light because this printing uses a special kind of ink which can only be seen under ultraviolet light [29]. Figure 2.8 illustrates the signature panel and magnetic stripe on a bank card.

Figure 2.8: Signature panel and magnetic stripe

2.2.1.5 Embedding of chip module into Smart card

The embedding of a semiconductor chip into the card body is a very sensitive process. Three techniques are used to embed the chip into a smart card body. These techniques are: [13].

- Embedding by lamination technology,
- Embedding by mounting technology, and
- In-mould technology.

Mounting embedding technology is widely used in the manufacturing process and is further discussed below.

2.2.1.5.1 Milling, Implanting, and Punching After the preparation of the smart-card chip module, the next step is to embed it into the card body; which can be done by a milling process. A milling machine is used to make a chip cavity in the card body, then an implanting machine is used to glue the chip module into the card body [13]. To check the integrity, an answer to request (ATR) test is performed in the implanting machine. Sometimes, an inkjet printer is used to print extra information on the card, if the customer requests this printing.

2.2.1.6 Sorting

Before moving to the next production stage, a detailed set of quality checks must be passed. In order to assure the smart card's quality, a sorting step is introduced where a physical check of the card body is performed. The physical checks includes a lamination quality check and an art-work [3] print quality check.

2.2.2 Smart Card Personalization

The word "personalization" is used differently in different contexts. Here, the meaning of personalization is to tie an individual card to a customer based upon an ID or key. The data is provided by the customer for the personalization process via secure encrypted media or the data is securely transferred by mean of a secure virtual private network (VPN). The data is sometimes delivered on a data compact disk (CD) or other physical

[3] This check ensures that the user defined graphics or images are properly printed on the card body.

media. This physical media must be carefully protected and access to it must be carefully controlled.

2.2.2.1 Card Personalization

Depending on the customer's requirements, various personalization steps may be utilized. There are many types of personalization, including:

- Group 1
  - Laser Engraving
  - Embossing and Indent Printing
  - Hologram
  - Inkjet Printing
  - Thermal Transfer, Colour Dye Sublimation, and Re-transfer Printing
- Group 2
  - Magnetic Stripe Encoding
  - Chip Encoding

User information, identification number, card owners' personal information, signature, photo, barcode, and other information could be printed by using a group 1 process. For encoding a Personal Identification Number (PIN), cryptographic keys, and biometric data, we use a Group 2 process, specifically magnetic stripe encoding or chip encoding technologies [13].

2.2.3 Packaging

Packaging performs two functions. It primarily helps in logistic management or the supply chain process. Secondarily, from a product presentation perspective, it gives the first impression about the product to the customer. Additionally, the packaging keeps the product safe from the environment and also protects the environment from the product [16].

Communication is the major tool for marketing. Packaging provides three communication functions; firstly, the communication of information, secondly the product promotion, and finally increasing the communication with customer [16]. For these reasons the packaging is carefully designed to realize these three functions.

2.2.3.1 Packaging Types

Generally, there are two types of packaging:

- Value Added Packaging (VAP) and
- Standard Packaging (SP).

2.2.3.1.1 Value Added Packaging (VAP) Different customers have different requirements for packing their product. The packaging industry uses the term "VAP" to refer to customer defined packaging, for example: blister packaging, wooden box, CD boxes, sophisticated cardboard boxes, and leather cases [9].

2.2.3.1.2 Standard Packaging (SP) The word "standard packaging" is generally used to refer to packaging that the card manufacturer defines as their generic standard packaging hierarchy (this is further discussed in section 2.2.3.2) for all customers.

2.2.3.2 Packaging hierarchy

Any product is packed according to a packaging hierarchy, which is either a customer defined or a standard packaging (i.e., manufacturer defined) hierarchy. This packaging hierarchy involves a series of hierarchal packaging steps, where the subsequent steps depend on the previous step. This concept of a packaging hierarchy is illustrated by considering as an example Universal Serial Bus (USB) memory stick packaging. The process flow is described in figure 2.9.

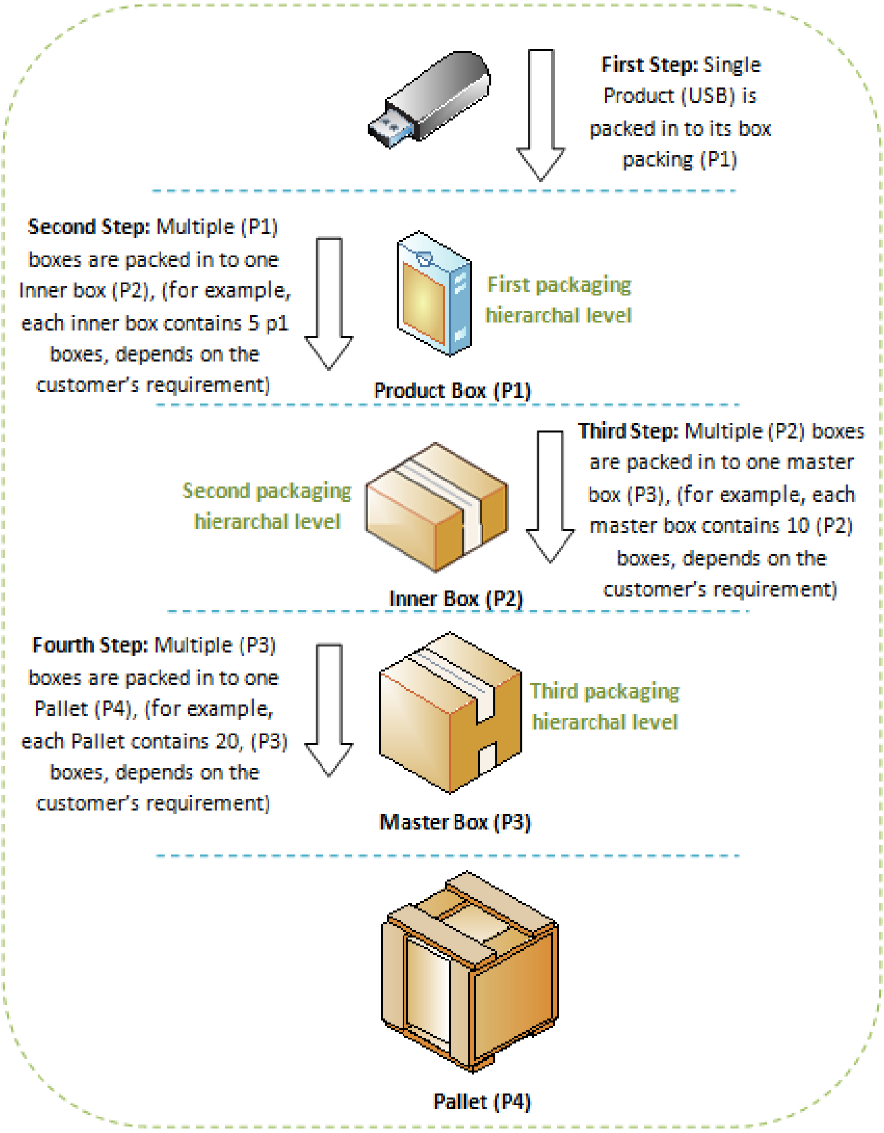

Figure 2.9: Packaging Hierarchy example

In the first step, a single USB is packed into its own product box as shown in the figure. We refer to this as "P1" packaging. The next step is to pack the "P1" boxes into inner boxes referred to as "P2". Each inner box contains five "P1" boxes, but this number may vary and change according to the customer's requirements. The third step is to pack the inner boxes into their master carton/box. This master box packaging is referred to as "P3". Each master box (P3) contains ten inner boxes (P2). Finally the master boxes are stacked onto a pallet; for example, twenty master boxes create one pallet load as shown in the figure. In the last step, the pallet is moved to the warehouse where it may be assembled into a shipment to the customer (perhaps in an industry standard shipping container).

This packaging hierarchy can be classified into three levels: Primary packaging (P), Secondary packaging (S), and Tertiary Packaging (T) [16].

Tertiary packaging is on the top level of hierarchy, because it contains many primary and secondary packages. While secondary packaging is at intermediate level and it contains many primary packages. Primary packaging involves a direct contact with the product as shown in figure 2.10 [16].

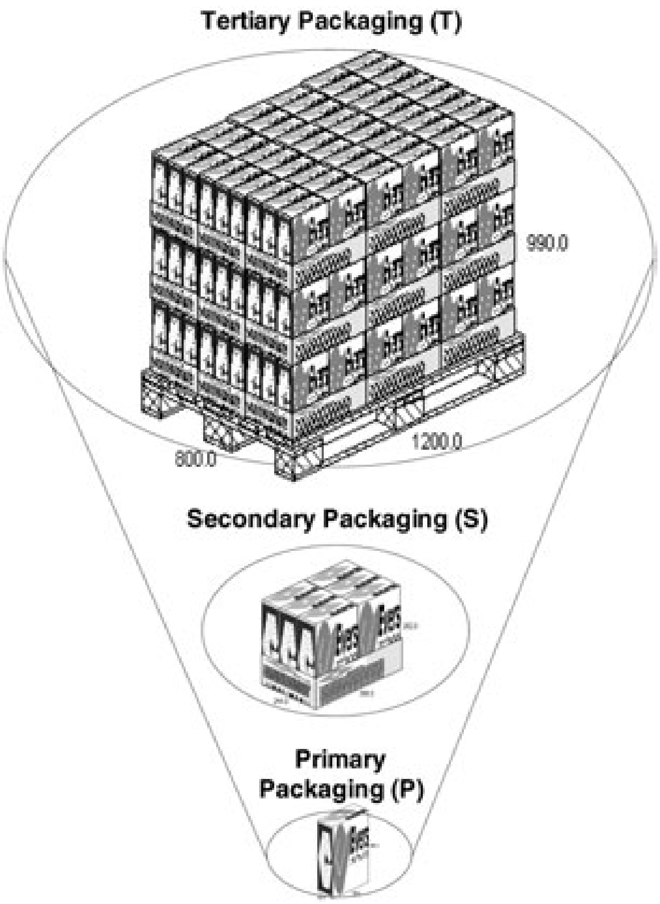

Figure 2.10: Packaging Hierarchy example [16]

2.2.3.3 Packaging Process

We focus on the packaging process of a Subscriber Identity Module(SIM)/Global System for Mobile Communications(GSM) card, Scratch card [4], or bank card. While there is a great deal of similarity in these three types of cards, they differ in some steps, which are detailed in the next paragraph.

2.2.3.3.1 SIM/GSM Card packaging Process

The SIM card packaging is similar to the chain process, i.e. every step follow the previous step. The process flow is illustrated in the process flow diagram 2.11. An overview of each step involved in the packaging process is discussed in the following paragraphs.

[4] A scratch card is a kind of phone card in the form of a debit card with the personal identification number (PIN) covered by a scratch off label. The user purchases the card and scratches the label off to read the PIN code. This PIN code is generally used to increase the phone's electronic balance [22].

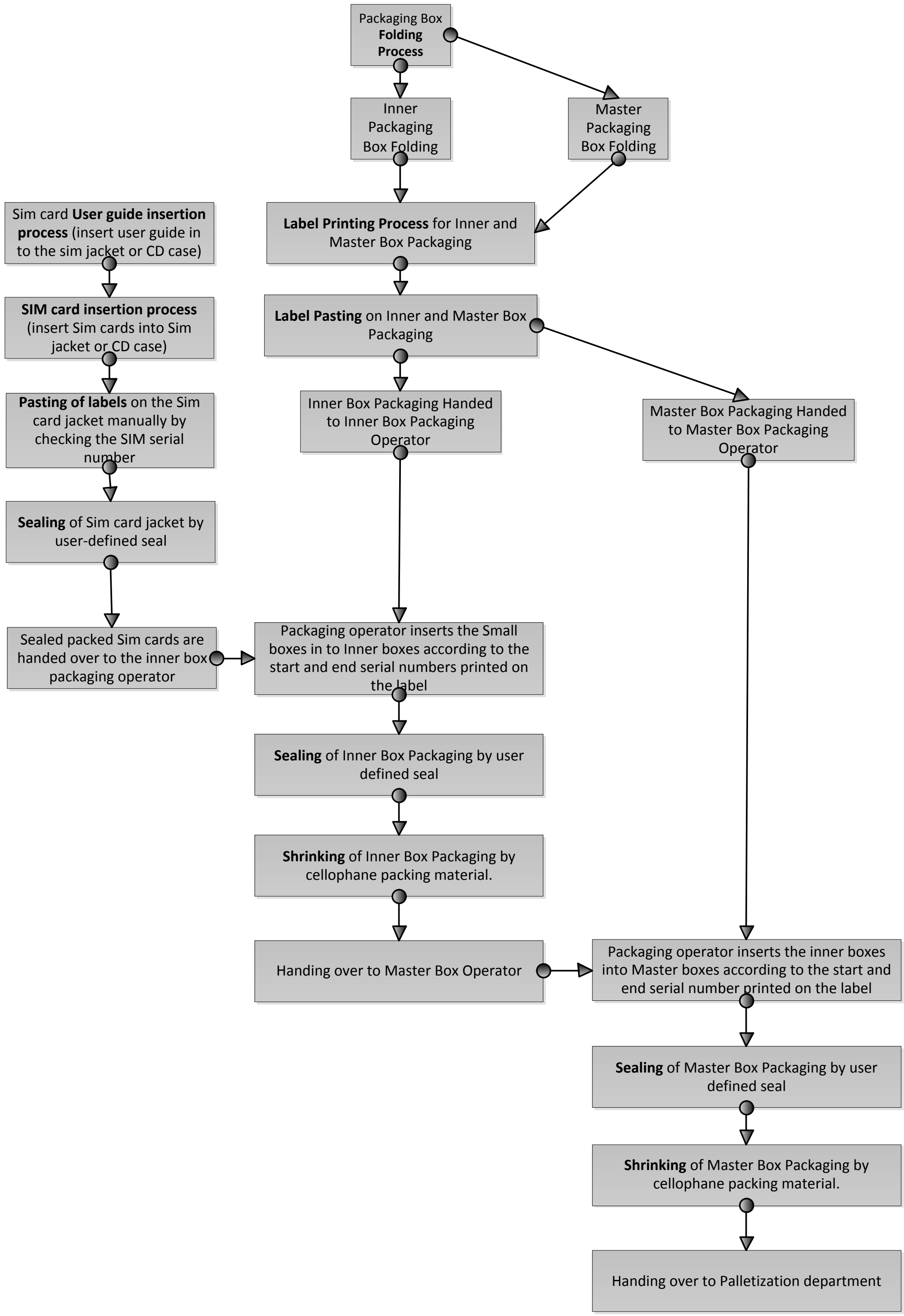

Figure 2.11: SIM cards packaging process flow diagram

2.2.3.3.1.1 Packaging Box Preparation Step This step consists of two main tasks: Folding process and Label printing and pasting process.

First, the operator folds the different box packaging materials, i.e. inner and master boxes properly and also performs the box quality check.

After the folding process, the label printing and pasting process is done. Printed labels are generated by a label printer, which is discussed in the section 2.5. The label is applied manually to the package by the operator. Finally, these boxes are handed over to the destination department as shown in the process flow diagram shown in Figure 2.11.

2.2.3.3.1.2 Insertion Step (User guide and SIM card) The first task of the operator is to insert the user guide into the SIM card jacket or CD case. After insertion of the user guide, the operator pastes a label with this SIM card's serial number on the SIM card jacket or CD case.

The next step is considered to be a very sensitive step, i.e. to insert the SIM card into the SIM card jacket or CD case. The SIM card must match the serial number printed on the label of the jacket or CD case. The SIM card insertion step is sensitive in the sense that if the operator mistakenly inserts the SIM card in incorrect jacket or CD case, it will be hard to detect this insertion error in the subsequent steps.

2.2.3.3.1.3 Sealing of SIM Card Jacket/CD Case In order to protect against product tampering, a sealing process is performed. The operator places a seal on the SIM card jacket and tranfers the sealed jacket to the inner box packaging operator.

2.2.3.3.1.4 Inner Box Packaging The operator carefully places the packed SIM cards in the inner box according to their start and end SIM card serial numbers as shown in figure 2.12. This process is further divided into two steps: Sealing of inner box and Shrink wrapping of the inner box.

Figure 2.12: Inner Box SIM card Packaging

Sealing of inner box was done by placing a seal on the inner box as shown in figure 2.13. After sealing, a shrink wrapping process is performed on the inner packaging and finally packed inner boxes are moved to the next step, i.e. master box packaging.

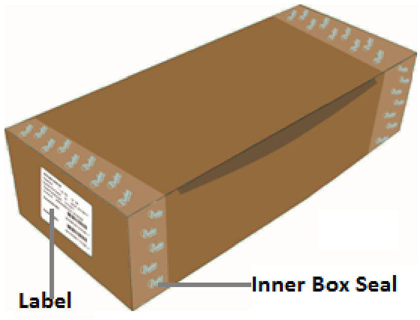

Figure 2.13: Inner Box SIM card Packaging

2.2.3.3.1.5 Master Box Packaging This step consists of tasks similar to those in the previous step. First, the operator carefully places the packed inner box into the master box according to their start and end SIM card serial numbers. After placement of packed inner box, the process is further divided into two steps: sealing of master box and shrink wrapping of the master box.

Sealing of master box is done by placing a seal on the master box. After sealing, a shrink wrapping process is performed on the master packaging and finally the packed master box is moved to the next step, i.e. palletization. The master box packaging is illustrated in figure 2.14.

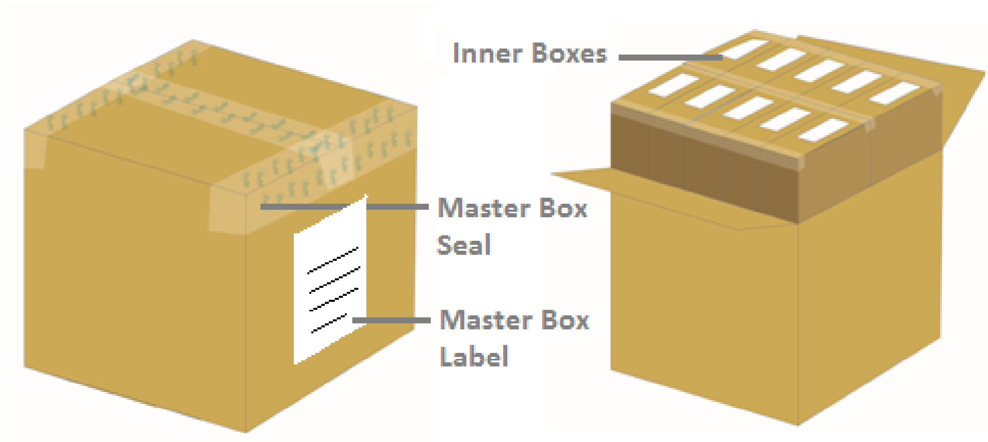

Figure 2.14: Master Box SIM card Packaging

2.2.3.3.1.6 Palletization This step is the final step of the packaging process. The operator stacks the master boxes on a pallet in an counter-clockwise direction and places the information label according to the start and end serial of the master box as shown in figure 2.15. The placement of the master boxes to create a pallet is depends on the customer requirement specification. Finally the pallet is shrink-wrapped and moved to the warehouse.

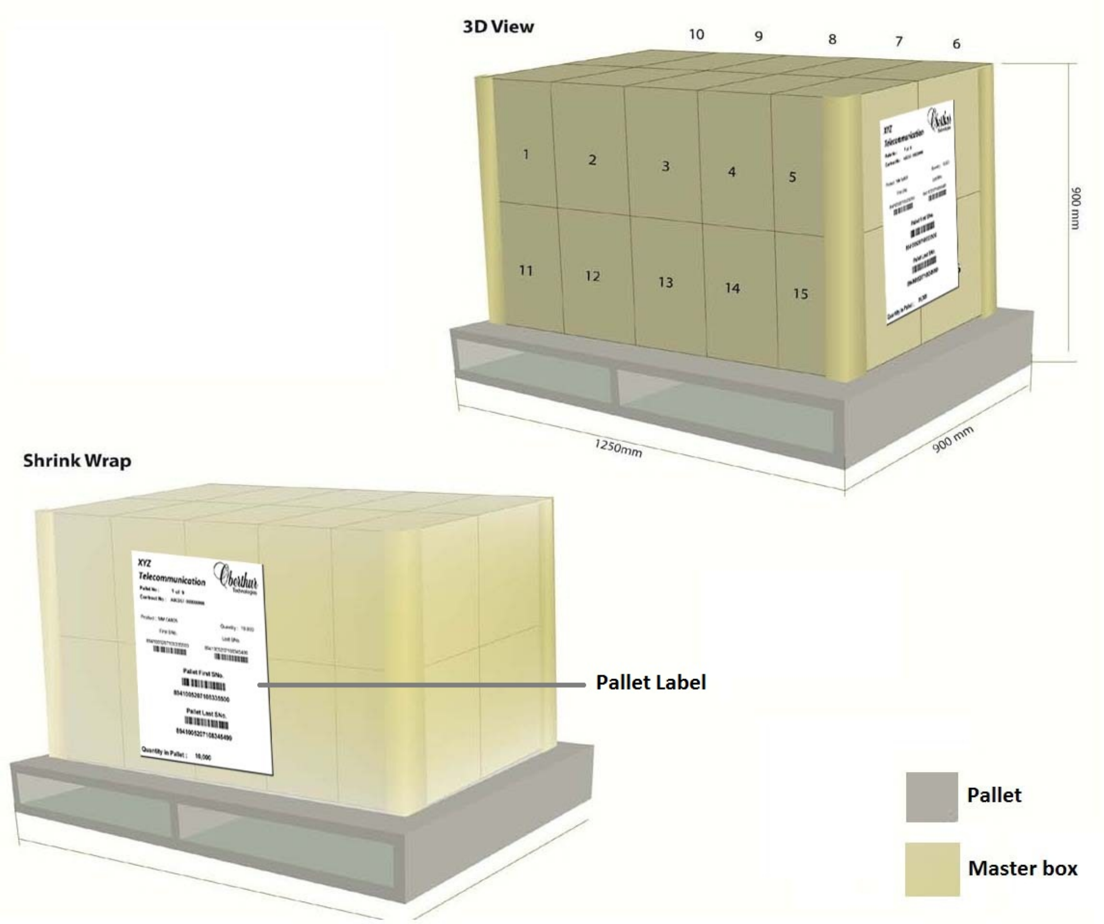

Figure 2.15: Palletization

2.2.3.3.2 Scratch Card (SC) / Bank card (BC) Packaging Process

The SC/BC packaging process is mostly the same as the SIM card packaging and differs in only a few steps. The process flow is illustrated in the block diagram 2.16. An overview of each step involved in the packaging process is discussed below in the next paragraphs.

2.2.3.3.2.1 Packaging Box Preparation Step This step consists of two main tasks: Folding process and Label printing and pasting process.

First, the operator folds the different box packaging, i.e. small, inner, and master boxes properly and also performs the box quality check.

After the folding process, the label printing and pasting process is done. Printed labels are generated by a label printer as is discussed in section 2.5, whereas the label is manually applied by the operator. Finally, these boxes are handed over to the destination department as shown in the process flow chart in Figure 2.16.

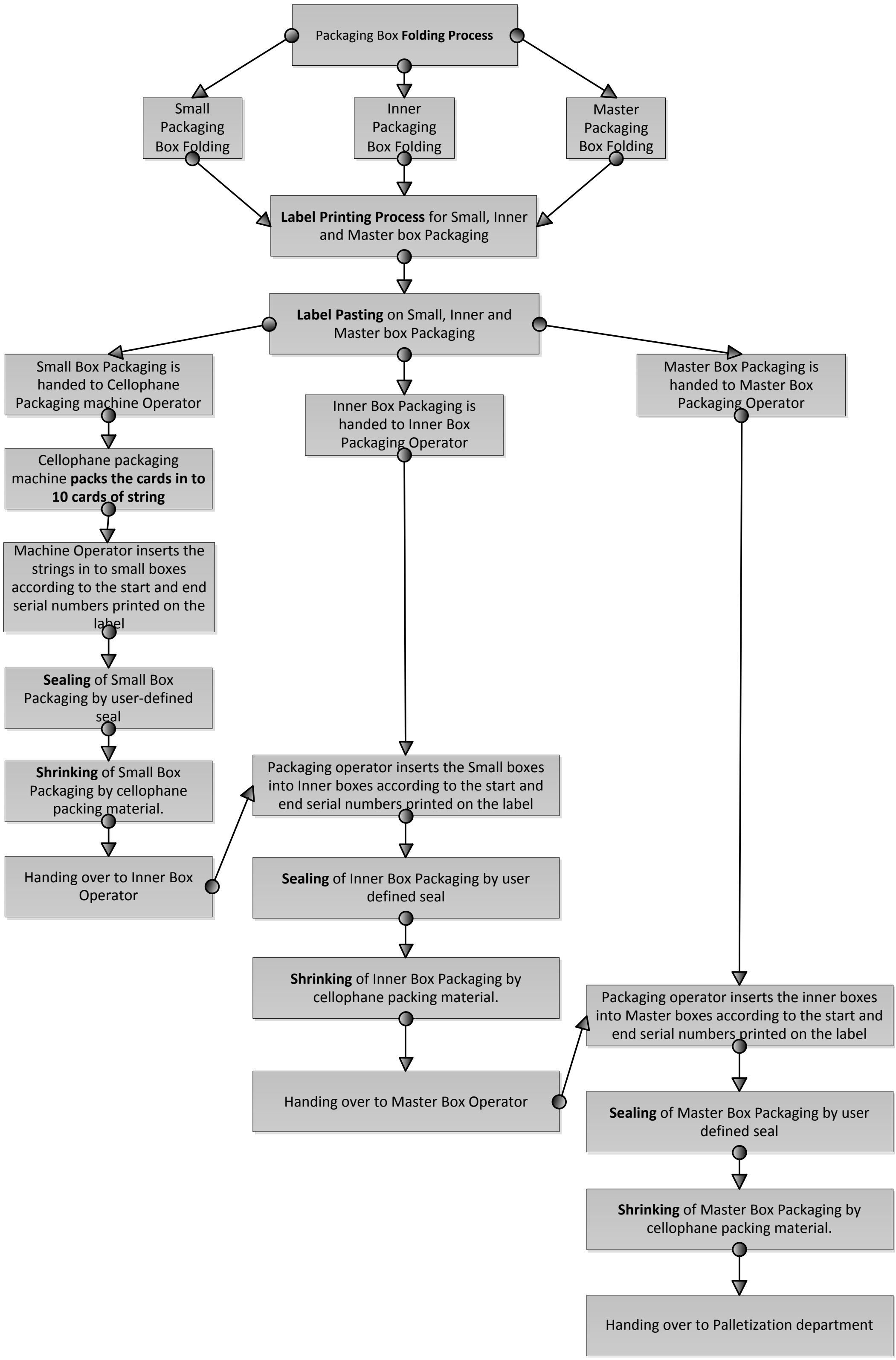

Figure 2.16: Scratch Card (SC) / Bank card (BC) Packaging process flow diagram

2.2.3.3.2.2 String of cards creation with small box packaging A high tech cellophane packaging machine can be used to make the strings of 10 or 20 cards, as per the customer's requirement. The machine operator collects the strings of cards from the delivery stack of the machine and puts each string into a small box as shown in figure 2.17. The machine packs 30 thousand cards per hour, hence there is a high probability of error, i.e. the operator by mistake puts the strings of cards into an incorrect small box. At 3 thousand strings per hour, the operator has a little more than one second to perform the correct operation. Again this is a sensitive operation as once the string of cards is in incorrect box it is not possible to detect this error during later processing. (Note that if the card being packaged contained an RFID chip, then it would be possible to read them while in the package, hence reducing the probability of an error in this stage going undetected.)

After the string is packed into the small box, the process is further divided in to two steps: sealing of small box and shrink wrapping of small box.

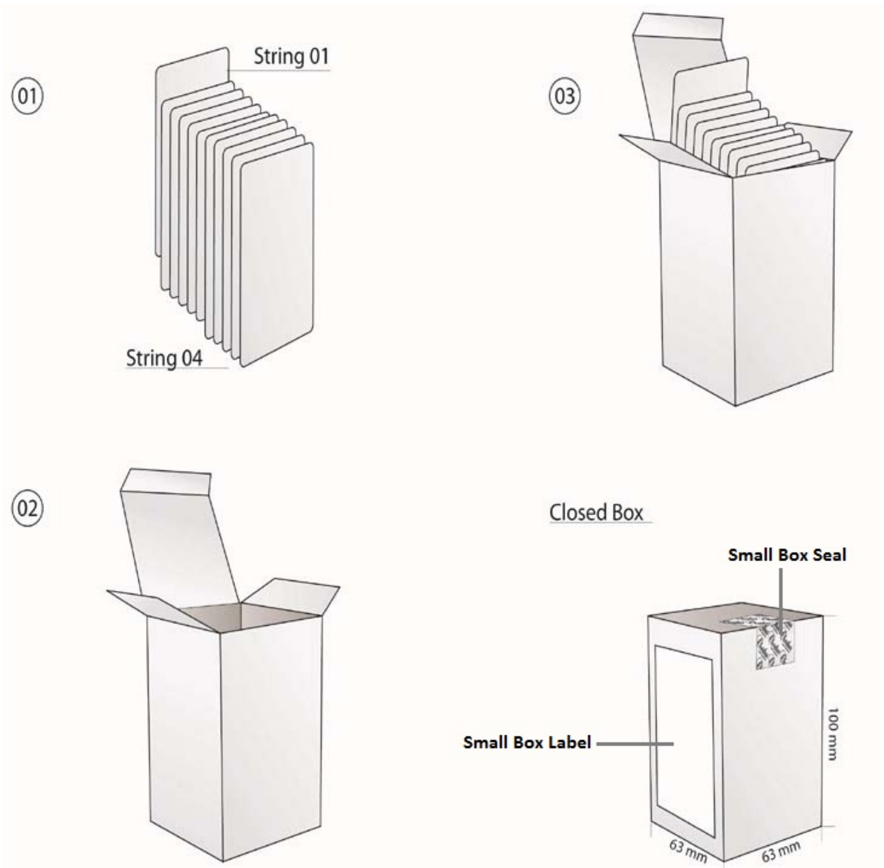

Figure 2.17: Small Box Scratch/Bank card Packaging

Sealing of the small box is done by placing a seal on the small box. After sealing, the small box packaging is shrink wrapped and finally moved to the next step, i.e. inner box packaging.

2.2.3.3.2.3 Inner Box Packaging The operator carefully places the packed small box in the inner box according to their start and end card serial numbers. The process is further divided into two steps: sealing of inner box and shrink wrap of the inner box.

Sealing of inner box is done by placing a seal on the inner box. After sealing, the inner box packaging is shrink wrapped and finally moved to the next step, i.e. master box packaging. The flow of the process is shown in figure 2.18.

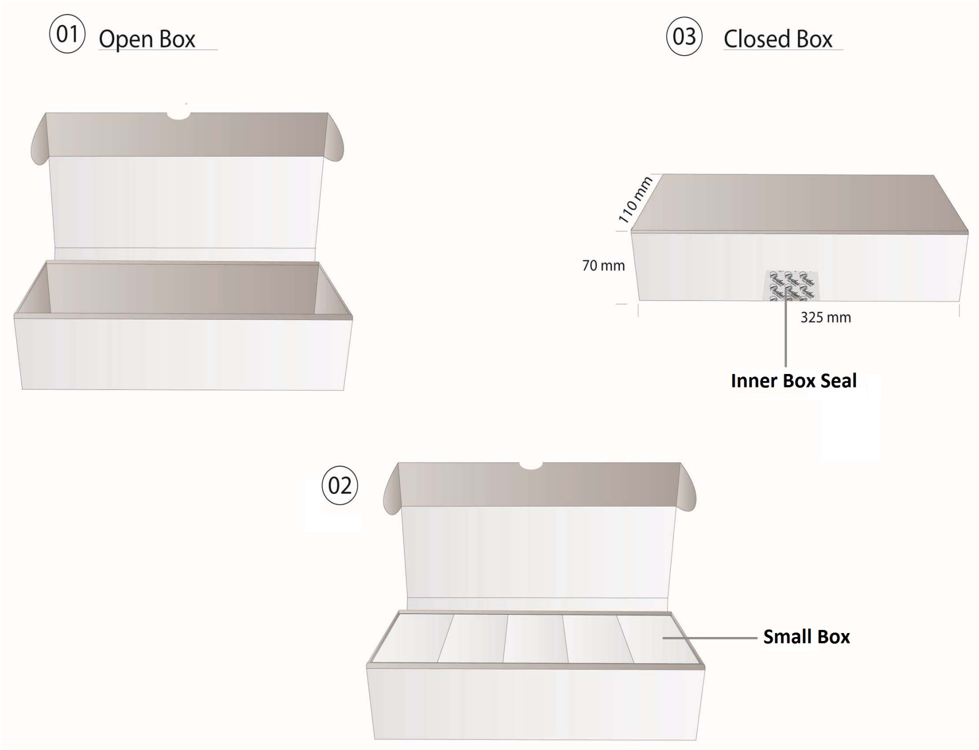

Figure 2.18: Inner Box Scratch/Bank card Packaging

2.2.3.3.2.4 Master Box Packaging This step involves similar tasks to the previous step. First, the operator carefully places the packed inner boxes into the master box according to their start and end card serial numbers. After placement of the packed inner box, the process is further divided in to two tasks: sealing of master box and shrink wrap of master box.

Sealing of master box is done by placing a seal on the master box. After the sealing, shrink wrapping of inner packaging is performed and finally packed master boxes are moved to the next step, i.e. palletization. The complete master box packaging process, is illustrated in figure 2.19.

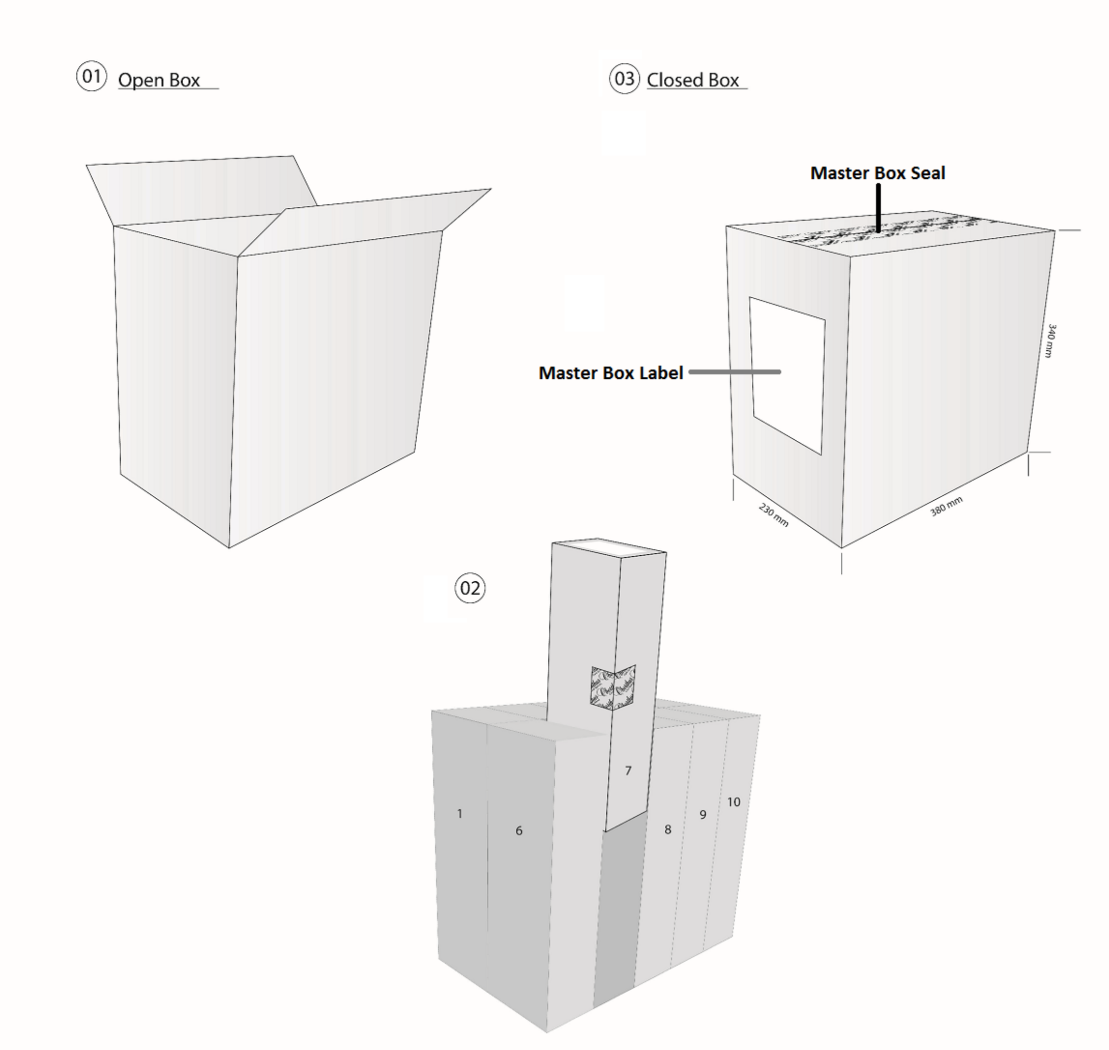

Figure 2.19: Master Box Scratch/Bank card Packaging

2.2.3.3.2.5 Palletization The palletization step is the final step of the packaging process and is same as discussed above in the section 2.2.3.3.1.6.

2.3 Identification System

There is a technological boom in all aspects of life, but still there is a white space in some parts, especially when we talk about control systems in the manufacturing sector; for example, raw material or finished product control. Manufacturers take full advantage of technology by utilizing identification systems to control their production work flow. There are many types of identification systems; some of them are discussed below.

2.3.1 Radio Frequency Identification System (RFID)

A series of tags and antennas are used to identify products that communicate using high frequency radio transmission [37]. The advantage of this technology is that it can be read through some amount of packaging material.

2.3.2 Magnetic Stripe

A magnetic stripe is used to save data which can be erased. The disadvantage of this technology is that the read head has to be quite near the magnetic stripe to read it. The advantage of this technology is that it is quite low cost.

2.3.3 Optical Character Recognition (OCR)

To reduce data entry costs, OCR technology has been used since the early 1970's [24]. The technology is based on human-readable characters. These characters are printed with light absorbing inks on light-reflecting backgrounds, and the reflected light from the illuminated pixels is sensed by a photo transducer (converting light energy in to an electrical signal) [37]. The advantage of this technology is that it is both human and machine readable.

2.3.4 Datacode Technology

Data is stored in a datacode in the form of square matrix made up of small dark and light areas, and can be read by a camera at the speed of five codes / second [37]. This technology is often referred to as two-dimensional barcodes. However, datacodes can be more than simple barcodes.

2.3.5 Barcode Technology

Barcode technology is a widely used technology for automatic identification. It can be used in various activities, including supply chain management, retail process control, product identification, etc. [39]. Bar-coding is a reliable data storage technique which can be used for fast data entry into a computer system [39]. Barcoding is a labelling system with black and white lines printed side by side on the object [37]. Note that both the black and white lines need not be printed, but one or the other can come from the background color of the label. Further details of barcode technology is given in the next section.

2.4 Barcode

A barcode is an optical machine-readable data representation [19].

2.4.1 Types of barcode

We can classify barcodes into two types: i.e. linear barcodes and two dimensional barcodes. A linear barcode consists of bars and spaces. In contrast, a two dimensional barcode utilizes an array of square cells [39].

2.4.1.1 Linear Barcode/Barcode

A linear barcode (also known as a 1D, a one-dimensional, barcode) is the most commonly used type of barcode. It is composed of start and stop patterns, a bit oriented data character structure (message bytes). Reed Solomon redundancy encoding is used for error detection and correction (check bytes) [1]. This type of barcode is commonly used in household products [19]. Figure 2.20 illustrates a 1D barcode.

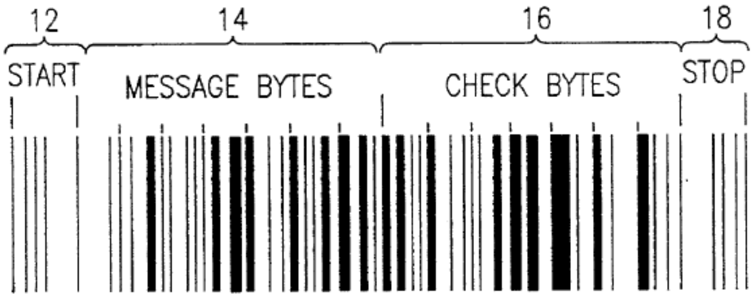

Figure 2.20: Linear Barcode/1D Barcode [1]

2.4.1.2 Two Dimensional Barcode/2D Barcode

Two dimensional barcodes are frequently used where the amount of data is considered too large to encode as a linear barcode. The two-dimensional barcode is considered to be an emerging technology, but is widely used on driving licences with secure data encoding [25]. The composition of a two dimensional barcode is not as simple as a linear barcode. It consists of black and white stackable dark and light regions arranged into rows and columns, having a start pattern on the left and a stop pattern on the right side of the barcode. There is a row indicator after the start pattern and before the stop pattern. This row indicator contains information about the number of rows, number of columns, and the error correction level [25]. Due to the availability of additional data storage space, these types of barcodes are frequently used in industrial products [19]. Examples of 2D barcodes are PDF417, Datamatrix, QRCode, etc. An example of a QRCode is shown in figure 2.21.

Figure 2.21: Two dimensional barcode/2D Barcode (QRCode)[21]

2.4.1.3 Three Dimensional Barcode/3D Barcode

There are advantages and disadvantages of every system, hence there are shortcomings of the 1D and 2D bar-coded systems. Generally, 1D and 2D barcodes need a white background, and they also do not work in harsh environments such as damp conditions, etc.

2.4.2 Barcode Symbologies

Barcode symbology is the method by which the information is encoded in the barcode. There are various barcode sysmbologies available; a few of them are discussed below.

2.4.2.1 Two of five Unidirectional (2/5 Unidirectional)

A 2 of 5 unidirectional barcode consists of 5 bars, out of which 3 are narrow and the rest of 2 are wide/broad bars. The wide bar represents a logic 1 and the narrow bar represents a logic 0. At the end of the barcode, there is odd parity-check bit, which is rarely used.

2.4.2.2 Two of five Bidirectional (2/5 Bidirectional)

If we place the start pattern "ST" at the beginning and stop pattern "SP" at the end of the 2/5 unidirectional symbology, we get the 2/5 bi directional symbology. The preferred ratio between broad to narrow bars is 3:1 in 2/5 symbology [37].

2.4.2.3 Code 3 of 9 (Code 39)

The code 3 of 9 consists of two broad bars, one broad inter-character space, three narrow bars and three narrow inter-character spaces. Due to the use of 3 elements out of 9, it is known as code 3 of 9 or Code 39 [37].

2.4.2.4 Interleave 2 of 5 (Interleaved 2/5)

This symbology uses the same encoding technique as 2/5, with the only the difference being that both the spaces and bars are encoded [37].

2.4.2.5 UPC

Universal Product Code (UPC) is a widely used and successful standard in retail stores. Moreover, due to its ability to provide unique product identification, it performs a key role in an inventory management process. A UPC barcode consists of a 12 digit sequence number. the first digit is used as a numbering system character. For example, 'o' identifies a regular UPC code, where as '3' identifies a National Drug code, etc [8]. The next five digits are referred to as a "manufacturer ID number". After the manufacturer ID number, the next five digits identifies the item number. The latter are assigned by the manufacturer whom must ensure the uniqueness of the number. The last digit is the Modulo Check character, which is used to validate the correct interpretation of the machine scan [8]. A UPC barcode is illustrated in figure 2.22.

Figure 2.22: UPC Barcode [8]

2.4.2.6 PDF417

PDF417 [5] is a 2D-stacked type barcode symbology. If we stack one-dimensional barcode in the y-axis direction, the resultant barcode is a 2D stacked type barcode as ilustrated in figure 2.23. This is the most commonly used barcode symbology. It is used by manufacturers to automate their production processes and in the banking sector to automate their billing or invoice processes. Identity documents such as ID cards and passports are also taking advantage of this technology. It consists of a stack of rows, having a minimum of 3 and a maximum of 90 rows per barcode. The barcade also contains start and stop patterns, with left and right row indicators [14]. This type of barcode can encode more than 1,100 bytes; 1,800 American Standard Code for Information Interchange(ASCII) characters; or 2,700 digits, giving it high data capacity with enhanced error correction capability [14][38].

[5] PDF stands for Portable Data File

Figure 2.23: Two dimensional barcode/2D Barcode (PDF417)

2.4.3 Barcode Labels

Barcode labels can be used to print information in a customer's required format. Additionally, the barcode can be used to track the product during the manufacturing process or for manual identification in less advanced facilities [27]. A barcode label can be either a pre-printed label and on-site printed label.

2.4.3.1 Pre-printed Labels

These types of labels have predefined data or information. These labels can be printed by label vendors and delivered to the customer. Pre-printed labels have a fixed printing format, which cannot be amended by the customer. The label can be produced by wet ink technology, such as letterpress, flexographic, or offset/lithographic techniques [37].

2.4.3.2 On-Site Printing

On-site printing is used when the customer wants variable data to be printed on the label. As a result each label can be unique. The label can be printed using dot matrix, laser, or inkjet printers connected to a computer[37].

2.4.4 Barcode Reader/Scanner

A barcode scanner is a device used to capture, store, and decode the information encoded in different types of barcodes. Barcode scanners are widely used in various industries to automate their processes by object identification [43]. Today there are various types of barcode readers available in the market. These barcode scanners (also called barcode readers) are mostly classified by the barcode type: 1D or 2D. There are also readers available which are able to read both 1D and 2D barcodes. Such readers are more costly than a simple 1D barcode scanner.

2.4.4.1 Methods of Barcode Reading

Three methods of barcode reading are discussed below.

2.4.4.1.1 CCD Barcode Scanner Charged coupled diode (CCD) technology is a little bit older and rarely used these days. It consists of a light emitting diode (LED) paired with a series of photocells to sense the light reflected from the barcode. The scanning range of these readers is very limited because the LED that are generally used are low in power and photocells have low sensitivity [6].

2.4.4.1.2 Laser-based barcode scanning method Laser barcode scanning is commonly used to scan a one-dimensional barcode. It is also able to read a dense barcode from a large distance. It consists of laser and a photodiode [6], along with either a moving mirror or a reciprocating prism to create a line by oscillating the laser into a stationary mirror.

2.4.4.1.3 Imager-based barcode scanning method Using an imager is the latest barcode scanning technology and it has a wide range of scanning capabilities. Due to advances in science and technology, imaging technology has the largest market share (as compared to the laser and CCD methods) because of its high performance and low cost. These two factors play a major part in attracting users. This scanning method is commonly deployed together with 2D barcodes in many industrial applications [5]. This scanning method uses a camera (to acquire an image of the barcode) and image processing techniques to correctly decode the barcode.

2.5 Label Printers

A label printer is a printing device used to print labels with customer defined data or barcodes. Label printers are widely used in industrial as well as commercial applications. Label printers are commonly used to print information such as product ID, manufacturing date, weight, unit price, total price, etc., along with a product ID encoded as a barcode [44]. Label printers are usually classified on the basis of their printing methods or techniques, which are discussed below.

2.5.1 Printing Methods

The three basic methods for label printing are described in the paragraphs below.

2.5.1.1 Dot Matrix Printing

Dot matrix printing is the oldest technique for printing labels. This method is primarily used for temporary label printing. The arrays of pins in a matrix format, are used to transfer an ink impression from an inked ribbon to the label.

2.5.1.2 Direct Thermal Printing (DP)

Direct Thermal Printing is generally used to print labels for shipping, warehouse management, and production monitoring. There is no need for an inked ribbon in this method; the thermal print head is used to print the information on a heat sensitive label [18]. The image on the heat sensitive label is printed by applying light energy or radiant thermal energy from a thermal heat source [18].

[6] A photodiode converts a light signal into a voltage or current.

2.5.1.3 Thermal Transfer Printing (TTP)

Thermal transfer printing is the most advanced printing method used to print the labels. This method is specifically used when detailed printing, with high quality and durability, is required. In order to obtain high quality, a thermal transfer ribbon is used with a thermal print head [30]. The ink is melted by the thermal print head and transferred to the label. A print sample of thermal transfer printing is shown in figure 2.24

Figure 2.24: Pallet information label is printed by Thermal Transfer Printing (TTP)

2.6 Data Security

Data is an integral part of any business organization. This data can be utilized within a software application or appear as printed information. Data security has been an active research and development area during the last several decades. However, there are still several challenges to overcome in order to reduce security vulnerabilities. Data security is an important issue in every organization, especially in the smart card manufacturing industry as each and every product contains sensitive data. For example, in the banking sector, our bank cards store customer information along with our PIN code. The smart card used in telecommunication products also need a data security. For example a SIM card contains all the user-specific information needed to authenticate a GSM or universal mobile telecommunications system (UMTS) user. Data security is also important in scratch card products [7], as each and every scratch card has some value, hence even the leakage of a single PIN would create a complaint from the client.

2.6.1 Encryption

Encryption is defined as the process to convert plain text or data into cryptic text. The term cryptography refers to "the study of the secret" [40]. We commonly used use cryptograph to provide us with methods of encryption and decryption; as well as methods of integrity protection and authentication. Cryptography plays a vital role in security by providing many different functions. Confidentiality, authentication, integrity, non-repudiation, access control, and high availability are major goals when applying cryptography [40].

2.6.2 Security Algorithms

A cryptographic algorithm is used together with keys for communication between sender and receiver(s). If two different keys are used by sender and receiver(s), this method is "asymmetric" [4]. Where as, if the same key is shared by both sender and receiver(s), the method is called as "symmetric" [4].

2.6.2.1 Symmetric Algorithm or Conventional

Symmetric algorithms are either block based ciphering [8] (shown in figure 2.25) or stream based ciphering [4]. In the later, a binary stream of data is enciphered by stream based ciphering each bit separately as shown in figure 2.26. A typical stream based method consists of two components: first is a mixing function and the other one is a key stream generator. The Exclusive-OR (XOR) function is frequently used as a mixing function. The key stream generator is the central unit [40], as illustrated in figure 2.26. If the data is in a block format, then block based ciphering is used. The basic form of block ciphering is Electronic Codebook Mode(ECB), where cipher blocks are generated directly by encrypting data blocks [40]. Examples of block based ciphering are Data Encryption Standard (DES), Triple DES, Blow fish, Fast Encryption algorithm (FEAL), and International Data Encryption Algorithm (IDEA) [20] [4].

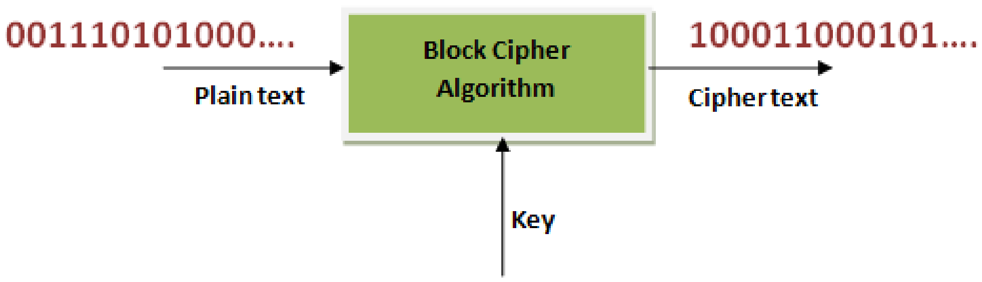

Figure 2.25: Block Cipher Symmetric Algorithm [4]

[7] They are used to recharge (credit/balance) our phone accounts.
[8] The algorithm used to perform encryption is known as a "cipher".

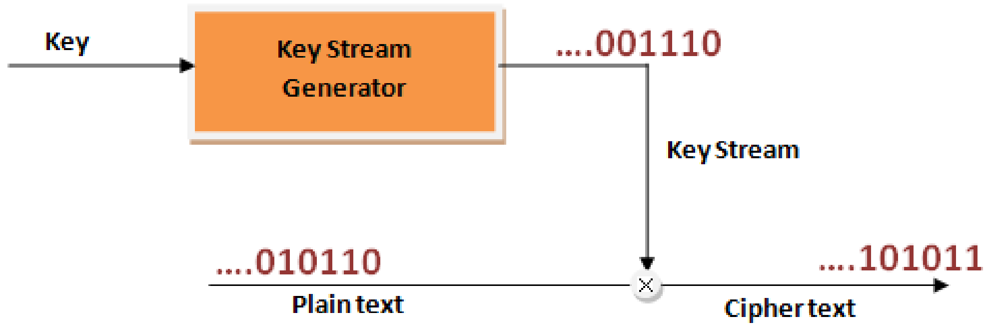

Figure 2.26: Stream Cipher Symmetric Algorithm [4]

We use the triple DES (3-DES) encryption algorithm for data security because it is widely applied for protecting information throughout the globe; e.g. in smart card transactions, automatic teller machine(ATM) PIN pads, etc. [15][42].

2.6.2.2 Asymmetric Algorithm

A pair of keys is used to encrypt and decrypt the data in an asymmetric algorithm. For data confidentiality the key that is made public and is called the "Public key". Conversely the key used to decrypt the message is kept secret. This key is known as the "Secret key" or "Private Key" [12]. There are various asymmetric algorithms which are commonly used nowadays, such as the RSA (Ron Rivest, Adi Shamir, and Leonard Adleman) algorithm and the Digital Signature Algorithm (DSA) [12].

2.7 Prior Research Work

Industry is reluctant to publish their data or results concerning smart card packaging process control research and development due to proprietary issues; therefore, it was hard to find relevant related work about this thesis topic. Nevertheless, this section details some loosely-related research in the broad areas of packaging and handling methods. First, the effects of different packaging parameters in the retail industry are discussed in detail in the next sub-sections. Following this the growing influence of RFID in production and packaging is described. Finally, the realization of an Enterprise Resource Planning (ERP) System in a warehouse management system is discussed.

2.7.1 Realization of efficient packaging

S.G.Lee and S.W.Lye proposed a methodology, named "Design for manual packaging (DFPkg)", to evaluate the efficiency of a manual packaging process, i.e. folding, insertion, sealing, and scanning [35]. The packaging time in each of the steps, i.e. insertion, folding, and labelling, was measured and then the manual packaging efficiency was calculated by dividing the ideal packaging time by the actual measured packaging time.

By applying the proposed methodology in different industries, they realized that by reducing the number of unnecessary steps in the packaging process and reducing the volume of material, we can improve the production process. Furthermore, as a result of applying this method to packaging of different products, they discovered that by using one label and one moulded tray, and rather than using a four-flap box, using a two-flap box, that packaging efficiency was increased by 13.7 percent [35].

2.7.2 Realization of packaging handling evaluation methods

Gunilla Jönson and Mazen Saghir [32] analyzed the packaging handling process by reviewing different literature and case studies. They identified that packaging handling is the main factor that influences the overall logistical cost of a grocery chain. Another study claims the same results by quoting the example of Sweden's largest grocery retail, i.e. ICA. About 75 percent of the total handling time occurred in the retail store, and this handling time was due to packaging handling [35].

Furthermore, based on interviews in different organizations, Saghir and Jönson also revealed that the lack of packaging evaluation tools and lack of published data for evaluating packaging handling is the main hindrance in this research area. To establish a performance model in packaging logistics, information transparency is an essential requirement [31]. Saghir and Jönson also identified the lack of reliable data collection techniques, hence they proposed analysis of a video sequence [32] to collect data to evaluate packaging handling. This technique saves time and helps to collect both quantitative as well as qualitative data. Further analysis of their case studies also revealed that quantitative data was not sufficient to evaluate the packaging handling; thus qualitative analysis and methods are necessary to evaluate the process. In order to cover both methods, acquisition of an analysis of a video sequence proved helpful.

2.7.3 Realization of production efficiency by RFID technology

Radio Frequency Identification (RFID) has been used for the last few decades and has recently attracted a lot of attention. It is widely used in our daily life: from personal usage, i.e. travel Cards, access control cards, etc. to warehouse management applications [9]. C.M.Liu and L.S.Chen [23], realized a new application of RFID technology by utilizing it to improve production efficiency in an integrated circuit (IC) packaging process. They developed an electronic control frame work [23], integrated with an enterprise resource planning (ERP) system to track wafers during the production and inventory control processes. Furthermore, they claim that the introduction of RFID in the packaging process was beneficial in many aspects, some of which are [23]:

- Reduction of clients' complaints,
- Reduction of overall packaging time,
- Decrease in work load on labours, and
- Remarkable reduction in operational cost.

RFID is also used to enhance the availability of products in the retail industry, as indicated by Samuel Fosso Wamba, Louis A. Lefebvre, and Elisabeth Lefebvre [41].

[9] RFID tags are use to track different products.

2.7.4 Realization of ERP System increases the efficiency in logistics

Antonio Rizzu and Roberto Zamboni discuss the role of ERP systems in logistic efficiency in [2]. They also highlight optimization techniques for warehouse management. They conclude, with a strong view, that an ERP system is an effective tool to achieve high efficiency standards [2]. However, after implementation in an actual warehouse and review from both practical and theoretical perspectives, they realized that an ERP system alone is not sufficient to improve a warehouse's performance parameters.

Chapter 3

System Design

This chapter introduces the design of the Smart Card Packaging Process Control System. It begins by explaining the proposed system and later, it explains in detail the design of each component by using unified modeling language (UML) diagrams.

3.1 Proposed System

The proposed system is based on a combined print-scan method shown in figure 3.1. As described in the previous chapter, SIM card packaging is divided into different levels of packaging hierarchy. Initially, a job is created and the data is loaded (i.e. start and end serial number, customer name, box number, etc.) and according to the customer's needs a label would be designed. After data loading, the operator scans the SIM card's barcode, the jacket label would be dispensed automatically and the operator would paste the label on the jacket. Note that this process assumes that a unique barcode is printed on each SIM card. In the next step the SIM jacket barcode is scanned and inner/outer box label would be dispensed automatically. All of these steps are dependent on the previous steps, thus creating a chain process as will be discussed in section 3.1.2. In order to prevent human error, the system does not allow the barcode to be printed in advance.

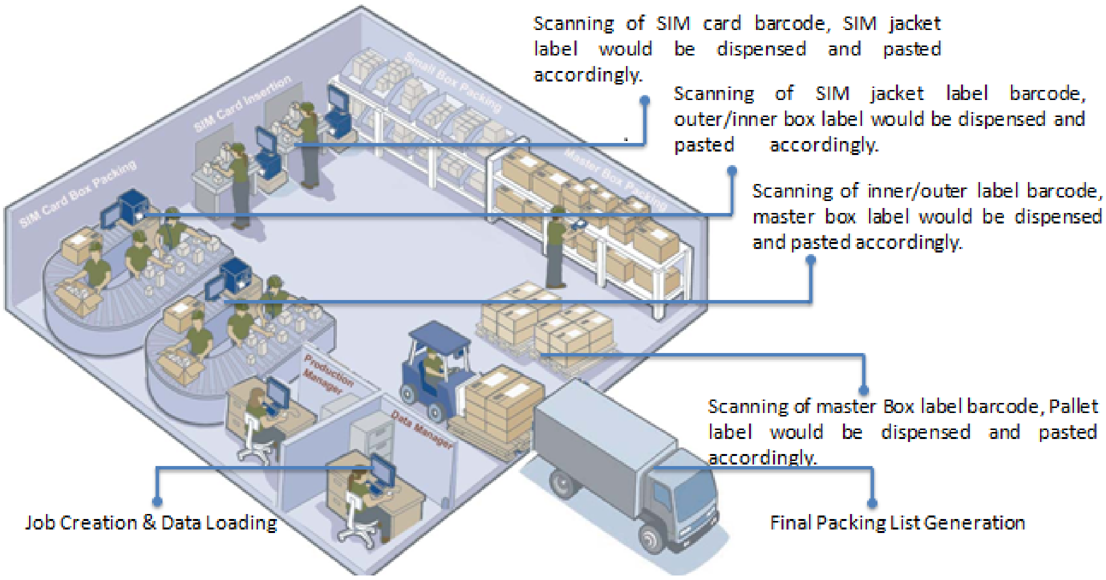

Figure 3.1: Proposed System

3.1.1 Scan and Print Method

In this method the operator first scans the barcode which is printed on the label and the required next level label is automatically generated. This method requires one barcode scanner and one label printer at each level of packaging hierarchy as shown in a figure 3.2.

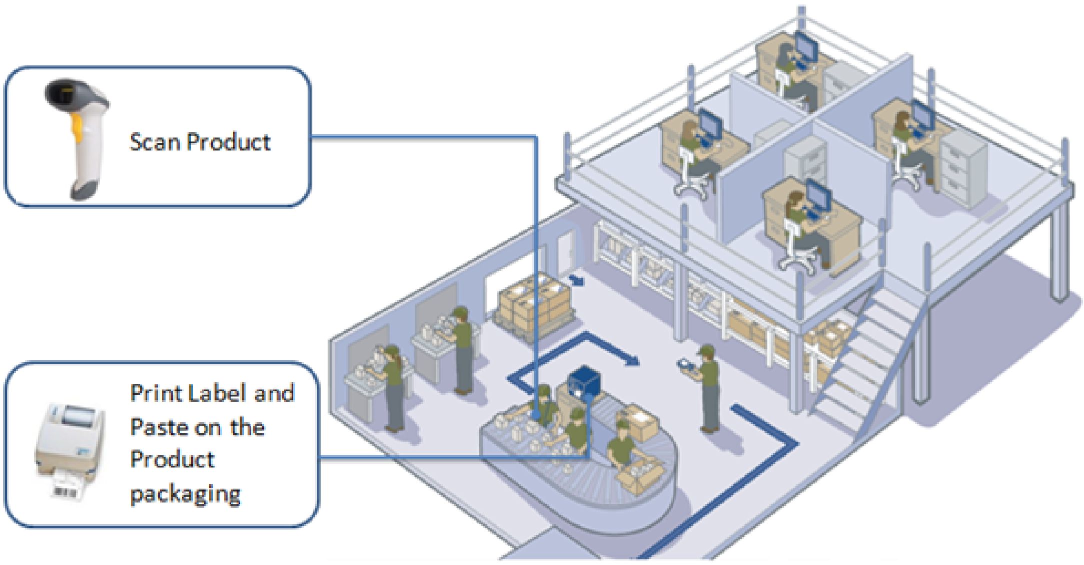

Figure 3.2: Scan-print method

3.1.2 Chain Process

A chain process is one in which the next step always depends on the previous step, as shown in figure 3.3. For example, the outer/inner label packaging level depends upon the previous stage, i.e. the SIM card jacket labelling level. Note that when a series of SIM cards or packages are placed into the next layer of packaging - both the first and the last object have to be scanned by the operator, as the label for this next level of packaging as the starting and ending serial numbers on it.

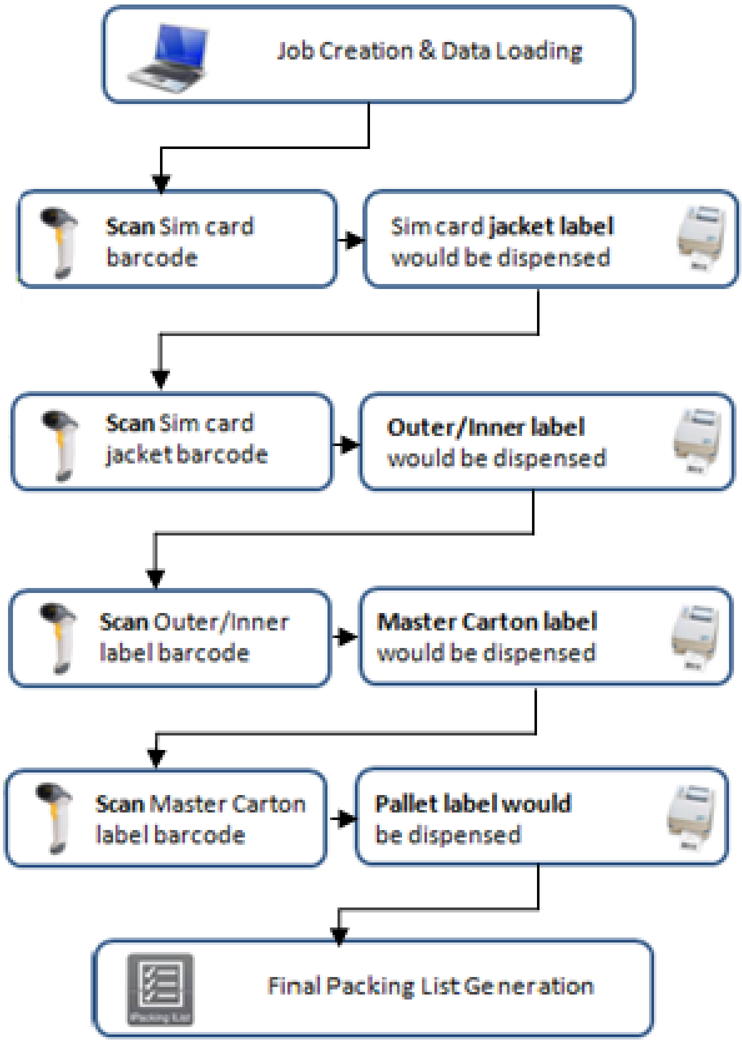

Figure 3.3: Chain Process

3.2 System modular architecture

The system design includes five modules: control panel, user management, error management, label designer, and operator module. These modules are shown in figure 3.4.

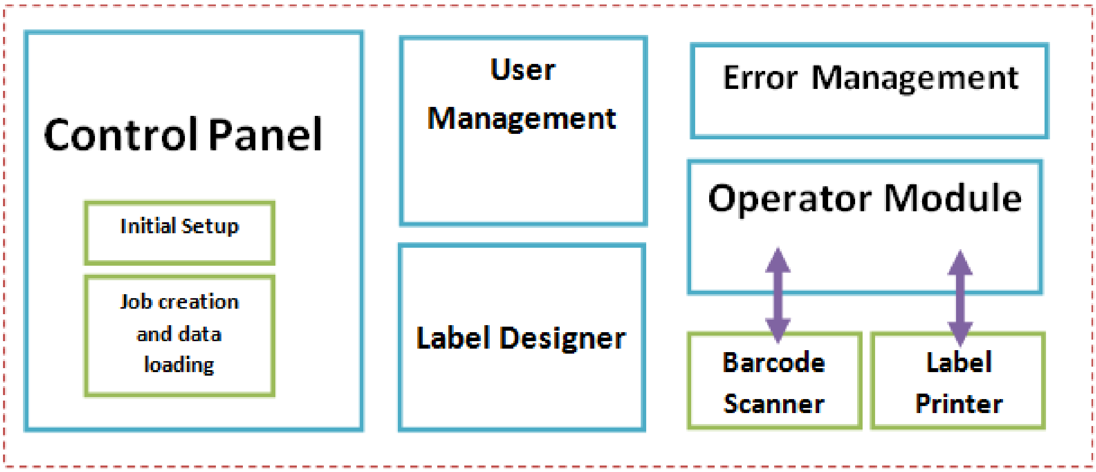

Figure 3.4: System design (modular structure)

Unified modeling language (UML) is used to define a behaviour of the system in terms of the system's functionality. The "actor" refers to a system user or users; whereas a "use case" defines the goals of a system. There are five actors: admin, data admin, designer, supervisor, and operator. The relationship between these actors are illustrated in figure 3.5. The "admin" performs a key role in this system. The initial system setup, user creation, and job creation are the main roles of the admin. Additionally, the admin has access to overall system as shown in figure 3.5. The data loading is a very sensitive part of this system and it is performed by a "Data admin". Data loading can also be performed by the "Admin" as shown in figure 3.5. Designing of label is the responsibility of two actors, i.e. "designer" and "supervisor", both have the necessary access control rights to create the layout of a label. The product barcode scanning and the label pasting operations are performed by a "production operator" as shown in the figure 3.5. The label re-print process and the packing list generation can be performed by two actors: "production supervisor", and "production operator". Error management is done by the "admin", while the error logging task would be perform by either an "operator" or "supervisor" as illustrated in figure 3.5.

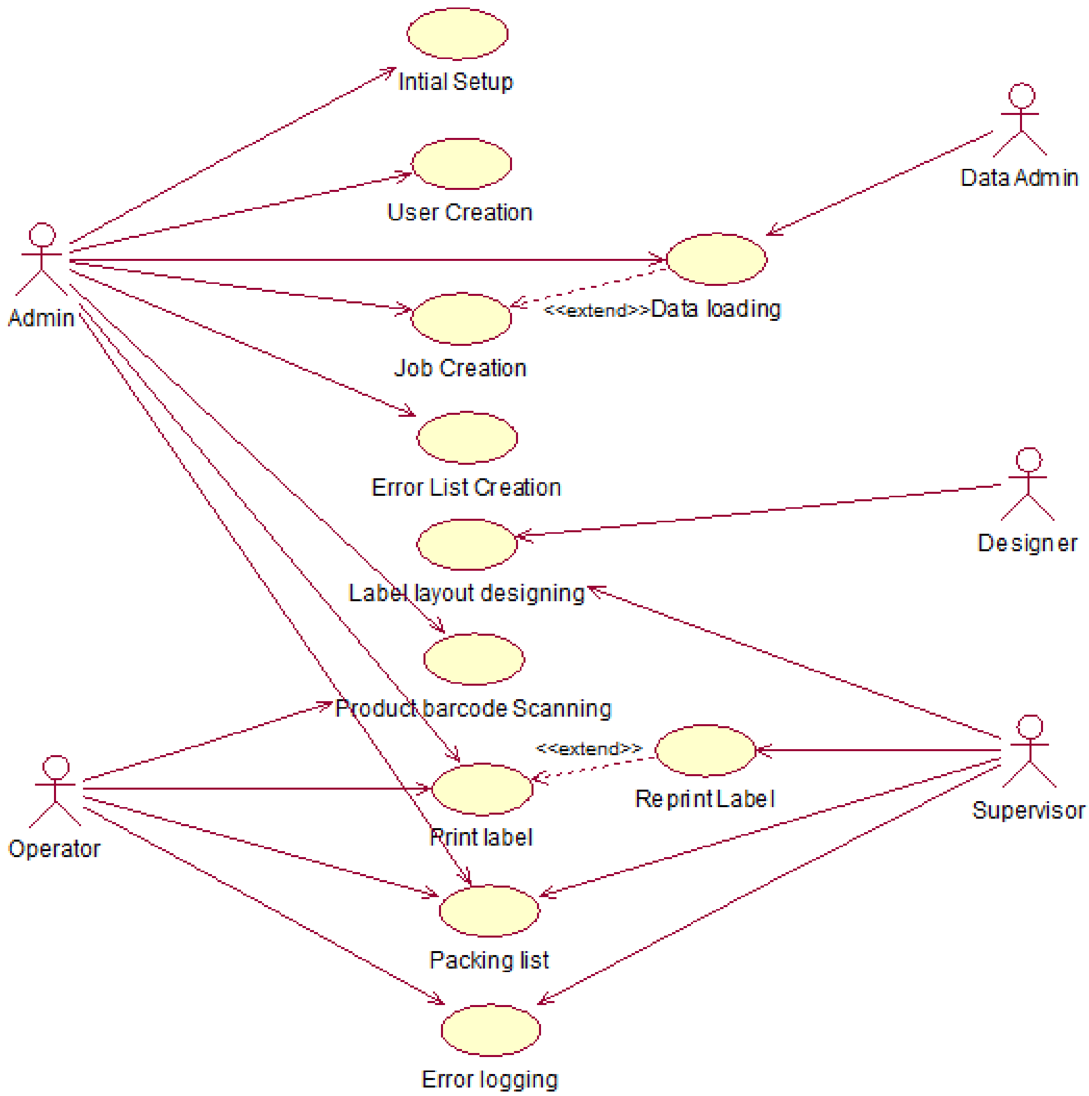

Figure 3.5: Overall system use case diagram

3.2.1 User management

User management provides the basis to control and manage each user's access during the system's operation. The "admin" performs the following tasks: new user creation, deleting old users, changing a user's password, and assigning/un-assigning the user's access rights within the system as shown in figure 3.6.

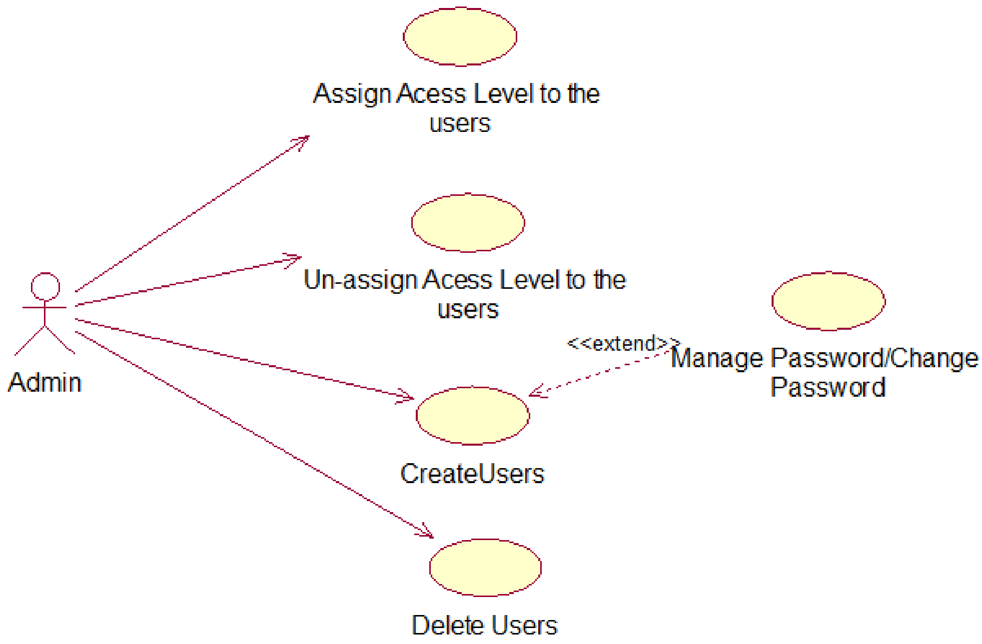

Figure 3.6: User management use case diagram

3.2.2 Error management

The error management module is used to define system errors and production machine errors. The system administrator creates a list of errors including the assigned machine and user as shown in figure 3.7. The system error's include; bad quality of label printing, missing cards, barcode scanning problems, label printer problem, barcode scanner problem, data fetching problem form database server, etc. There are several problems that can occur in each production or manufacturing process, but we have focused on packaging specific problems. If we use the system with a packing machine, an operator logs different machine errors as compared to when the system is being used with the personalization machines. The machine errors include compressor pressure, an anomalous sensor reading, sealing problems, etc. The operator or supervisor performs the error logging task because by analyzing this data we can reduce the machine downtime by providing timely and relevant data to the maintenance department. Note that the maintenance department employees are outside the scope of this thesis project.

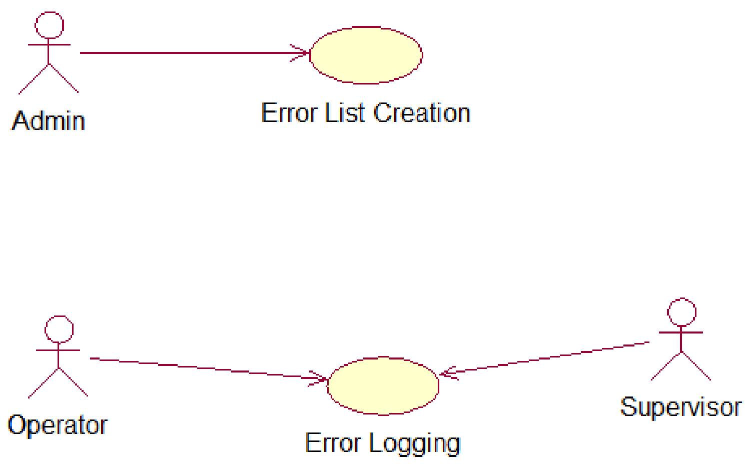

Figure 3.7: Error management use case diagram

3.2.3 Label designing

There are various tools available to create the layout of a packaging label, but the proposed system assumes that the design of a label is suitable for using the label as a product tracking tool throughout the production process. The design of the label (i.e. the label layout creation process) is performed by a production supervisor or a graphic designer, but the sample proofing [1] is done by the production supervisor as shown in the use case diagram shown in Figure 3.8.

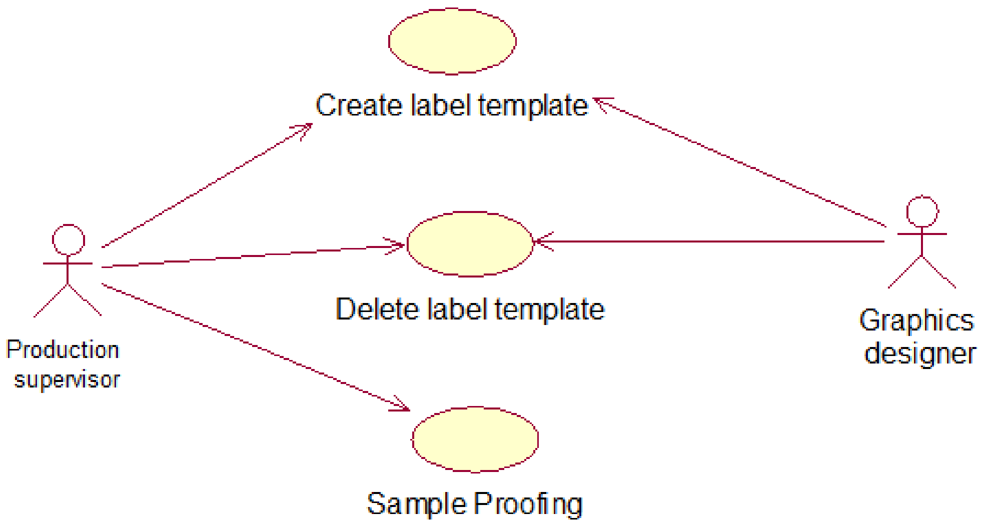

Figure 3.8: Label layout design use case diagram

[1] Proofing is a process through which the label information is verified against the customer's provided sample label.

3.2.4 Control panel

A control panel module is divided in to two modules: initial setup module and job creation/data loading module . Each of these is discussed below.

3.2.4.1 Initial Setup

A single time or initial system setting is called the "initial system setup" and is considered to be the foundation of any system. The initial system setup is performed by a system administrator. The default database table creation, creation of the company profile, and creation/deletion of each department along with their production process is the primary role of the system administrator (System admin) as illustrated in figure 3.9.

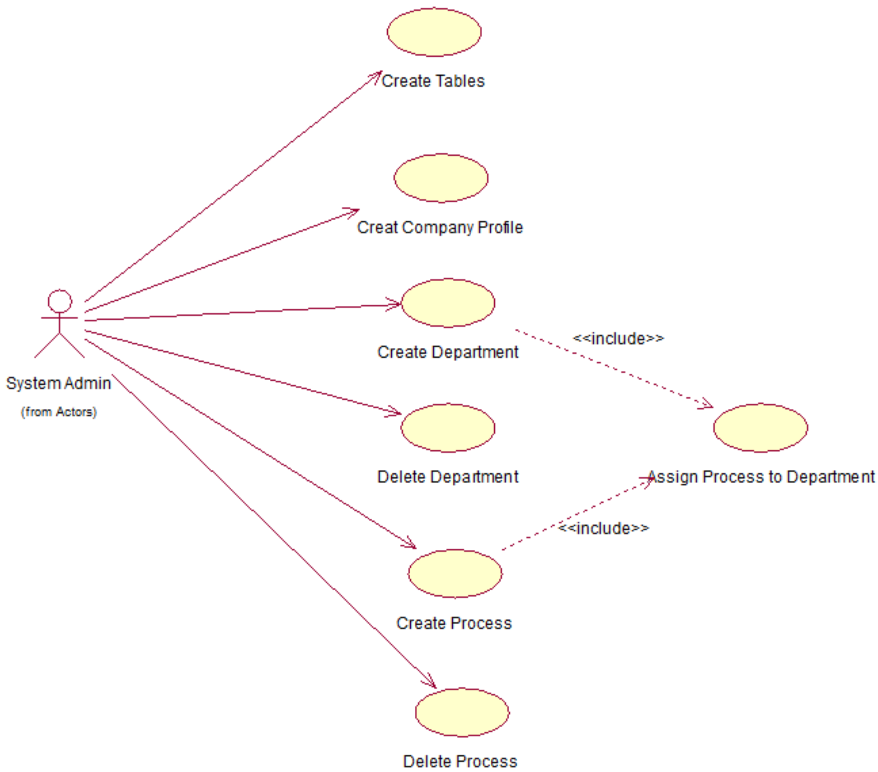

Figure 3.9: System initial setup use case diagram

3.2.4.2 Job creation and data loading

The data administrator is responsible for creating a new job for customer's order. Job creation is mainly divided in to four tasks. The first task is to enter the default job parameters such as job name, batch quantity, etc. The second task includes the creation of packaging hierarchy levels. The third and main task of the data administrator is to create the level parameters for this job, i.e. default parameters and user defined parameters. After this the level linkage and label layout would be assigned to each level. Finally the fourth task is very sensitive in nature, i.e. "Data loading". The actual data loading can be extended into a data grouping task. A data viewer is used to provide a view to the data administrator to check that the loading of data into the database has occurred correctly. Due to the need for data security, the database records are encrypted by using the 3DES encryption algorithm; hence unauthorized users cannot access the data by simply making an SQL query. Job creation along with data loading are shown in figure 3.10.

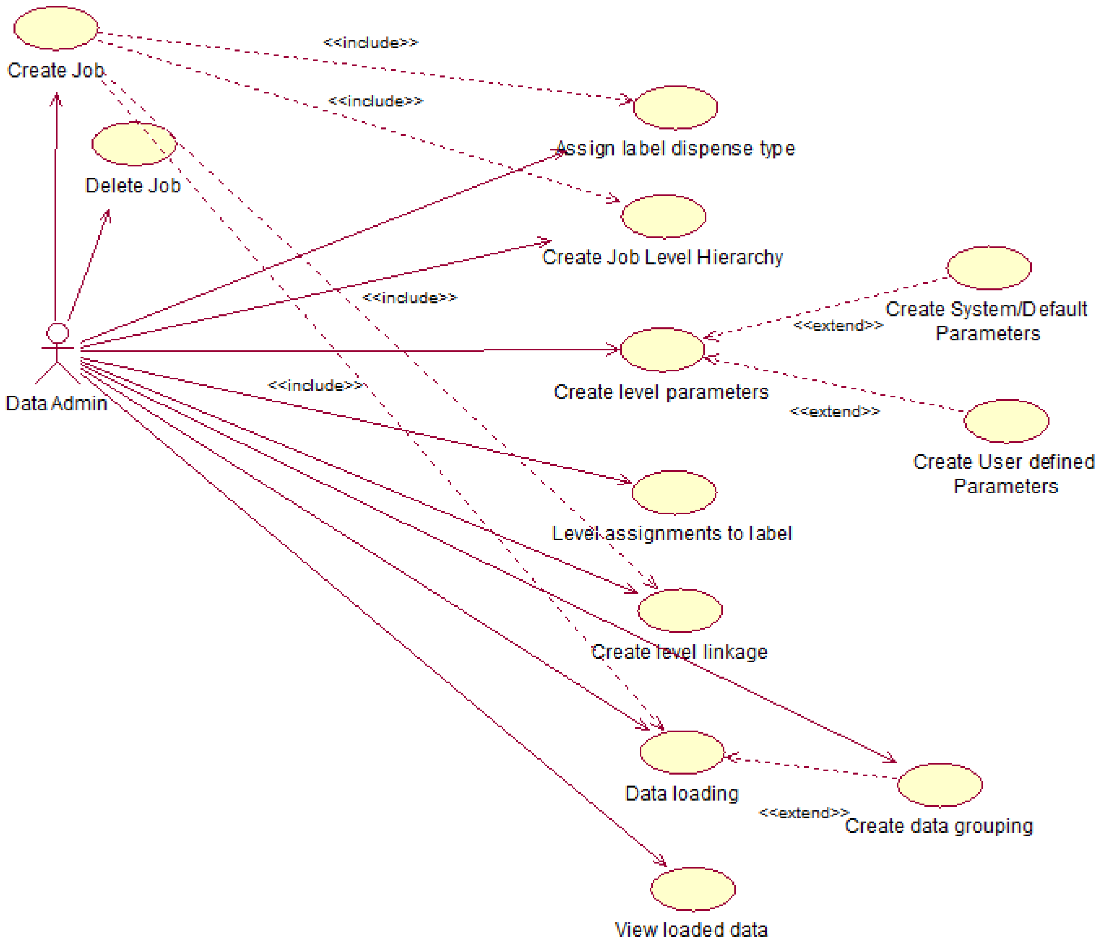

Figure 3.10: Job creation and data loading use case diagram

3.2.5 Operator module

The production operator performs the primary role during the production process. Along with the production task, an operator performs various tasks regarding the packaging system. For example: scanning of the product barcode, label pasting on the product packaging in different packaging hierarchies, packing list generation, and label printing, etc. as shown in figure 3.11. Different production errors such as, a cellophane packaging seal problem, barcode readability problems, etc. are logged by the production operator.

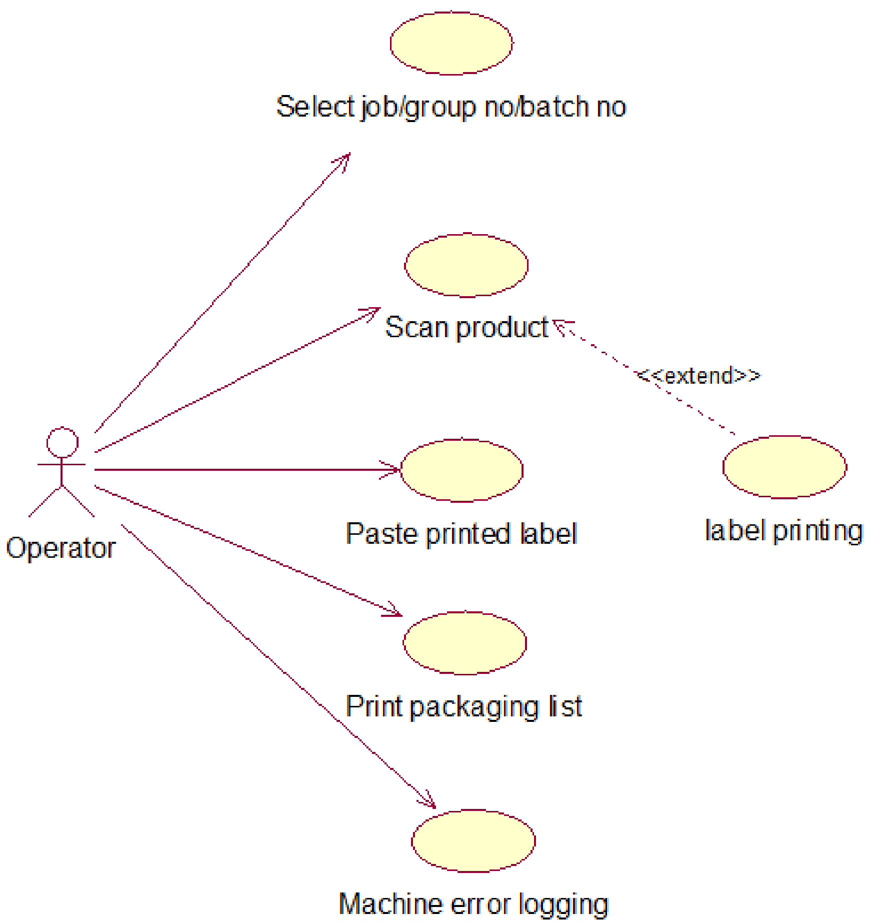

Figure 3.11: Operator use case diagram

Chapter 4

System Implementation

This chapter presents the functional requirement and the implementation of the proposed Smart Card Packaging Process Control System. The implementation combines user management, control panel, error management, label designer, and operator level as its major components. The chapter begins by presenting the overall implementation view of the system. Later each of the major component is explained in subsequent sub sections.

4.1 Implementation Over view

All the implementation work was done using Microsoft .net as a front-end and an SQL server as a back-end tool. The system consists of five major components: user management, error management, control panel, label designer, and operator level. The overall system interactions with SQL server database are shown in figure 4.1. Insert, update, and select SQL queries are used. An ID-automation barcode font is used to generate a code128 barcode along with the relevant library functions as discussed later. Database connectivity and data security function are the same throughout the implementation, hence these are implemented as a reusable component.

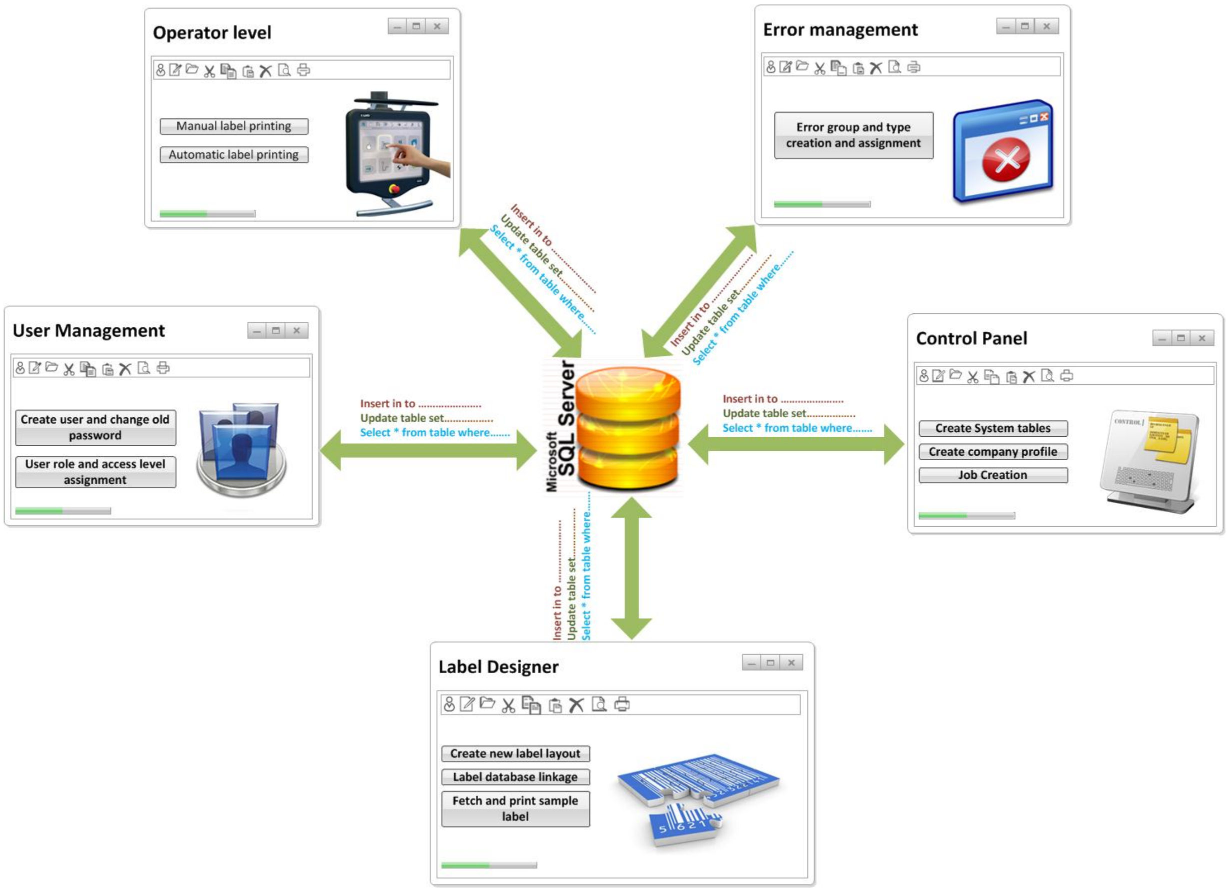

Figure 4.1: System implementation overview

4.1.1 Initial system setup

The config.ini file is created during the initial setup of the system. This file contains the basic information such as company name, number of users, and the data base location as shown in the figure 4.2. The company name is used to encrypt/decrypt the actual key, where as the Internet Protocol address (IP) is used to connect with the centralized database server.

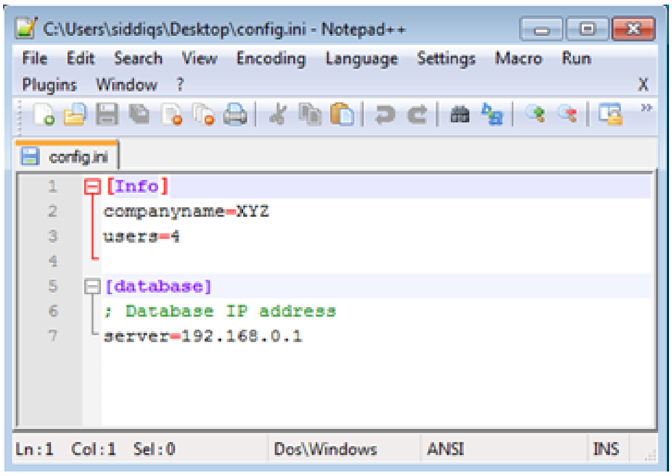

Figure 4.2: Config.ini file defines system initial parameters

4.1.2 Database connectivity

Connectivity between an application and a database is implemented by using a SQL connection string as shown in figure 4.3. A connection query consists of five parameters: the database provider name is passed as the first parameter, integrated security and persistent security are the second and third parameters. Finally SQL server user ID and the database name are passed as the last two parameters in the SQL database connection query.

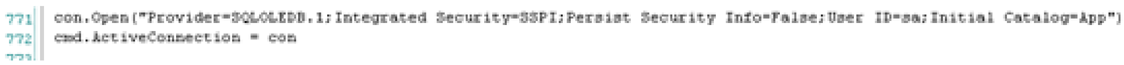

Figure 4.3: SQL database connection string

4.1.3 Data security

The 3-DES encryption algorithm was implemented for data security. The Microsoft .net cryptographic library is import in a class file to implement the desired data encryption algorithm. The following line shows the syntax for this import in Visual Basic.net:

```
Imports System.Security.Cryptography
```

As a result a class with the name "Crypto" is defined and provides the encryption and decryption functions shown below:

```
Public Shared Function EncryptTripleDES(ByVal sIn As String, ByVal sKey As
String) As String
```

```
Public Shared Function DecryptTripleDES(ByVal sOut As String, ByVal sKey As
String) As String
```

4.1.3.1 Encryption key management

During an initial setup, the administrator enters the company name, and the company name is saved into the config.ini file. Furthermore, the administrator enters the actual data encryption key. The company name is used as a key to encrypt the original key by using 3DES encryption algorithm and finally stored in to the system registry as shown in the figure 4.4.

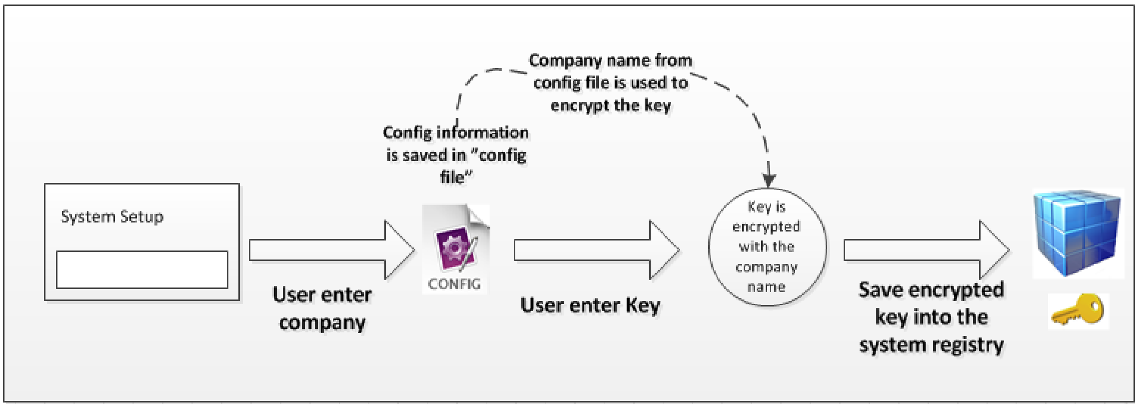

Figure 4.4: Encryption key storing procedure

When the system is initialized, it read the config.ini file to get the company name and also from the system registry to read the actual encrypted key. The company name is used as a key to decrypt the original key and finally load the actual key into the system memory or RAM for data decryption as show in the figure 4.5.

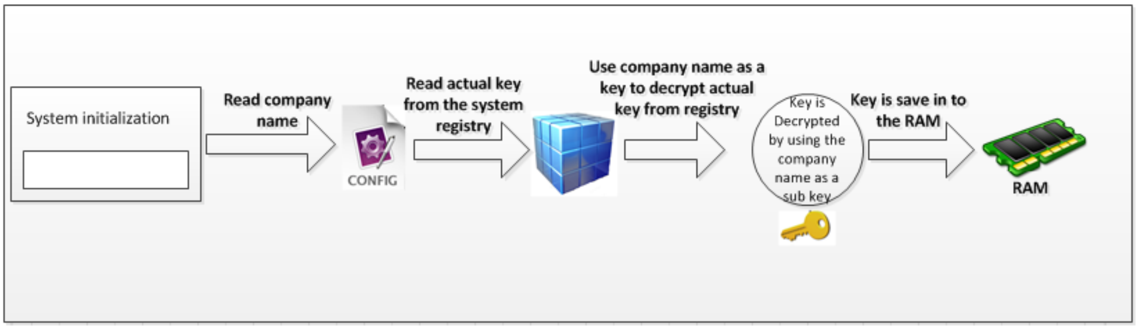

Figure 4.5: Encryption key reading procedure for data decryption

4.2 Functional requirement implementation

The functional requirements of each of the system's component are discussed in the following subsections. Each subsection begins by describing the functional requirement and then discusses the implementation of these functional requirements.

4.2.1 User management functional requirements

The functional requirements of the user module are:

- Create user and change old password and
- User role and access level assignment.

4.2.2 User management implementation

The implementation of the user management module is discussed in the following subsections.

4.2.2.1 Create user and changing old password

Creating a new user is implemented by using an SQL insert query. An example of such a query is shown in figure 4.6 . The insert query adds a new record for this new user in the user table. Changing a user's password is done in two steps: first we check for the existence of this user's record in the user table and then use an update SQL query to modify the user's password record in the database. An update query structure is illustrated in figure 4.6.

```
INSERT INTO "table_name" ("column1", "column2", ...)
VALUES ("value1", "value2", ...)

UPDATE Store_Information
SET Sales = 500
WHERE store_name = "Los Angeles"
AND Date = "Jan-08-1999"
```

Figure 4.6: Insert and update sample SQL queries

4.2.2.2 User role and access level assignment

To realize the functional requirement of user role and access level assignment , we use the .net list control component to get the access level and user role data from the database. This assumes that we use an insert SQL query to add a new user record with their role and access level in the database when their role is created or changed.

4.2.3 Control panel functional requirement

The functional requirements of the control panel module are:

- Creating system tables,
- Create company profile, and
- Job creation.

4.2.4 Control panel implementation

The implementation of the control panel module is discussed in the following subsections.

4.2.4.1 Creating system tables

Creating a system table is implemented by using the create table SQL query. The table's column names are provided along with their data types as shown below. Note that in the case of character fields the maximum length of the field is also defined.

```
CREATE TABLE customer
(First_Name char(50),
Last_Name char(50),
Address char(50),
City char(50),
Country char(25),
Birth_Date date)
```

4.2.4.2 Create company profile

Implementing this functional requirement involves both insert and update SQL queries. Adding a new record containing the company name and logo, department name, etc. in the database is done by using an insert query. The subsequent assignment of a department is done by executing a SQL update statement.

4.2.4.3 Job creation

Job creation is a large and complex process and can be divided in to three steps: job parameter definition, data loading, and data grouping.

The first step is job parameter definition. This is implemented by using the SQL insert query to add a new job record into the database. This step includes defining the level or hierarchy parameters. There is a separate table to store the information for each level/hierarchy in the database. However, by using the create table SQL statement, the level definition functionality can be implemented.

The next step is to load the customer data which is to be printed on a label. First we retrieve the level parameter information from the table defined in the previous step. A text file is used to enter the job information, specifically the initial parameters, i.e. start serial number, end serial number, start batch number, etc. Level parameters are user defined and not known a priori because the values varies from customer to customer. Using the level parameters, an SQL insert query is dynamically generated at run time and the data loaded according to the text file's contents as shown in figure 4.7. To make the system more customizable, it imports the start and the end serial number corresponding to each batch number from the text file. The text file is most useful when the ranges of serial numbers are not contiguous through out the job. The system is also capable to generate the data without using a text file, if the serial numbers are contiguous over the batches through out the job.

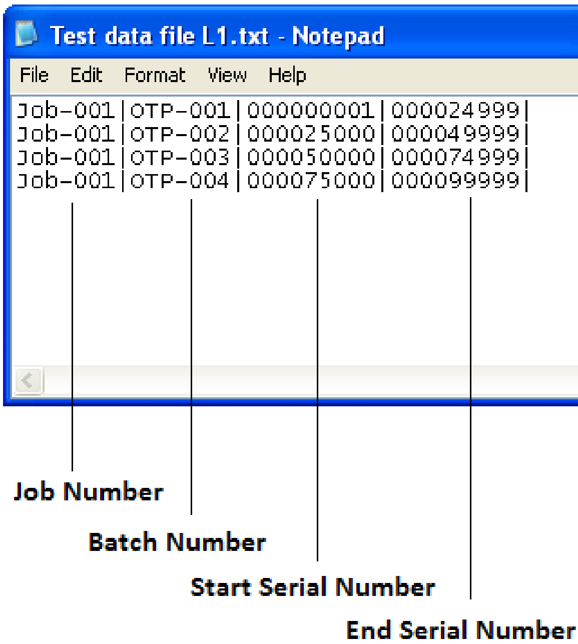

Figure 4.7: Text file data format for defining the parameters for each job

Finally the loaded data is grouped by using the update SQL statement. The group number table field is updated in the level table. Since we store only encrypted data in the database, it is impossible to verify the data by simply using the SQL server enterprise manager, but rather we have to make our own SQL select query to retrieve the job table field information and decode it. Note that the table data is load by a normal SQL select query. An example of the select query for the table field is:

```
select COLUMN_NAME from INFORMATION_SCHEMA.COLUMNS
where TABLE_NAME = 'tablename'
```

4.2.5 Label designer functional requirements

The functional requirement of the label designer module is to:

- Create a new label layout design,
- Label database linkage, and
- Fetch and print already created labels.

4.2.6 Label designer implementation

The implementation of the label designer module is discussed in the following subsections.

4.2.6.1 Create new label layout design

Label layout creation is implemented by using .net controls, i.e. panel, label, line, and picture box. The panel control is use to provide a canvas to draw a label. Label, line, and picture objects are created at runtime according to the user's selections. There are two types of label controls: one is used to create text in a label layout and the other one is used to generate a barcode. To generate a barcode, the "Font Encoder class" is used, as provided by "ID automation" [1]. The "Code128a" function is implemented in the "Font encoder" class by passing two parameters: "DatatoFormat" as a string and "ReturnType" as an integer (as shown in the following code):

```
Public Function Code128a(ByVal DataToEncode _
                         As String, Optional ByVal ReturnType As Integer = 0) As String
```

Next the designer assigns each of the objects' parameters, i.e. object name, object background color, object border style, object text, etc. Additionally, the code assigns an event handle to each object which handles mouse up, mouse move, and mouse down events. Finally these objects are added to the panel control as shown in the following code snippet.

```
'' create a an object of type label
lblNew = New Label

'' assign parameters
lblNew.Name = "Label" & Control_Counter
lblNew.Text = "Label"
lblNew.BorderStyle = BorderStyle.None
lblNew.AutoSize = True
lblNew.BackColor = lblNew.BackColor.Transparent


AddHandler lblNew.MouseDown, AddressOf DraggableLabel_MouseDown
AddHandler lblNew.MouseMove, AddressOf DraggableLabel_MouseMove
AddHandler lblNew.MouseUp, AddressOf DraggableLabel_MouseUp


Me.Panel1.Controls.Add(lblNew)
```

4.2.6.2 Label database linkage

The database linkage is used to link each variable label object to the desired field in the database or to provide a data link to each field of the label. For example, the "start serial" label object is linked with the start serial field of the "level hierarchy" table in the database. However, in order to link the label to the database, we must first check for the existence of a label record in the database. If the record already exists, then we use

[1]ID Automation is an organization which provides software components for development, especially for the automation of identification using barcode fonts, etc. [17]

an SQL update query to link the database field to the object, otherwise we use the insert SQL statement to add a new record along with a database linkage with the object.

4.2.6.3 Fetch and print sample label

Fetching a label layout from the database is implemented in two steps. First we clear the canvas drawing by using the following code:

Me.Panel1.Controls.Clear()

Next we fetch the label design parameters from the object table, this includes: object name, object font style, database linkage fields, etc. in a while loop until all the control objects are correctly created in the panel. Finally we print a sample label using the .net "printDocument" control to send a sample label to the label printer. The different types of label printers were discussed in chapter 2 section 2.5.1. A label layout print code snippet looks as follows:

```
Private Sub Btn_Print_Label_Click(ByVal sender As System.Object, ByVal e As System.EventArgs)

    Try
        Create_Label_For_Print_Privew()
        page = 1
        maxPage = totalPages
        Dim prd As PrintDocument
        prd = New PrintDocument
        AddHandler prd.PrintPage, AddressOf OnPrintPage
        prd.Print()
        frm.Visible = False

    Catch ex As Exception
        Err_Str = ex.StackTrace
        Err_Str_1 = Split(Err_Str, ".")
        Error_Management(Me.Name, ex.TargetSite.GetCurrentMethod.Name, ex.Message, Err_Str_1(
    End Try
End Sub
```

4.2.7 Operator module functional requirements

The functional requirements of an operator are:

- Manual label printing, and
- Automatic label printing.

4.2.8 Operator module implementation

The implementation of the operator module module is discussed in the following subsections.

4.2.8.1 Manual label printing

The operator selects a job number, data group number, and batch number. The target start serial number value is fetch from the table according to these parameters. After the manual label button click event is generated, an SQL query is used to fetch the label layout design data from the table according to the operator selected parameters. After that the system creates a label layout, as discussed in the previous section and sends the required label to the label printer. Finally, the target start serial number is advanced to the next serial number until we reach the last serial number specified for this job and batch.

4.2.8.2 Automatic label printing

The operator selects a job number, a data group number, and a batch number. The target starting serial number value is fetched from the table according to these parameters. The barcode scanner reads the barcode value and sends a read value request to the "txtscan" text box. If the target value and the scanned value match, then system generates the label; otherwise the "txtscan" textbox text is changed to the color red. This change in colors indicates to the operator that the scanned value is not correct. The label generation process is same as was discussed above concerning manual printing, i.e. an SQL query is used to fetch the label layout design data from the table according to the operator's selected parameters. After that the system creates a label layout, as was discussed earlier and sends the required label to the label printer. Finally the target start serial number is advanced to the next serial number.

4.2.9 Error management

The functional requirement for the error management module is to provide: error group, error type creation, and error assignment.

4.2.10 Error management implementation

The error group and type creation is implemented by using an SQL insert query. An insert query adds a new record of an error group and error type in the correct error group management table. Similarly, for an error group to error type assignment, an SQL insert query is used.

4.3 Implementation of the system from the user's perspective

The implementation of the label designer module is discussed in the following subsections.

4.3.1 User management

User management should be the first module of the system to be implemented. The flow chart of this module is shown in figure 4.8. This process consists of three main tasks which are described in the following paragraphs.

4.3.1.1 Create new user and change a user's password

The user is created by entering a user name and a password. If a user wants to change their password, they only need to enter their current password along with their new password. However, to change the password, the current password must match that in the database.

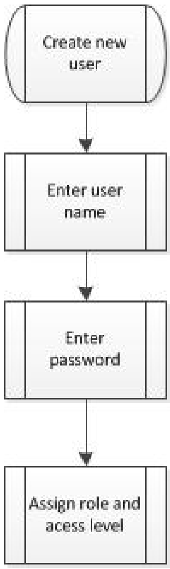

Figure 4.8: Flow chart: user management

4.3.1.2 Role and access level assignment

There are predefined roles (such as data administrator, machine operator, supervisor, etc.) and user defined roles. All roles are defined by the system administrator. The user's access or in other words the user's rights to access the system's functionality or to invoke the system's modules is defined by selecting the user name and user role from a list and invoking the access's level assignment function. For example, the data administer has access rights to the data loading options in the control panel, while a machine operator have no right to access the control panel.

4.3.2 Control panel

A control panel is the heart of the system and it provides two main options: creating a company profile and job creation with data loading. After the initial system installation the database has only a few system tables, the rest of the tables will be created by the administrator by using the Create Database Table option. The company profile enables the administrator to enter a company name and store the associated company's logo. The company logo is necessary and is used in all the system's generated reports. Subsequently a department can be created by entering the name of the department, such as printing, personalization, packaging department, etc. Each department has various processing units, for example the printing department has printing, UV coating, cutting, and sorting processes. Furthermore, a process is created and assigned to the respective department. The flow of the control panel is shown in figure 4.9.

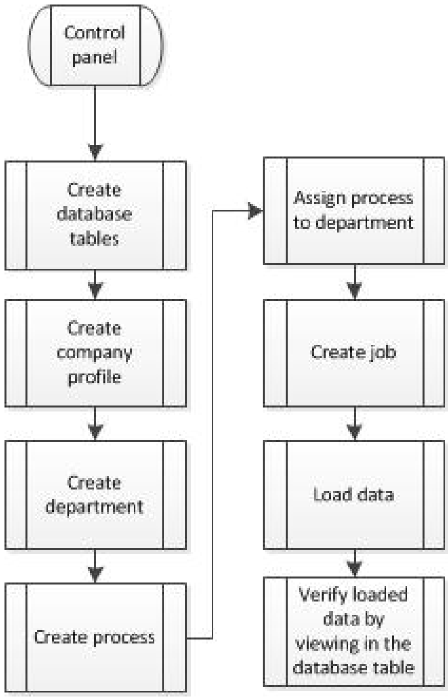

Figure 4.9: Flow chart: Control panel

There is a new job for every new customer order. Job creation with a data loading is a very sensitive process which is monitored by a data manager. Finally the created job is verified by a data administrator by viewing the loaded data from the database.

4.3.3 Job creation

After receiving a customer's order, a new job is created by using a sequence of the following processes:

- Initial setup,
- Level linkage,
- Level's parameter definition,
- Data loading, and
- Data viewer.

4.3.3.1 Initial setup

Initially the user enters a job name, job quantity, batch number, etc. then creates a number of levels which are required for the job. After this the user selects the label layout and number of label copies to be produced by the system. There are two types of labels that can be generated: one is a "manual label dispense process" and the other one is an "automatic label dispense process". If the user selects a manual process, then the user should also select a label mode, i.e. "multiple label mode" or "Single label mode" as shown in figure 4.10. Finally the error group and error type should be selected.

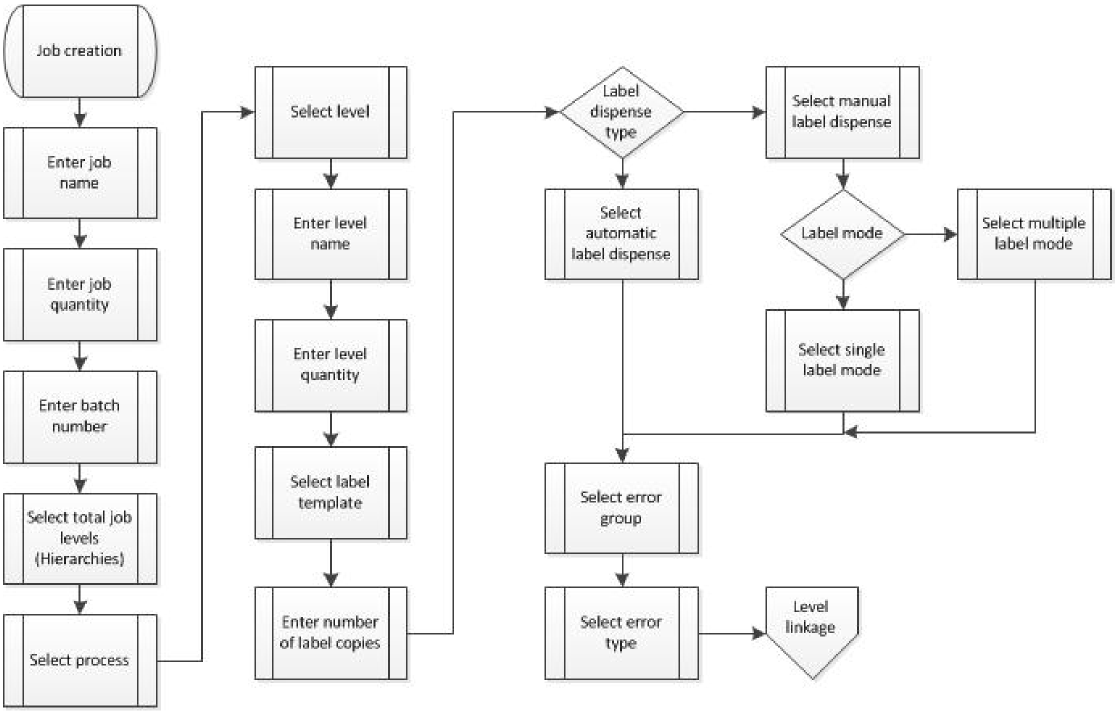

Figure 4.10: Flow chart: Job initial setup

4.3.3.2 Level linkage

Level linkage is used to create a link between two levels. The user selects a job number, process, and an operator and then selects a level linkage type as shown in a figure 4.11. There are two types of level linkage: standalone level and automatic level linkage. A standalone level linkage is also known as a manual or independent level link, while an automatic level linkage is referred to as a dependent level link.

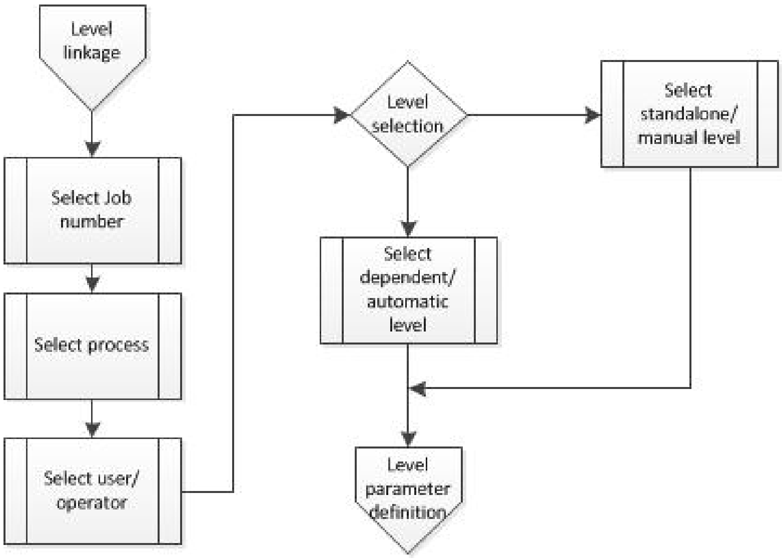

Figure 4.11: Flow chart: Level linkage

4.3.3.3 The level's parameter definition

The level parameter is defined by first selecting the job number and the level. After this a system defined parameter, such as start serial number, end serial number, etc. is defined by clicking on the create system defined parameters option as shown in the figure 4.12. The next process creates a user defined parameter such as box number, purchase order number, etc. by entering the name of the parameter and clicking on a user defined parameter option.

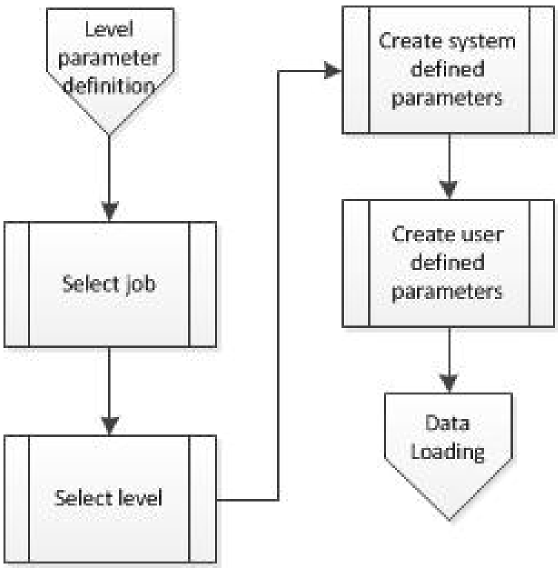

Figure 4.12: Flow chart: Level parameter definition

4.3.3.4 Data loading

The customer's label information data is loaded by the data administrator by performing a sequence of operations. First the user selects a job number and a level number followed by selecting a field type. There are two types of fields: a static field and a serialized field. Static fields include: Batch number, customer name, job number, etc., while serialized fields are start serial number, end serial number, etc. A serialized field has two options: serialization with jumping and serialization with jumping and formatting (as shown in figure 4.13). Separate field formatting and a string append option are provided as options to the user. The data administrator can flexibly load the data according to the customer's needs. After filling in all the fields, the data administrator selects the save settings option and finally loads the text file to complete the data loading process.

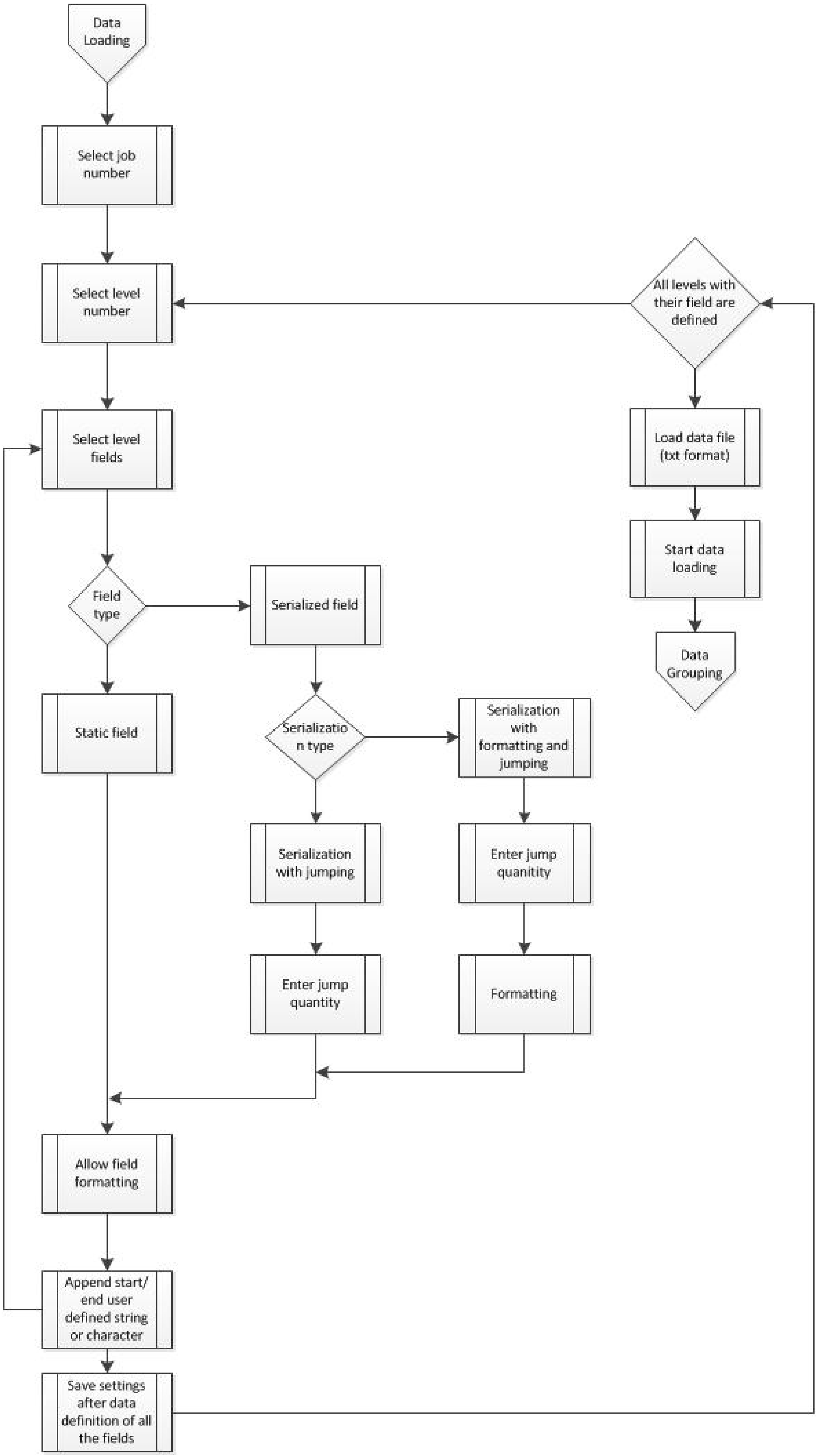

Figure 4.13: Flow chart: Data loading

4.3.3.5 Data grouping

To meet the dispatch deadline and a heavy production load, the data grouping option is very helpful. A data administrator can create different data groups and perform packaging tasks in parallel at different work stations. For example, if the batch consists of 25000 cards, the data administrator can create five data group of 5000 cards of per batch and assign each of these batches to different operators so that they can work in parallel. The data grouping process is very simple and easy for a data administrator as shown in figure 4.14. After selecting a job number, a process, and a level, the data administrator chooses one of the data grouping methods. There are three ways to group the data: job wise data grouping, batch wise data grouping, and multiple data group distribution (as shown in the flow chart in Figure 4.14). The grouping method selected by the data administrator depends upon the current production load. If there is an urgent need to package cards, then generally the multiple data group distribution is used.

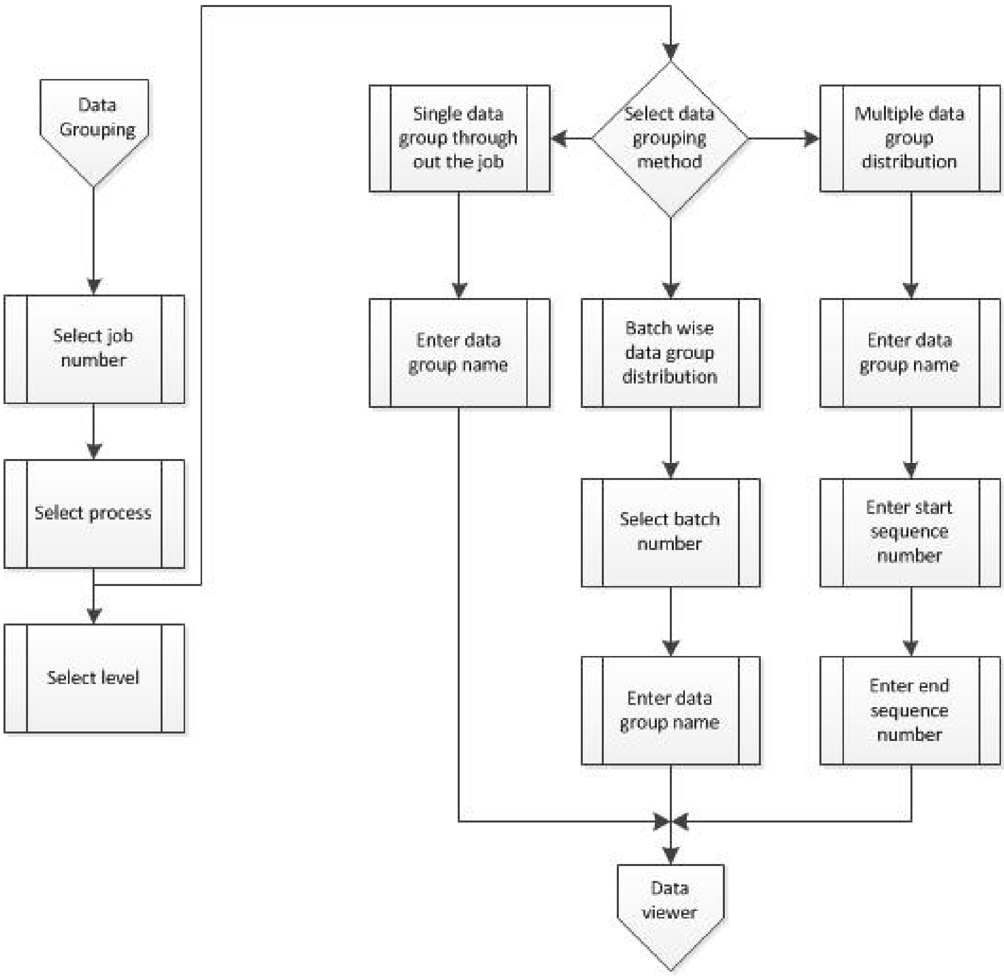

Figure 4.14: Flow chart: Data grouping

4.3.3.6 Data viewer

The data viewer is used to view the decrypted data loaded during the job creation process. To check that the data is loaded correctly, the data viewer function is used by the data administrator. The data administrator simply selects the table name, job number, and batch number, then the system fetches the relevant data from the database and displays it appropriately. The flow chart of the data viewer is shown in figure 4.15.

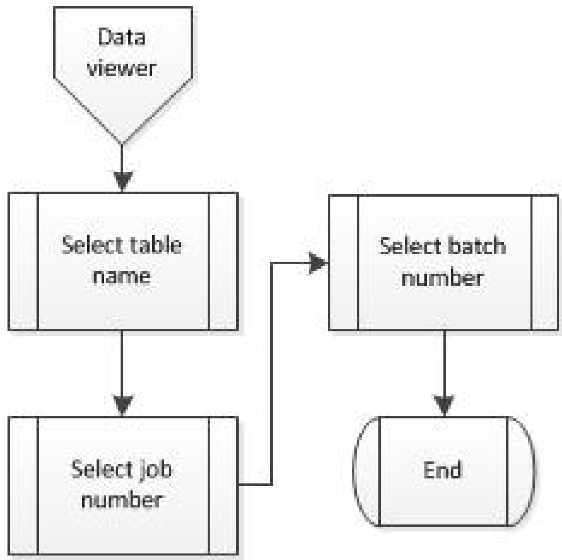

Figure 4.15: Flow chart: Data viewer

Chapter 5

Evaluation

This chapter begins by discussing the initial setup needed for the system evaluation. Following this, the data collection process is explained in detail. Next, the data collected from two different scenarios is presented. A system analysis by using the comparative studies is presented at the end of this chapter.

5.1 System evaluation

Evaluation of the system was the hardest phase of the project, due to the factory's busy production schedule it was really hard to get a free production slot to implement and test the system.

In order to evaluate the system in a real production packaging environment, we selected a production line performing packaging for the Scratch cards/ Bank cards.

5.1.1 Job parameters

To evaluate the system, following basic job setup parameters were used:

- Total number of cards: 25000,
- Packaging hierarchies: 3 levels,
  Small box packaging contains: 500 cards,
  Inner box packaging contains: 1000 cards, and
  Master box packaging contains 5000 cards.

We need the following quantities of boxes at each level of hierarchy to realize the above job setup:

- Small boxes: 25000/500 = 50 boxes.
- Inner boxes: 25000/1000 = 25 boxes.
- Master boxes: 25000/5000 = 5 boxes.

5.1.2 Hardware setup

Hardware setup included a computer connected with a barcode scanner and a label printer to print packaging labels as shown in the figure 5.1.

Figure 5.1: Hardware setup

5.1.3 Software setup

The following actions were performed in the software setup to create a new job based on the above job setup parameters.

- A new job was created with the above job parameters, i.e. total job size, batch size, small box cards quantity, inner box cards quantity, master box card quantity, etc.
- A label design was created for each hierarchy, i.e. creating mini, inner, and master label templates, and then assign each of level via the database.
- Load the job data file containing the start and end serial numbers. It is helpful when the data administrator loads different batches if the serial number are contiguous.
- Generate test labels to ensure the correctness of the data loading parameters.
- Generate a packaging list for each level of the hierarchy.

5.1.4 Evaluation parameters

The following list of evaluation parameters were used to evaluate the system:

- Packaging time reduction,
- Cost reduction, and
- Human error reduction.

5.1.5 Data collection process

The cards were produced and packed in different production shifts. We have collected data from five different shifts to get five different samples of data to evaluate. Furthermore, to examine the evaluation parameters stated above, the data collection process recorded the following two parameters:

- Time, and
- Number of human errors.

5.1.5.1 Data collection scenarios

These two parameters are collected in two different scenarios:

- Without packaging system (i.e,. before system deployment), and
- With packaging system (i.e,. after system deployment).

5.1.5.2 Data collection stages during production process

To evaluate each packaging steps in detail, the packaging process is divided into the following different stages of production:

- Job preparation,
- Small box label printing and label pasting,
- Inner box label printing and label pasting,
- Master box label printing and label pasting,
- Card packaging by machine and small box packaging,
- Inner box packaging, and
- Master box packaging.

5.1.5.3 Human error classification

The human errors were classified in to the following three categories:

- Card missing,
- Bad label printing, and
- Wrong label pasting on mini/ inner/ master box packaging.

5.1.5.3.1 Card Missing Card missing is considered to be the worst problem. Before the implementation of the system, missing cards were tracked by using an OCR system mounted on the packaging machine. If any card is missing, then the machine's software stopped the machine and logged an error. If the machine operator ignores this error and restarts the machine, this can be tracked subsequently by the Quality department using the machine's log.

After the implementation of the system, if the operator by mistake ignores such an error by a packaging machine, this error will be capture by our system. For example the string is to contain 10 cards and at the delivery stage the operator receives 9 cards, then one card is missing. At this stage the operator scans the start and end serial numbers of the first and the last cards of the string, and the system will not print a label because the start and the end serial number values are different from the expected values. In such a case the operator cannot ignore the missing card(s). In order to resume production an operator informed the production supervisor about this error and logged an error in his production report. To save the production time the supervisor marks this card as a missing in the system and resumes the production. Meanwhile in parallel supervisor fix the missing card issue according to the standard operating procedure (SOP) defined by the production manager.

The supervisor effort in fixing the missing card issue is not much effects the packaging time because before the system's implementation the supervisor follows the same standard operating procedure (SOP) [1] as after the system's implementation, accept to log a missing card in the system to resume the production. The only difference is the detection of an error at an early stage of production and prevents it for further propagation.

5.1.5.3.2 Bad label printing quality If the label printer generates a bad quality printed label due to dust particles on a print head. This will create a problem later reading the label barcode in a warehouse, etc. To maintain the best quality the label should be scanned shortly after being printed, so that a bad label can be replaced with a good label, the printer cleaned and other maintenance preformed as necessary. The result is that no bad label printing quality is accepted.

The bad label printing quality somehow impact on the production packaging time. Initially this error increases the production time because an operator has to take some measures to fix this error. It saves a lot of time and money as compare when the error detect later at quality control stage. The detection of this error by quality department can create a lot of rework and consume more production time and cost of packaging. In short term it produce a lag during the production but in long term it is more productive in terms of cost and time.

5.1.5.3.3 Wrong label pasting on mini/ inner/ master box packaging This category of error includes the following scenarios:

- Box serialization, and

[1] An SOP is a written document or an operational instruction for the production staff to elaborate the steps involve in the production process.

- Card string mismatches their respective small boxes.

Due to the heavy load of production, the operator by mistake might not place the correct card strings in their respective small box, this will generate a complaint from the customer. Furthermore, if the operator places wrong serial number small box in the sequence, it breaks the box serialization and will result in the firm needing to pay a penalty to the customer.

5.1.6 Scenario I: Data collection without the packaging system

Using the set of job parameters stated in section 5.1.1, data was collected in five different samples. This data is shown in the table 5.1. The variation of time during card packaging by machine is due to the machine stoppage for various reasons such as bad cellophane sealing quality, etc. and it takes a bit time to resume the production.

Table 5.1: Sample time data on each production steps without packaging system

Sample Number	Job Preparation (min)	Small box label printing and label pasting (min)	Inner box label printing and label pasting (min)	Master box label printing and label pasting (min)	Card packaging by machine Mini box packaging (min)	Inner Box Packaging (min)	Master Box Packaging (min)
1	10	25	12	3	80	10	4
2	12	28	12	3	76	13	5
3	10	24	13	4	78	10	5
4	11	25	12	3	90	14	4
5	13	23	14	5	100	12	6

The average time for each of these production steps are shown in figure 5.2.

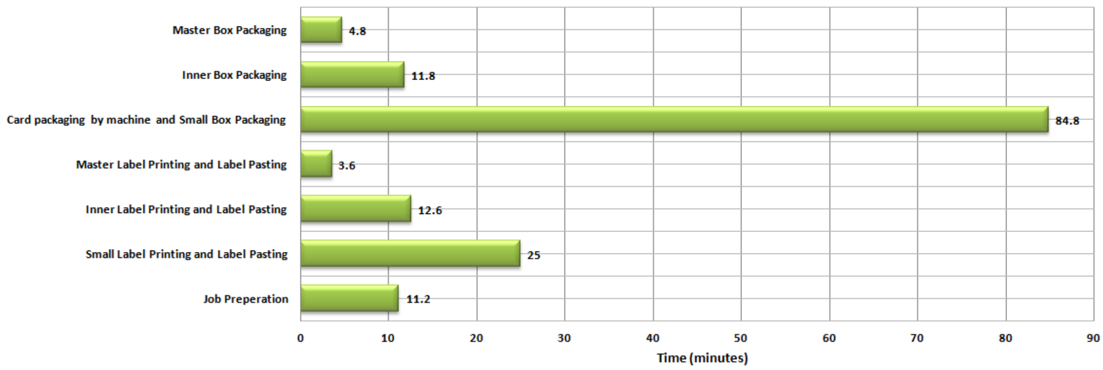

Figure 5.2: Average time on each production steps without packaging system

The number of human errors are shown in table 5.2.

Table 5.2: Human errors without packaging system

Sample Number	Card Missing	Bad label printing quality	Wrong label pasting on small box packaging	Wrong label pasting on inner box packaging	Wrong label pasting on master box packaging
1	1	0	0	0	0
2	0	4	2	0	0
3	3	0	0	1	0
4	2	0	1	0	0
5	0	1	0	0	0

5.1.7 Scenario II: Data collection with the packaging system

After deploying the system five samples were made of the packaging process using the set of job parameters stated in section 5.1.1, data collected in five different samples is shown in the table 5.3.

Table 5.3: Sample time data on each production steps with packaging system

Sample Number	Job Preparation (min)	Card packaging by machine Mini box pasting (min)	Inner Box Packaging (min)	Master Box Packaging (min)
1	6	85	12	3
2	8	80	11	4
3	7	85	12	4
4	8	97	10	3
5	7	93	11	3

The average time for each of the production steps are shown in Figure 5.3.

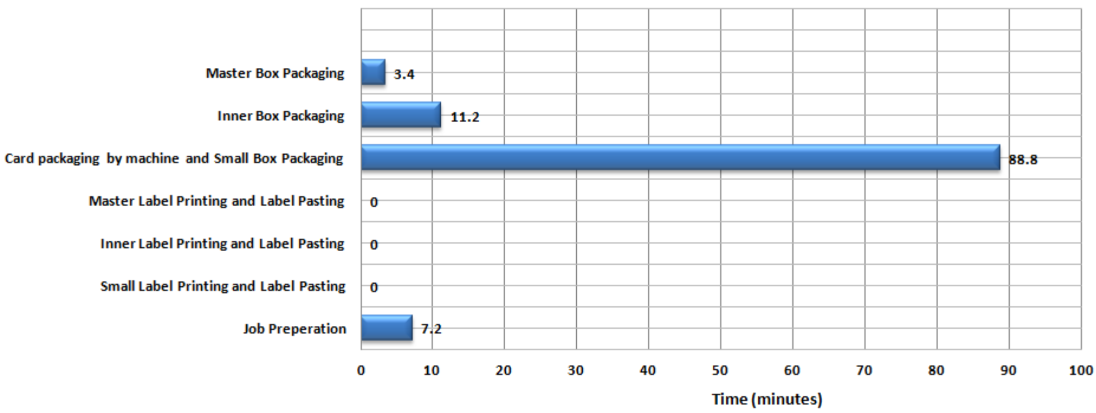

Figure 5.3: Human errors with packaging system

After the system's implementation, the numbers of human errors collected were tabulated. These results are shown in the table 5.4. Note that with the packaging system none of the five types of human errors could occur nor did occur.

Table 5.4: Human errors with packaging system

Sample Number	Card Missing	Bad label printing quality	Wrong label pasting on small box packaging	Wrong label pasting on inner box packaging	Wrong label pasting on master box packaging
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0

5.2 Analysis

The analysis of the system is based a comparison study of above two scenarios for each of the evaluation parameters. Each of these evaluation parameters are discussed in a following subsection.

5.2.1 Packaging time

Comparing table 5.1, and table 5.3, we can see that the total average packaging time before the system deployment was 153.8 minutes whereas after system deployment this average was 111.8 minutes. The difference is shown graphically in figure 5.4. The time difference before and after the system deployment is 42 minutes. This is clearly shows that the packaging system reduced the average production time for this set of job parameters approximately 27.3%. The reduction in packaging time achieved by eliminating the three steps involved in the production process, i.e. small box label printing and pasting, inner box label printing and pasting, and master box label printing and pasting as shown in figure 5.5. By reducing the number of steps in the production process definitely improves the production efficiency. The production time line graph illustrates the time difference between two scenarioes and the different stages of each scenario is shown in figure 5.5. The most important aspect of the reduction in time for performing the same job is that this saved time can be used to schedule other production jobs, while still using the same amount of equipment and personnel.

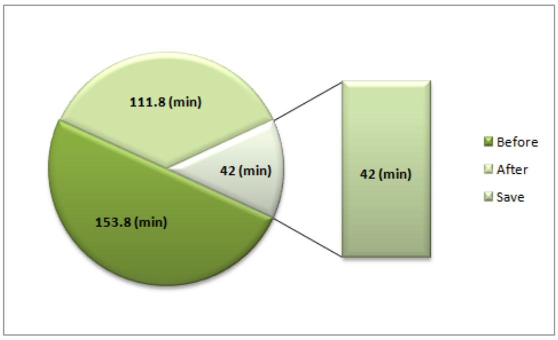

Figure 5.4: Production time save pie chart

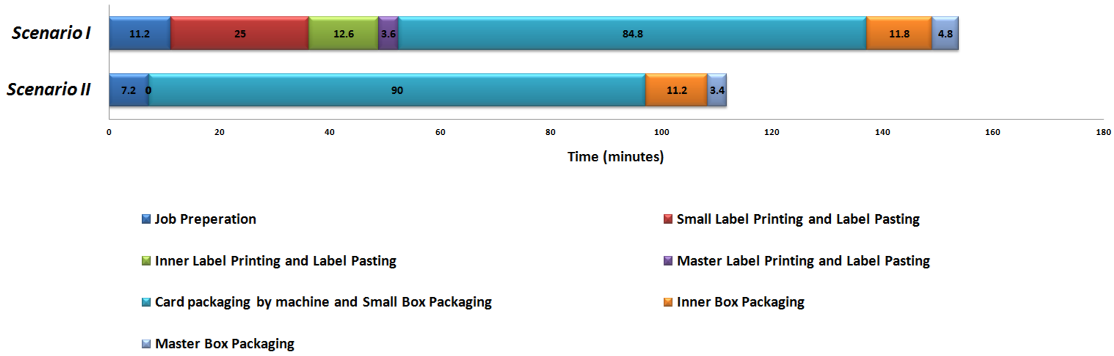

Figure 5.5: Comparative analysis of production time with and without the packaging system

5.2.2 Cost reduction

We have calculated the production cost on the basis of the production crews per hour wages. This cost does not include the machine operating costs, such as machine maintenance, electricity cost, etc. Note that the production supervisor cost is not included in the production cost analysis. The cost calculation is shown as follows:

Total number of cards = 25000
Total production time (before system implementation) = 153.8 min
Total production time (after system implementation) = 111.8 min

One production operator costs 31.64 €/hr [10] or 0.5273 EUR/min

5.2.2.1 Before system deployment

Total cost = total time to produce cards * operator cost
Total cost = 153.8 * 0.5273
Total cost = 81.103 €

5.2.2.2 After system deployment

Total cost = total time to produce cards * operator cost
Total cost = 111.8 * 0.5273
Total cost = 58.95 €

5.2.2.3 Comparative cost analysis

Cost difference = Total cost before system deployment - total cost after system deployment

Cost difference = 81.103 - 58.95
Cost difference = 22.153 €

According to the above calculation, the cost reduction for this set of job parameters was reduced by 22.153 €.

5.2.3 Human errors

When we compare the human error data collected from two different scenarios, it is clear that the human error is reduced to 0%, which was our main goal. Due to the elimination of human errors, packaging related complaints from the customer should also be reduced. This has a direct benefit to the company of both greater customer satisfaction and elimination of any need to pay penalties for failing to deliver the complete order.

Chapter 6

Conclusions and Future work

This chapter concludes the thesis by discussing our results in the context of prior research work. This chapter also summarizes the results developed during the thesis. Future extension to this thesis project are in this chapter. The chapter concludes with some required reflections on the economic, social, and ethical aspects of this thesis project.

6.1 Conclusions

When we searched for previous research work regarding automation of the packaging process, we found that very few effort had been done and published in this research area. It was clearly point out in several of the research papers that due to the lack of published data and lack of packaging evaluation tools, it is very hard to progress in this research area. We hope that the measurements reported in this thesis can help provide some useful data for others.

Different possible ways discussed in the literature to increase packaging efficiency include:

- Introducing RFID in the packaging process,
- Using an ERP system, and
- The analysis of video sequences for data acquisition.

Additional ways to increase packaging efficiency were also discussed in literature studies, such as by reducing number of unnecessary steps in the packaging process or using different types of boxes reduced the production time. It is important to note that all of these methods can be used in conjunction with the print-scan method proposed in this thesis. For example, the labels could include RFID tags - so that scanning could be extended to include both barcode scanning and/or RFID reading. The manual data entry process described in this thesis for the proposed method could be replaced by automatic data entry using information from the ERP system. Video analysis of the print-scan and packaging operations can be used to further enhance the proposed method.

The proposed system provides new results to this research area. Packaging time reduction, packaging cost reduction, decrease in human error, and a reduction in the number of complaints were the primary goal of this thesis. To achieve these goals, the new "scan and print" method was introduced and evaluate in two different real production scenarios. The system was tested and the evaluation data collected in an actual production environment at Oberthur Technologies. The Scratch card/Bank card packaging line was selected for data collection and analysis based upon data from five different production shifts with and without the proposed method. It is clearly shown in the analysis that the production packaging time was reduced on average by 23.7%. Although human handling error was not a focus in prior research, the proposed system can reduced this error near to essentially 0% as shown in figure 6.1. The reduction in production time and strict monitoring of human handling errors can also reduce the production cost while reducing the number of customer complaints.

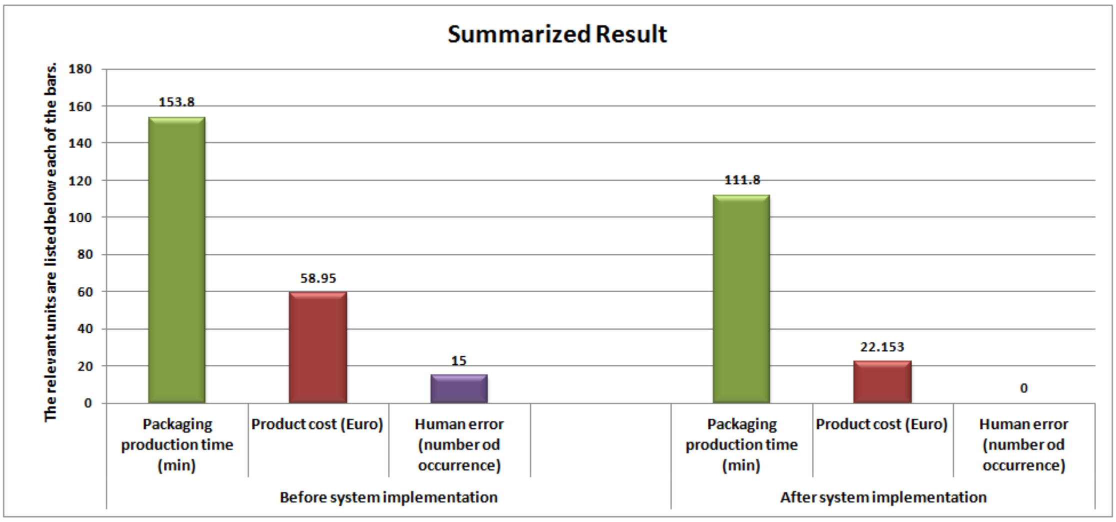

Figure 6.1: Graphical view of the summarized result

Moreover, by introducing the 3DES data encryption technique, the production data is stored more securely. Therefore, it is not possible to update records manually in the database because all the data is encrypted. Furthermore, the traceability of the product is also increased by using the "scan and print method". After each product is scanned, the system records a date and time stamp corresponding with the operator, workstation, and packaging hierarchy. The production manager can easily monitor and track each product by querying the production status from the database in a real-time manner. This data might be used in an ISO 9000 and ISO 9001 quality management process.

Now the proposed system is successfully in operational at Oberthur Technologies on the Scratch/Bank card packaging production line. There are not any noticiable issues reported by them.

6.2 Future Extensions

The proposed method open a new way to think in this research area. The future expansion of the thesis project is discuss below.

6.2.1 Evaluation on SIM card packaging

Due to the unavailability of SIM card production time slot, I have evaluated and tested the proposed system only with the Scratch card/ Bank card production line. To further evaluate the "scan and print" method, the system should be evaluated on the SIM card packaging production line.

6.2.2 Evaluate in other packaging industries

The proposed system will introduce in other packaging industries to evaluate the "Scan-Print" method in more detail. The other packaging industries includes: electronic items, packaging of food items, etc.

6.2.3 Combine the proposed method with other methods

The proposed method combined with the other packaging efficiency method will be evaluate to get further improvement in the packaging production efficiency. The combination of two methods, probably give more better result in terms of production packaging time and production cost.

6.2.4 Data security analysis

The data security analysis is not covered in this thesis project. There will be an opportunity in future to analyze the data security in detail and make the proposed system more secured. The storing procedure of the encryption key is not totally secured, it needs further improvement in future to make the encryption key management process more secure and reliable.

6.2.5 Human error handling production time analysis

The time duration analysis between the error occurred and then to resolved it by either the production operator or the production supervisor is not taken in to an account in the thesis project. The error time analysis will be done in future to provide more accurate production time and cost analysis.

6.2.6 Evaluate "scan and print" method by using RFID technology

The data coding technology, i.e. barcode is used for product identification in this project. The scan and print method will be further analyze by introducing the RFID technology for scanning the product and generate a label at each level of packaging hierarchy.

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